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FEEDING PATTERNS OF SOME CYPRINID FISH LARVAE IN LICHEŃSKIE AND GOSŁAWSKIE LAKES IN 1994

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ABSTRACT. Studies were carried out on feeding patterns of roach, bleak, white bream, rudd, and bream larvae from the beginning of exogenous food consumption until fry stage. Species composition of food changed with fish size from Rotatoria, Cladocera, and Copepoda to larvae and pupae of Chironomidae. Food deficiency reduced growth rate of fish.

Key words: HEATED LAKES, LARVAL FEEDING, 5 SPECIES OF CYPRINID FISH.

INTRODUCTION

Observations of fish juveniles in heated Konińskie lakes usually focused on the composition of fry communities in shallow littoral. Changes in species composition (disappearance or appearance of the species), densities and fish growth were analysed (Wilkońska and Żuromska 1977, 1983, Wilkońska 1988, 1989).

The present study is one of the first to focus on feeding of fish juveniles. It concerns food composition analysed from the beginning of exogenous feeding to the fry stage of roach (*Rutilus rutilus* L.), bleak (*Alburnus alburnus* L.), white bream (*Blicca bjoerkna* L.), rudd (*Scardinius erythrophtalmus* L.), and bream (*Abramis brama* L.).

MATERIAL AND METHODS

The fish were sampled from April 14 to June 7, 1994, from three sites: two in Licheńskie Lake, situated at both banks of the discharge channel, and one in Gosławskie Lake (Fig. 1). The fish were netted and preserved in 4% formaldehyde. They were identified to species according to morphometric features (Koblickaja 1966) and developmental stage (Vasnecov 1953). At the same time, plankton samples were collected (10 l of lake water was filtered through plankton net) and fixed using Lugol solution and formaldehyde. Density and species composition of plankton were evaluated using Bogorov's chamber and a binocular.

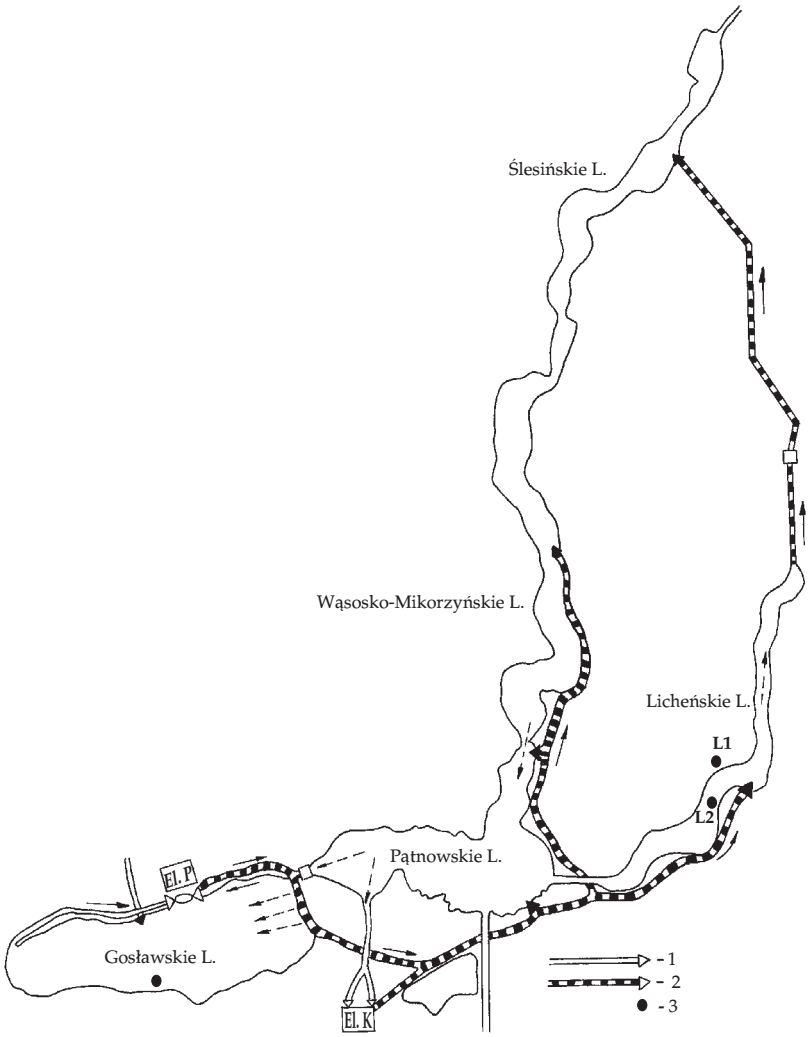


Fig. 1. Diagram of the cooling system and places of catching fry. 1 - cool water, 2 - warm water, 3 - station

Fish food was analysed according to "Metodicheskoe posobie po izucheniju pitanija i pishhevykh otnoshenij v estestvennykh uslovijakh" (1974).

