ACTA HYDROBIOL.	28	3/4	451—461	KRAKÓW 1986

Food of juvenile stages of rudd *(Scardnius erythrophtalmus* L.), roach *(Rutilus rutilus* L.), and perch *(Perca fluviatilis* L.) in the heated waters of the Rybnik dam reservoir (Southern Poland)

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Manuscript submitted October 29, 1985, accepted January 30, 1986

Abstract — The food of the fry of rudd, roach, and perch from the littoral of the Rybnik reservoir was investigated. The reservoir is supplied with warm post-cooling water from the Rybnik power station. The material was collected in the spring and summer of 1979 and 1980. The content of the alimentary canal of fry from hatching until about the 120th day of life was investigated. Differences were shown in the food of the individuals of species investigated in stages II, III, and IV.

Key words: reservoir, heated waters, fry, food, rudd, roach, perch.

1. Introduction

The effect of heated post-cooling waters on the dam reservoir environment has been a matter of interest for many scholars (Wilkońska, Żuromska 1977a, 1977b, Klimczyk-Jankowska 1978). A rise in water temperature above the average for a given geographic area is an important environmental factor which may positively affect the abundance of food resources and the fish metabolism level (Horoszewicz 1969, Backiel, Horoszewicz 1970, Pidgajko et al. 1970, Morduchaj-Boltovskoj 1975, Kaliszewska et al.

1976) and may have a negative effect on the maturation process of the gonads which in consequence sometimes leads to the destruction of oocytes (Weatherley, Lake 1967, EIFAC Technical Paper 1968, Hokanson 1977). Besides, increased water temperature lowers the sensitivity threshold to toxic substances (Łukjanienko 1974) and may increase the rate of development of parasites and pathogenic bacteria (Zmerzlaia 1965).

The comparative research embraced the food or rudd, roach, and perch fry. The mature individuals of these species, dominating in abundance in the Rybnik reservoir, use different trophic levels: the rudd feeds mainly on plants (Klimczyk-Janikowska unpubl.), the roach on phytoplankton and zooplankton (Klimczyk-Janikowska 1978) and the perch on zooplankton and fry (Jelonek 1985). The aim of the work was also to compare the diet of fry in the heated Rybnik reservoir and in natural waters, especially as the analysis, carried out by Skóra (unpubl.) and Wilkońska and Żuromska (1977a), of the growth rate of the fish juvenile stages in these two types of water body showed a distinctly better growth of fry in reservoirs with heated water.

2. Study area, material, and methods

The dam reservoir at Rybnik on the River Ruda, with an area of 555 ha and maximum depth of 11 m is supplied with warm discharge waters from the power station, raising the water temperature about 8°C higher than that normal in this part of Poland (Włodek unpubl.).

The fry was caught between 8.00 and 12.00 h, 4—6 times a month from April to September in 1979 and 1980 in the littoral zone of the reservoir. Catches were made by means of a lift net, spoon net and, as the fry grew, a small drag-net. After being measured and weighed with accuracy of 1 mm and 1 g the material was preserved in 4% formalin and the prepared under a stereomicroscope, the composition of the chyme being determined under a microscope. The age of the individuals was determined according to the date of spawning. The mutual proportion between the length and weight of the body was calculated according to the equation (Ricker 1975):

$$w = al^b$$

where: a, b — equation coefficients.

On the basis of the alimentary canal analysis of rudd, roach and perch aged from 8 to 120 days, four food stages were distinguished:

Stage I — 8—15 days in all three species
Stage II — 20—35 days in the rudd, 20—40 days in the roach and perch
Stage III — 40—60 days in the rudd, 50—80 days in the roach and perch

Stage IV — 70—90 days in the rudd, 90—120 days in the roach and perch.

To visualize the size of the individuals in particular stages, the relation between the length and weight of the body was marked on graph (fig. 1).

Altogether 330 individuals of rudd, roach, and perch were analysed. In July and August 1979 diel observations of pH, temperature, and oxygen content (Hermanowicz 1976) were carried out in the littoral water of the Rybnik reservoir.

