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The influence of heated waters on the growth and food of the perch population (*Perca fluviatilis* L.) in the Rybnik dam reservoir

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Abstract — The age distribution, growth rate, and food of the perch population in the Rybnik reservoir were studied. The water of this reservoir is about 8°C warmer than that in natural water bodies. The material was collected in May, June, August, and October of 1981. The growth rate of perch from the Rybnik reservoir was calculated and compared with that of perch in natural waters. The higher water temperature was found to influence the value and distribution of the annual growth rate. The perch in the studied reservoir fed on fish, crustaceans, insects, spawn, and detritus.

Key words: perch, dam reservoirs, heated waters, growth, food.

1. Introduction

The Rybnik reservoir, built in 1972 and situated on the River Ruda Śląska, serves as a cooling system for the power station "Rybnik". The mean temperature of its water is 8°C higher than that usual for the waters in the sourroundings of this reservoirs (Włodek unpubl.). It seemed interesting to investigate how the raised temperature of the Rybnik reservoir water affects the fish living there. It is known that even a slight rise in the water temperature has a favourable effect not only on the spawn and larvae (EIFAC Technical Paper 1968) but also on the age of sexual maturation (Koselev 1963) and length of fish life (Backiel and Zawisza 1966).

The aim of the present investigation was to discover whether perch, having a great adaptability to different environmental conditions and thus being widespread (Nikolski 1970), changes its growth rate and food habits in the heated waters of the Rybnik reservoir.

2. Material and methods

Perch were collected by means of an entangling net (gill net) and encircling net (beach seine) in the Rybnik reservoir in May, June, August, and October 1981 (Table I). The fish were measured (l_t and l_c) and weighed, their scales and alimentary tracts being removed and placed in 4% formalin. The chyne was identified under a binocular glass and micro-

Table I. Number of perch (Perca fluviatilis L.) collected for investigation from the Rybnik reservoir in 1981

Months	V	VI	VIII	X	Total
Number of species	96	51	52	68	267

scope. Age was determined on the basis of the scales, and the growth rate calculated back using the E. Lea formula (1910—1913), in R. Lee's modification (1920):

$$L_n = \frac{V_n}{V}(l_c - a) + a$$

The condition coefficient was calculated after Fulton's formula:

$$K = \frac{W \cdot 100}{l^3_c}$$

The length — weigth relationship of the body was calculated after the regression equation of Ricker (1975):

$$W = a \cdot l^b_c$$

3. Results

3.1. Age distribution and growth rate of the perch population

Altogether 276 individuals were collected (Table I). Among them, six age groups were distinguished (Table II). In the catches the third- (75.3%) and fourth-year (20.0%) groups were the most numerous.

The growth rate of the examined perch is shown in Table II. The

Table II. Body length and weight in different age groups and calculated growth in length of the perch (Perca fluviatilis L.) in the Rybnik reservoir

Age	Number of specimens	%	Fulton coefficient K	Mean			Computed lengths from 1st to 6th year of life					
				l^t [mm]	l^c [mm]	weight [g]	l_1	l_2	l_3	l_4	l_5	l_6
+1	1	0.37	1.0	97	84	10.0	84	-	-	-	-	-
+2	3	1.12	1.19	184	160	83.3	94	160	-	-	-	
+3	201	75.3	1.41	199	176	120.5	82	147	179	-	-	-
+4	53	20.0	1.25	242	220	214.3	69	142	184	217	-	-
+5	8	3.0	1.31	271	240	272.5	83	151	179	214	246	-
+6	1	0.37	1.21	310	260	360.0	73	138	181	204	232	260
Total	267	100.0				mean	79	147	181	212	239	260

Table III. Mean annual increase in body length of perch (Perca fluviatilis L.) from the heated water of the Rybnik reservoir and mean annual increase in body lenght of perch from natural waters according to different authors

Authors	Reservoir lake	Annual increase in body lenght of perch in different age groups [mm]				
		+2	+3	+4	+5	+6
Kuflikowski, unpubl.	Rybnik reservoir	-	42	31	36	30
Starmach, unpubl.		39	16	42	44	60
Piotrowska, unpubl.		72	30	23	50	48
Piotrowska, unpubl.		82	25	33	-	-
Piotrowska, unpubl.		-	34	34	36	37
Jelonek, authors data		76	16	44	20	20
Mean		67.2	27.2	34.5	37.2	39.0
Suskiewicz, 1961	Goczałkowice	35	38	28	29	28
Żuromska, 1961	Lake Węgielsztyńskie	43	39	33	35	22
"	Lake Wilkus	41	37	34	31	27
"	Lake Krzywa Kuta	33	36	40	39	40
"	Lake Gołdopiwo	37	36	29	25	21
Skóra, 1964	Kozłowa Góra	-	43	33	28	19
Mean		37.8	38.2	32.8	31.2	26.2