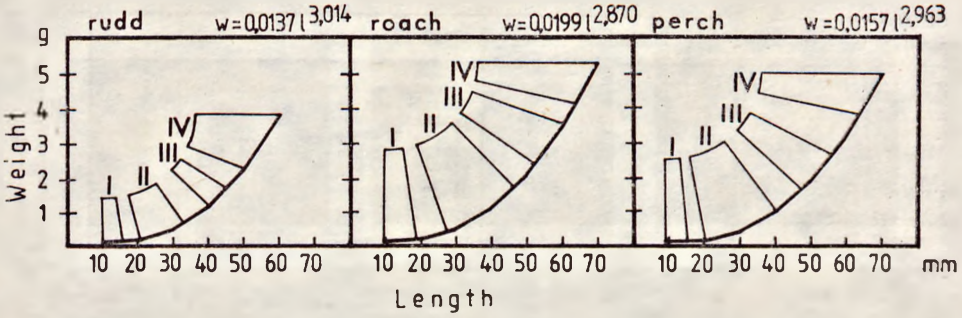

Fig. 1. Length-weight relationship of rudd, roach and perch fry. Alimentary stages I—IV

3. Results

3.1. Physico-chemical conditions

Fry in the Rybnik reservoir stay in the littoral zone. The water temperature here on sunny and windless summer days is about 2—5°C higher than that in the pelagic part. Besides, the oxygen saturation of littoral waters as a result of strong assimilation of periphyton sometimes

Table I. Diel variation of selected physico-chemical parameters of the water of the littoral zone of the Rybnik reservoir in summer 1979

Parameter	11^{00}	14^{00}	17^{00}	20^{00}	23^{00}	2^{00}	5^{00}	8^{00}	11^{00}
Temperature °C	25.0	25.3	25.3	24.8	23.6	23.2	22.5	22.9	24.7
pH	8.4	8.6	8.6	8.4	8.0	8.2	7.6	7.8	8.2
Dissolved oxygen mg dm^{-3}	11.9	12.3	12.8	12.2	9.0	8.4	7.8	8.6	11.4
Oxygen saturation %	142	148	154	145	105	97	89	99	135

reaches 200% of physical solubility of oxygen in the given water temperature. Diel observations of temperature, pH, and oxygen content in the waters of the littoral zone showed that the above-given parameters change to a small extent (Table I).

Table II. List of organisms in the alimentary canal of rudd, roach, and perch from the Rybnik reservoir in the years 1979 - 1980. + - single specimens; ++ - not numerous; +++ - numerous; ++++ - mass occurrence

Organisms	Rudd	Roach	Perch	Organisms	Rudd	Roach	Perch
Cyanophyceae				Scenedesmus quadricauda	++	+	+
Oscilatoria sp.	++	++	+	Scenedesmus sp.	++	+	++
Merismopedia sp.		+	+	Spirogyra sp.	++	+	
Microcystis aeruginosa	++	+		Staurastrum sp.	++	+	
Dinophyceae:				Ulotrix sp.	+++	+	
Ceratium sp.	+	++	++	Desmidium sp.	+	+	
Bacillariophyceae:				Oligochaeta	+	++	+
Asterionella sp.	+	+	+	Rotatoria			
Cymbella sp.	+	+		Keratella sp.	++	++	++
Diatoma sp.	+	+		Cladocera			
Eunotia sp.		+		Alona sp.	++	+++	+
Fragillaria sp.	+	+		Bosmina longirostris		+	+
Coephonema sp.	+	+		Bosmina sp.	++	+	++
Gyrosigma sp.	+			Daphnia magna	++	++	+++
Navicula sp.	++	+	+	Daphnia pullex	+	+	+
Nitschia sp.	+	+		Daphnia sp.	++	+++	++
Synedra sp.	+	+		Ceriodaphnia sp.	+	+	+
Tabellaria sp.	++	+	+	Leptodora kindti		+	
Chlorophyceae				Pleuroxus sp.	+	++	
Cladophora glomerata	+++	++		Eurycercus sp.	+	+	++
Cladophora sp.	++++	++		Copepoda			
Coelastrum sp.	+	++		Cyclops sp.	++	+++	++++
Cosmarium sp.	+	++		Nauplius	+	++	+++
Crucigenia sp.	+	+		Chironomidae - larvae	+	++	+
Pediastrum duplex	++	++	+	Detritus - non det	+++	+++	+++
Pediastrum boryanum	+	+	+	Fragments of higher plants, sand, mud	+	+	+
Pediastrum sp.	++	++	++				

3.2. Fry food (Table II, figs 2, 3)

3.2.1. Rudd

In the alimentary canals of rudd fry in the nutrition I stage mainly detritus and phytoplankton were found. The most numerous were blue-green algae of the *Oscillatoria* genus, small green algae (*Pediastrum* sp., *Scenedesmus* sp., *Cosmarium* sp.), and rotifers of the *Keratella* genus which, together with the undetermined remnants of other animals did not exceed 1.2% of the whole food.

In stage II the chyme was dominated by detritus, followed by phytoplankton and zooplankton.

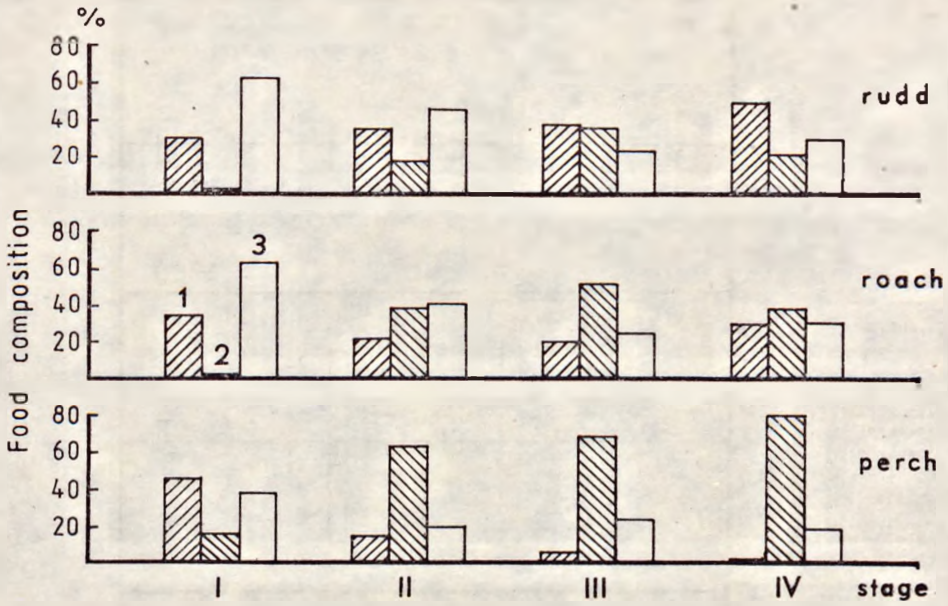

Fig. 2. Percentage changes of food composition in rudd, roach, and perch in their successive alimentary stages (average values from 1979—1980). 1 — phytoplankton; 2 — zooplankton; 3 — detritus

Phytoplankton was represented by: blue-green algae (*Oscillatoria* sp., *Microcystis* sp.), diatoms (*Navicula* sp., *Tabellaria* sp.) and green algae of *Cladophora, Pediastrum, Cosmarium, Coelastrum,* and *Ulothrix* genera. Food of animal origin consisted of the cladocerans *Alona* sp. and *Daphnia* sp., and exceptionally *Bosmina* sp., *Cyclopidae* and *Chironomidae* larvae.

Rudd fry in the stage III fed mainly on phytoplankton and zooplankton. Detritus did not usually exceed one fourth of the content of the alimentary canal. The species composition of the phytoplankton was the same as in the preceding food stages only more and more large algae were found (*Cladophora* sp.). Zooplankton was represented by cladocerans of the *Daphnia* genus.

In stage IV juvenile rudd individuals had a wide alimentary spectrum with phytoplankton dominating. The share of zooplankton and detritus in the diet of the examined fish was smaller.