mean annual increase in body length was: in the second year — 76 mm, in the third — 16 mm, in the fourth — 44 mm, in the fifth — 20 mm, and in the sixth — 20 mm. These values did not basically differ from those given by other authors (Table III). The length-weight relationship in the examined population of perch is described by the regression equation $w = 0.106164 \cdot l_c^{2.323}$ on the basis of which a curve was made (fig. 1).

3.2. Perch food

In the food of perch in the Rybnik reservoir six groups of invertebrate alimentary organisms, fish, spawn, detritus, and sand were distinguished (fig. 2). In May, in the chyme, spawn (25.0%), water fleas (15.0%) and

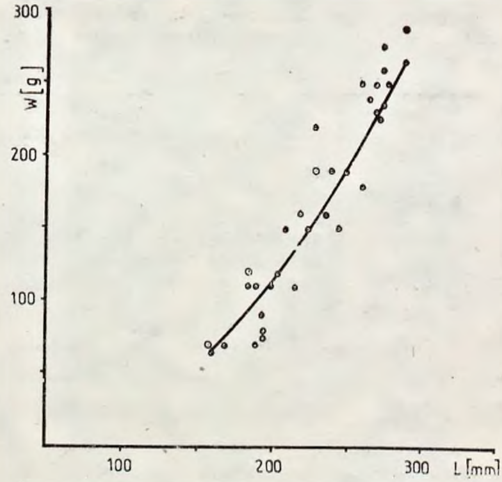

Fig. 1. Curve showing the body weight (W): body length (L) relationship in *Perca fluviatilis* L. from the Rybnik reservoir

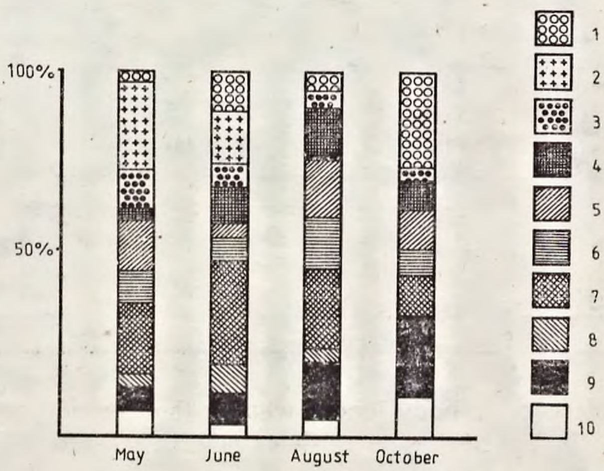

Fig. 2. Food of perch (*Perca fluviatilis* L.) from the Rybnik reservoir in 1981. 1 — fishes; 2 — eggs; 3 — *Ephemeroptera*; 4 — *Trichoptera*; 5 — *Chironomidae*; 6 — *Copepoda*; 7 — *Cladocera*; 8 — *Oligochaeta*; 9 — *detritus*; 10 — fragments of higher plants, sand, and mud

mayflies, and Chironomid larvae (about 12% each) predominated. In June, a distinct dominance of waterfleas coud be seen while spawn constituted about 14.0%. Besides, fish, mainly ruffe, and caddis worms were found. The most numerous group of alimentary organisms in August were water fleas (up to 32%), detritus (19.0%) and caddisflies larvae (15.0%) also being observed. In October, the food consisted mainly of fish (29.6%)

and water fleas (18.0%), besides which as much as 22.3% of detritus was found (fig. 2).

4. Discussion

The growth of perch in the Rybnik reservoir in the particular age groups, was about 8.2% lower in 1981 than the mean value calculated by Kuflikowski (unpubl.) and Piotrowska (unpubl.), and about 1.5% higher than that given by Starmach (unpubl.) and Piotrowska (unpubl.) for perch in the same reservoir. It would seem that such small differences in the growth rate indicate a relative constancy of growth in the examined population (Tables II, III). The mean annual growth rates of perch in natural waters, as given by other authors, are also assembled in Table III, together with those from heated waters.