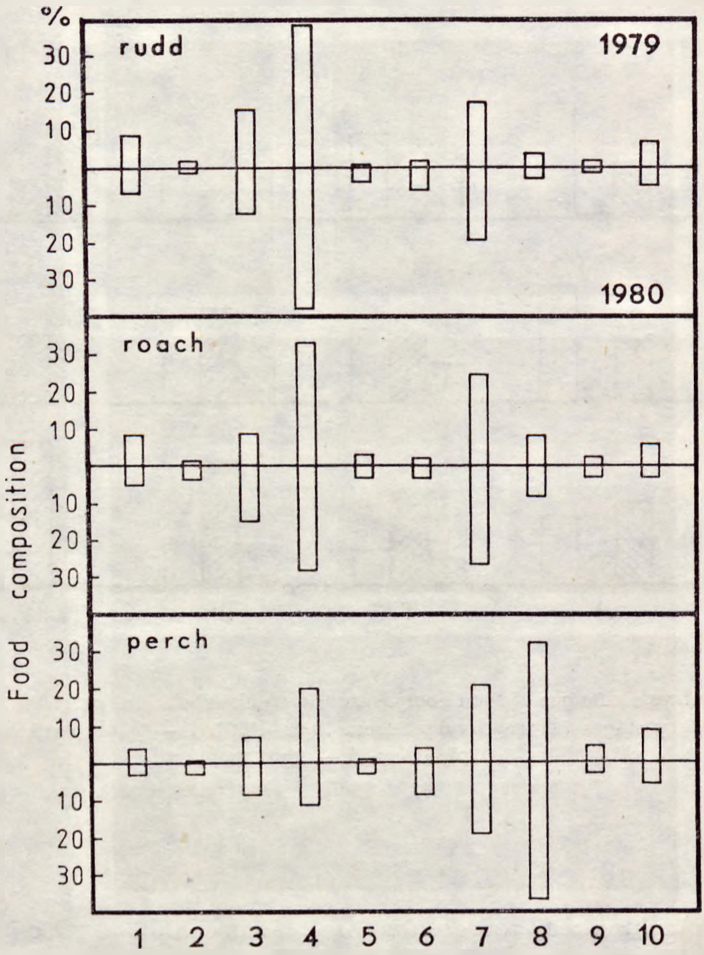

Fig. 3. Percentage food composition of rudd, roach, and perch fry (average values from 1979—1980). 1 — Cyanophyceae; 2 — Dinophyceae; 3 — Bacillariophyceae; 4 — Chlorophycae; 5 — Oligochaeta; 6 — Rotatoria; 7 — Cladocera; 8 — Copepoda; 9 — Chironomidae; 10 — detritus

3.2.2. Roach

In the alimentary canal of roach fry in stage I detritus and phytoplankton dominated. The species composition of phytoplankton was similar to that in the first food stage of the rudd. Animal food was represented by cladocerans of the *Bosmina* genus.

In stage II rudd fry fed on detritus and zooplankton, in greater quantity than in stage I, and phytoplankton. In the chyme of rudd there appeared such animals, hitherto uncommon in its food, as *Alona* sp., *Daphnia* sp., *Daphnia magna*, and *Cyclops* sp. The species composition of phytoplankton remained unchanged.

In stage III of juvenile roach individuals food was dominated by zooplankton followed by detritus and phytoplankton. Animals consumed belonged to the following genera: *Alona, Bosmina, Daphnia, Cyclops,* and a small percentage of *Oligochaeta* and *Chironomidae* larvae. In the phytoplankton the number of diatoms decreased and such green algae appeared as *Cladophora* sp., *Coelastrum* sp., *Pediastrum* sp., and *Desmidium* sp. Roach in stage IV fed mainly on zooplankton, phytoplankton, and detritus.

The species composition of both vegetal and animal food was the same as in the preceding stage.

3.2.3. Perch

The chyme of perch in alimentary stage I consisted of phytoplankton, detritus, and zooplankton. In vegetal food blue-green algae, diatoms, and green algae occurred. Animal food was represented mainly by cladocerans.

Perch fry in stage II consumed mainly zooplankton, the share of detritus and phytoplankton being small. Zooplankton was dominated by *Cyclopidae,* this domination becoming more and more distinct in older individuals. Zooplankton was found in the food of perch in stage III more often than detritus and phytoplankton. No great species variation in alimentary organisms was observed either among animals, represented mostly by *Cyclopidae,* or among plants.

In stage IV perch fry fed mainly on zooplankton, where individuals of the *Cyclops* genus dominated. Also detritus and small amounts of phytoplankton were found in the chyme.

4. Discussion

Most authors examining the food of juvenile stages of various fish species (Pliszka, Dziekońska 1953, Boruckij 1960, Leszczyński 1963, Marciak 1967) found certain similarities in its qualitative composition. They emphasized at the same time that differences in the composition of the chyme in the fry of the particular fish species concern mainly mutual quantitative proportions. This probably results from two factors:

— a poorly developed alimentary specialization of fry (Boruckij 1960);
— the occupation of the common ecological niche by the juvenile stages of various fish species (Backiel 1953).

The four stages of fry feeding distinguished in the course of the investigation illustrate the changes in the food spectra of the rudd, roach,

and perch during their ontogenesis. Stage I was similar in all the investigated species. The domination of phytoplankton and detritus with the minimal use of phytoplankton is marked here (fig. 2). As the fry grew, in stage II, the first essential differentiation in the diet of the examined fish was noted. The food of the perch consisted mainly of zooplankton with strong *Cyclopidae* domination, whereas in the roach and rudd, despite the increasing quantity of zooplankton, a large share of phytoplankton and detritus was still observed (fig. 2). The 20—40 day fry of the roach and 20—35 day fry of the rudd (stage II) had an almost identical food spectrum and it was not until stage III that differences appeared; the rudd took mostly phytoplankton and the roach zooplankton. The alimentary stage IV allows a certain differentiation between the food of rudd (herbivorous), roach (omnivorous), and perch (predator) (fig. 2).

In comparing the author's own results with those of other authors investigating fry in reservoirs with a normal water temperature, vital differences appear. They concern not only the species composition of the chyme, closely connected with the amount of food available in the environment, but also other differences of a more general character. The rudd, roach, and perch in the alimentary stage I in the Rybnik reservoir consumed mainly phytoplankton and detritus, whereas the 9—16 mm long rudd fry, in Lake Gołdopiwo consumed 41—60% of food, described by the authors Leszczyński (1963) and Marciak (1967) as small littoral *Cladocera* up to 2 mm in length. Similarly in 8—11 mm roach the above-quoted authors found domination of littoral *Cladocera* (inhabiting submerged meadows). In the alimentary stage II of fry in the Rybnik reservoir, the diet showed a division between the non-predatory fish (rudd and roach) and the predatory (perch).

Pliszka and Dziekońska (1953), Leszczyński (1963), and Marciak (1967) agree that the rudd of about 20 mm in length feeds almost exclusively on animal food consisting above all of large littoral *Tendipedidae, Copepoda,* phytophalus *Insecta,* and littoral *Cladocera* — *Acroperus harpae,* and *Ceriodaphnia quadrangula.* Results concerning the feeding of 19—29 mm roach (corresponding to alimentary stage II) are more differentiated. According to Pliszka and Dziekońska (1963), the examined roach fry consumed mainly phytoplankton (*Cyanophyceae* 10% and *Chlorophyceae* 13%), *Chydorus sphaericus* 31%, and *Oligochaeta* 10%, whereas according to Leszczyński (1963) and Marciak (1967) the chyme of the roach was dominated by littoral *Cladocera* (*Ceriodaphnia* and *Bosmina*). Perch fry (21—31 mm long) in Lake Tajty (Pliszka, Dziekońska 1953) fed almost exclusively on *Cyclopidae* (about 95% of the chyme). The importance of *Cyclopidae* in the food of perch fry up to several centimetres in length are confirmed by the in-

vestigations of Chodorowska and Chodorowski (1969) and Spanovskaya and Grygorash (1977).

In the alimentary stage III of fry in the Rybnik reservoir it was possible to observe differences between the food of the rudd and roach (fig. 2) which accord with the data given by other authors. According to Pliszka and Dziekońska (1953), in waters with natural temperature the rudd consumes *Trichoptera* larvae (67%) and considerable quantities of vascular plants (16%). Marciak (1967) also mentions that in the food of 24—39 mm rudd a domination was found of large *Tendipedidae, Chydoridae,* and *Insecta,* including the mature *Culicidae* which fell from the air. However, 27—40 mm roach had a fairly monotonous diet consisting either of pelagic crustanceans or phytoplankton.