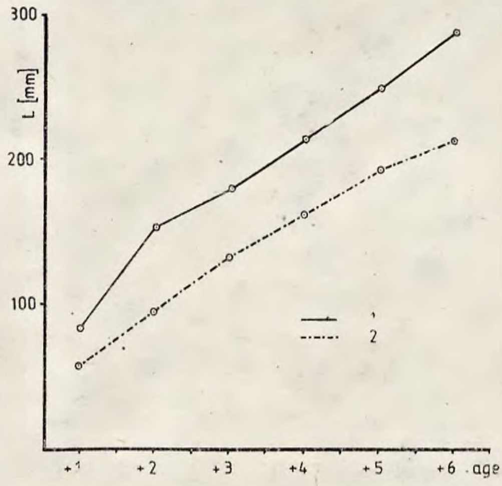

Fig. 3. Comparison of the average growth curve of perch (*Perca fluviatilis* L.) from the heated water of the Rybnik reservoir: 1 — calculated from the author's results and Kuflikowski (unpubl.), Piotrowska (unpubl.), and Starmach (unpubl.), with the average growth curve of perch from natural waters; 2 — calculated from the results of Suskiewicz (1961), Skóra (1964), and Nikolski (1970)

(Table III, fig. 3). In the Rybnik reservoir, the growth of perch in its second year of life was about 80.04% better than in the natural waters. However, in the third year the mean growth rate in the waters of natural temperature was 40.4% better; on the other hand, the IV, V, and VI age-groups of perch from the heated waters were larger in size by about 5.2%, 18.2%, and 48.9% respectively (Table III, fig. 3). The increasing differences between the growth of perch from heated and natural waters from the IV to the VI age-group was brought about by the absence in the heated water of the natural phenomenon of a reduction in the annual growth with ageing of the fish. This phenomenon did not occur in the reservoir probably for three reasons: the good supply and availability of natural food, a prolonged vegetation period, and the stimulating effect of the temperature on the metabolism of the fish.

In its first months of life the perch in the Rybnik reservoir feeds almost entirely on plankton, in the following years gradually supplementing this with benthos and then fish (fig. 4). The assumption of a predatory way of living leads to a marked increase in its growth rate (Thorpe 1977). Other authors have also described the twice changed diet observed in the Rybnik reservoir. According to Chodorowska and Chodorowski (1975), the first, plankton stage (plankton-phage phase) lasts until the fish reaches 7.5 cm in body length, and the second stage, in which benthos dominates (entomophage phase) until 11 cm in body length is reached. Above that length the perch begins a predatory life

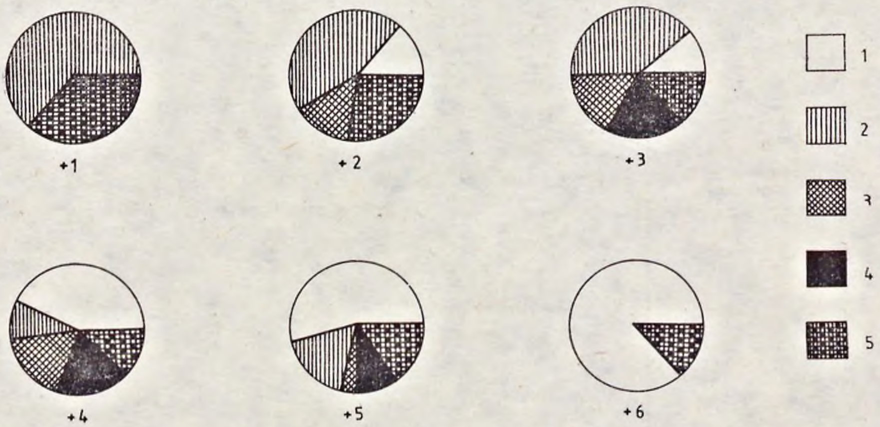

Fig. 4. Food of the different age groups (from +1 to +6) of perch (*Perca fluviatilis* L.) from the Rybnik reservoir. 1 — fishes; 2 — *Cladocera, Copepoda;* 3 —*Ephemeroptera, Trichoptera, Chironomidae,* and unidentified terrestrial insects; 4 — eggs; 5 — detritus, sand, and mud

style (ichtiophage phase) and passes to food consisting mainly of fish. Pliszka and Dziekońska (1953) reported that perch in Lake Tajty begin a predatory life at a length of 13—15 cm and a weight of 40—50 g. Antosiak (1963) accepted 15 cm as the length when most of the population feed on fish, while Popova and Sytina (1977) estimated this as 10—25 cm. Chodorowska and Chodorowski (1975) believe that the length at which the perch makes its début as an ichtiophage (i.e. the first individual of the age group devours fish) is characteristic for the population and they propose the term PDI (point de début de l'ichtiophagie). For perch examined by the above-mentioned authors, PDI is 9.3 cm. In the Rybnik reservoir, the same value (PDI) is 14.5 cm. Assuming that the difference between PDI and the ichtiophage phase proper (FI), when 50% + 1 of individuals devour fish, is for perch a constant value, it may be concluded that perch populations in waters of natural temperature begin to feed on fish much earlier than in the heated ones.