In the alimentary stage IV of fry the food of species examined in the Rybnik reservoir was similar to that of mature specimens (Klimczyk-Janikowska 1978 and unpubl. data, Jelonek 1985).

This composition of the chyme of fry and a slightly altered manner of food spectra differentiation, unlike that in waters with a natural temperature, was probably caused by the environmental conditions of the "warm" Rybnik reservoir. A certain role in the process discussed above should be ascribed to the blooms which occur frequently in the reservoir. This can be clearly seen in the analysis of the diet of individuals in the initial alimentary stages (Table II, figs 2, 3).

It should be assumed that vegetal food consumed by fry consists not only of living but also of decayed algae constituting detritus. This supposition is based on the following premisses. The main source of detritus in dam reservoirs and lakes are macrophytes (Pieczyńska et al. 1984), followed by the leaves and remnants of terrestrial plants, phyto- and zooplankton, bodies and shells of snails, excrements of littoral animal, and the like. In the Rybnik reservoir on whose shore there are not macrophytes, the composition of detritus is different.

Assuminig after Jassby and Goldman (1974) that the daily physiological death rate of phytoplankton may amount to 20—87% of production and that a considerable part of it is transformed into detritus (Pieczyńska et al. 1984), plankton organisms and matter of allochtonous origin may be regarded as the main constituent of detritus in the Rybnik reservoir. The share of this matter in the detritus is traceable at a maximum distance of 10 m from the shore (Gasith 1974 after Pieczyńska et al. 1984), hence it is important only for the earliest age stages of the examined fish feeding in the littoral waters. In addition, the absence of macrophytes in the littoral part of the investigated reservoir may decrease to a minimum the accumulation rate of detritus in the littoral zone as a result of intensified undulation. It may be assumed that detritus from the littoral zone of the reservoir undergoes constant replacement (reneval). Therefore, the value of effective assimilation of

detritus by animals (in this case fry), estimated by Berrie (1976) as 6—35%, becomes probable. It shows, at the same time, the role of detritus in the circulation of matter and energy in fry populations of rudd, roach, and perch in the heated Rybnik reservoir.

5. Polish summary

Pokarm stadiów młodocianych wzdręgi (*Scardinius erythrophthalmus* L.), płoci (*Rutilus rutilus* L.) i okonia (*Perca fluviatilis* L.) w podgrzanych wodach zbiornika zaporowego Rybnik (Polska Południowa)

Badano narybek wzdręgi, płoci i okonia żyjący w litoralu zbiornika Rybnik (tabela I). Zbiornik ten zasilany jest ciepłymi wodami zrzutowymi elektrowni Rybnik, które powodują, że temperatura wody jest o około 8° wyższa niż normalna temperatura wód tego rejonu Polski (Włodek unpubl.). Badania przeprowadzono na 330 osobnikach wzdręgi, płoci i okonia odławianych w miesiącach wiosenno-letnich w 1979 i 1980 roku. Przeanalizowano treść pokarmową narybku od wylęgu do prawie czterech miesięcy życia (ryc. 1, 2, 3), wyróżniając cztery stadia odżywiania. Stadium I jest u badanych gatunków podobne. Zaznacza się tu dominacja planktonu i detrytusu z minimalnym wykorzystaniem zooplanktonu. W miarę wzrostu narybku, w II stadium, zauważono pierwsze istotne zróżnicowanie diety badanych osobników. W pokarmie okonia było najwięcej zooplanktonu z silną dominacją *Cyclopidae* (tabela II, ryc. 2), u płoci natomiast i wzdręgi pomimo zwiększania się ilości zooplanktonu w diecie obserwowano w dalszym ciągu przewagę detrytusu oraz fitoplanktonu. U narybku w III stadium pokarmowym występują różnice pomiędzy pokarmem wzdręgi zjadającej fitoplankton i płoci żywiącej się głównie zooplanktonem. W IV stadium zauważa się wyraźne zróżnicowanie pokarmu wzdręgi (ryba roślinożerna), płoci (ryba wszystkożerna) i okonia (drapieżnik) (ryc. 1, 2, 3).

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