In examining the kind of food of the age groups (fig. 4) it can be seen that fish constitutes not more then 15.5% of the perch's food in the first three years of its life. Only in the fourth year is there an increase in the proportion of fish in the chyme, in other words in the ichtiophage phase proper (FI). According to Chodorowska and Chodorowski (1975), the ichtiophage phase starts at a body length 8.45% smaller than that given for FI. In the Rybnik reservoir, the beginning of FI (50% + 1 of individuals feeding on fish) was observed at a body length of 19.8 cm, and PDI was found at the length 7.33% smaller. It is worth emphasizing that, in spite of the varying environmental conditions of the heated reservoirs and waters of natural temperatures and the variable growth of fish in these two types of water body (fig. 3), the difference between PDI and FI calculated in percentage is very close.

The perch diet, from the moment of its first feed, is a sequence of genetically conditioned events, which are modified by the environmental conditions (zooplankton supply). After the juvenile diet period, perch should become ichtiophagous. In natural waters, with a "normal" amount of zooplankton available, the amount of energy expended by the fish of feeding may be greater than that gained from its digestion. The individual cannot therefore prolong the second alimentary phase. In the heated waters of the Rybnik reservoir, where the zooplankton biomass is greater than in natural waters (Krzanowski unpubl.), the perch has plenty of easily available food during its second year of life. Natural mortality is consequently reduced and a rapid growth of the whole age group occurs (Table II, fig. 3). Hence, in the third age group, there is such a large number of individuals living on plankton and benthos that this ecological niche is unable to support them. This explains why in the Rybnik reservoir the perch population, which in the second year of life achieved growth rates almost double those in water bodies with natural thermal conditions, in the third year of life had average growth rates 11 cm poorer than in such waters (Tables II, III). This "insufficient" capacity of the ecological niche occupied by the third-year group of perch and the associated distinct reduction the number of the fish of the fourth age group, are probably caused by such factors as:

1. too great a number of individuals in relation to the food supply,
2. post-spawning weakness in perch of the third group, spawning for the first time,

3. infectious diseases and parasitic invasion, having a direct connection with post-spawning weakness,

4. the lack of macrophytes at the banks of the reservoir, which provide a natural cover for the perch and its prey and also widen the overgrown littoral zone, increasing the trophic capacity of the habitat.

The perch in the Rybnik reservoir is omnivorous. In the chyme of its first three age groups plankton, benthos, and seasonally spawn predominate, only the four-year-old group feeding on fish alone (fig. 2). Similar results were obtained by Piotrowska (unpubl.). She examined perch from the Rybnik reservoir and found that in the first period of life it fed mainly on plankton. Only in the third year did the perch start eating fish (about 15%) which in the following years became the fundamental food component. Bogdanov (1959) reported that perch in the Ust--Kamenogorski reservoir (with water of natural temperature) usually fed on *Chironomidae* larvae, while fish constituted only 10% of the alimentary mass. Skóra (1964) found in the Kozłowa Góra reservoir that perch food consisted not only of fish but also of invertebrates, and that zooplankton was more important only in the food of younger, 1—2 year--old perch. On the other hand, according to Suskiewicz (1961), the main diet of perch in the Goczałkowice reservoir, apart from fish, usually consisted of *Chironomidae* followed by *Diptera, Ephemeroptera, Hemiptera,* and *Trichoptera*. Thus, the results of the quoted authors are as different as the environmental conditions in the reservoirs they investigated.

The role of temperature in a water body has been discussed by many authors (Pidgajko et al. 1970, Morduchaj-Boltovskoj 1975, EIFAC Technical Paper 1968, Neuman 1979, Karas and Neuman 1981) who agree that a increased water temperature affects the alimentary basis and also the metabolism of fish. The studies made in the Rybnik reservoir by Kaliszewska et al. (1976), showed a positive effect of raised temperature on the qualitative and quantitative composition of the phytoplankton. A moderate rise in temperature (Pidgajko et al. 1970, Morduchaj-Boltovskoj 1975) in turn, stimulates the development of microorganisms and phytoplankton with a slight inhibition of that of macroinvertebrate fauna. A higher temperature accelerates the fish metabolism (Backiel, Horoszewicz 1970, Horoszewicz 1969) and raises the level of consumption (Swenson 1977). Pearson (1979) stated that the time digestion in the perch at a temperature of 21.7°C, from the point of maximum satiation to a residue of 4%, is 7 hours. At 16.5°C it takes more than 12 hours. Pearson's results illustrate the thesis of stimulation of the metabolism by a higher temperature.

The optimum water temperature for perch lies between 22 and 28°C, while the lethal one varies from 29 to 35°C (Hokanson 1977). In the Rybnik reservoir in 1981 there were 101 days with a water temperature from 15 to 20°C, 108 days with temperatures from 20 to 25°C and four days with a temperature above 25°C (W ł o d e k unpubl.). Thus, 30.8% days of the year had a water temperature within the optimum range for perch. The raised temperature of the water throughout the year brings with it certain dangers since, according to W e a t h e r l y and L a k e (1967) and H o k a n s o n (1977), a high temperature in winter inhibits maturation, this in due course perhaps leading to the destruction of oocytes and embryos.

The distribution of the water temperatures in the Rybnik reservoir is not uniform. In the depth of the effluent waters from the power station, the temperature of the water sometimes reaches 30°C, while in the depth, "beyond the earth embartment", where the water cooling process is concluded, the temperature is comparable to that of natural waters. Such a large gradient of temperatures favours the migrations of perch in search of, optimum thermal conditions. This was observed not only in the Rybnik reservoir, where the oldest individuals were caught in the depth of the effluent warm waters from the power station. N e u m a n (1979) also observed it in a bay heated by effluent warm water from the nuclear power station in Simpevarp. He compared several dependences in the size of catches on the temperature of the water and found that the best catches were made of temperatures approximating the optimum ones.

5. Conclusions

1. In the Rybnik reservoir there was a distinctly better growth rate of perch than in waters with a natural temperature.

2. The perch in the Rybnik reservoir progressed to an exclusively fish diet later than those in natural waters (not until the fourth year of life).

3. In accordance with the findings of C h o d o r o w s k a and C h o d o r o w s k i (1975), three phases in the perch diet were observed. A certain modification was a weak appearance of the entomophage phase.

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6. Polish summary

Wpływ wód podgrzanych na wzrost i pokarm populacji okonia (*Perca fluviatilis* L.) w zbiorniku zaporowym Rybnik

Badano strukturę wiekową, tempo wzrostu oraz pokarm populacji okonia z podgrzanych wód zbiornika zaporowego w Rybniku. Materiał stanowiło 276 okoni, odłowionych w maju, czerwcu, sierpniu i październiku 1981 roku (tabela I). Spośród odłowionych osobników wyodrębniono sześć grup wiekowych (tabela II) o następującym składzie procentowym: 0,37% jednorocznych, 1,12% dwuletnich, 75,3% trzyletnich, 20,0% czteroletnich, 3,0% pięcioletnich i 0,37% sześcioletnich. Średnie przyrosty badanych ryb wynosiły: w drugim roku 76 mm, w trzecim 16 mm, w czwartym 44 mm, w piątym 20 mm i szóstym 20 mm (tabela III). Wzajemny stosunek długości i ciężaru ciała opisuje równanie $W = 0{,}106164 \cdot L^{2{,}323}$ (ryc. 1).

W pokarmie okonia wyróżniono sześć grup bezkręgowców, ryby, ikrę, detritus i piasek (ryc. 2). Skład pokarmu zmieniał się w poszczególnych rocznikach. W treści żołądkowej drugiego rocznika spotykano prawie wyłącznie zooplankton i detritus (63,2 i 36,8%); w pokarmie trzeciego rocznika znajdowano ryby (15,6%), zooplankton (45,1%), owady (12,0%) i detritus (27,3%); w treści czwartego rocznika — ryby (43,3%), zooplankton (9,3%), owady (17,7%), ikrę (18,2%) oraz detritus (11,5%); w rocznikach piątym i szóstym okonie wyraźnie preferowały pokarm rybny (54,8 i 87,3%) przy stosunkowo niewielkim udziale innych organizmów pokarmowych (ryc. 4).

Na ryc. 3 przedstawiono średnią krzywą wzrostu okonia w zbiorniku Rybnik i średnią krzywą wzrostu tej ryby w wodach naturalnych. Okoń w zbiorniku z wodą podgrzaną rośnie szybciej, prawdopodobnie na skutek zasobności bazy pokarmowej, przedłużonego sezonu wegetacyjnego i stymulującego wpływu temperatury.

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