The study started at the beginning of exogenous feeding of larvae (C_1 stage), and continued until fry stage (F-G). The list of all food items observed during the study (Apr. 14-June 7) is shown in Table 1. Plankton samples and fish feeding patterns were analysed in the Laboratory of Bioproductivity of the Institute of Freshwater Biology of the Russian Academy of Sciences.

TABLE 1

Feed species composition of fish fry in lakes Licheńskie and Gosławskie in IV-VI of 1994

	Lake Licheńskie					Lake Gosławskie				
	Rutilus	Alburnus	Blicca	Scardinius	Abramis	Rutilus	Alburnus	Blicca	Scardinius	Abramis
Phytoplankton										
Anabaena flos-aquae						+		+		+
Aphanizomenon flos-aquae	+				+	+	+			
Colothrix sp.	+		+		+					
Flagilaria crotonensis	+		+					+		
Diatoma vulgare	+	+	+	+	+	+	+	+	+	+
Diatoma elegantum	+	+	+	+	+	+	+	+	+	+
Synedra sp.	+	+	+	+	+	+	+		+	
Asterionella formosa	+				+	+				
Tabellaria fenestrata	+	+	+	+	+					
Closterium moniliferum	+	+	+	+	+					+
Padiastrum sp.	+	+		+	+					
Protozoa										
Arcella sp.	+				+			+		
Rotatoria										
Brachionus angularis	+	+	+	+	+	+	+	+	+	+
Brachionus calyciflorus	+	+	+	+	+	+	+	+	+	+
Keratella cochlearis	+	+	+	+	+	+	+	+	+	+
Keratella quadrata	+	+	+		+		+			
Lecane luna	+	+	+							
Asplanchna priodonta	+	+	+			+	+	+	+	+
Filinia	+	+		+	+	+	+	+	+	
Copepoda										
Cyclopc sp.	+	+	+	+	+	+	+		+	
Harpacticoida sp.						+		+		
Cladocera										
Sida crystallina	+	+	+	+	+					
Limnosida frontosa										+
Diaphanosoma brachyurum						+				
Daphnia cuculata	+	+	+	+	+	+				
Ceriodaphnia affinis	+				+					+
Eurycercus lamellatus	+		+	+	+					
Camptocercus rectirostris	+	+	+	+	+					
Chydorus sphaericus	+	+	+	+	+		+	+		
Alona affinis	+	+	+	+				+	+	
Bosmina longirostris	+	+	+	+	+	+	+	+	+	+
Polyphemus pediculus	+						+		+	
Larvae Chironomidae										
Ablabesmyia monilis	+	+				+	+			+
Orthocladius sp.	+	+				+	+			+
Cricoptopus silvestris	+					+	+		+	+
Cryptochironomus sp.			+							+

	Lake Licheńskie					Lake Gosławskie				
	Rutilus	Alburnus	Blicca	Scardinius	Abramis	Rutilus	Alburnus	Blicca	Scardinius	Abramis
Gliptotendipes sp.	+		+			+		+		+
Polypedilum pullum						+		+		+
Tanytarsus sp.	+		+			+	+	+	+	+
Chironomidae pup.	+	+				+	+	+	+	+
Other larvae:										
Odonata	+					+				
Coleoptera	+					+				
Trichoptera	+					+				
Hydracarina	+									
Dreissena veliger	+	+				+	+		+	
Various:										
Nematoda	+	+	+							
Oligochaeta							+	+	+	
Gammaridae						+				
Ostracoda	+			+		+				
Coniferous seeds	+	+	+							

FEEDING OF THE LARVAE

Food composition changed with fish size and was related to the composition of lake plankton community. The share of organisms predominating in the digestive tracts of fish at various developmental stages (C_1-G) from the three sampling sites is shown in Table 2.

On April 14, the larvae of roach, bleak and white bream starting exogenous feeding (the end of B stage, beginning of C_1) at site L1 fed mainly on small Rotatoria (*Brachionus sp.*, on the average 1.8 ind. per fish), with slight addition of algae. In stage C_1-C_2 (Apr. 26) larger Rotatoria, such as *Keratella* and *Asplanchna*, appeared in fish food (3.4 ind. per fish in roach and bleak, and up to 9 ind. per fish in rudd). Digestive tracts of bream and white bream were filled in 80-90% with algae (diatoms and green algae). In the next stage (C_2-D_2, May 4) Rotatoria were replaced by crustaceans. Roach consumed mainly small Cladocera (*Bosmina longirostris*, *Chydorus sphaericus*) and juvenile Copepoda (nauplii and copepodites). Cladocera comprised up to 66.6% of total number of food organisms in rudd. Bleak, on the other hand, fed exclusively on algae (periphytic diatoms), while in larger roach (stage D_2-E) this food item comprised 80% of the diet. Two crustaceans per fish were found on the average. In bream 50% of the digestive tracts were empty. The larvae at D_2-E-F stages (May 16) still fed

TABLE 2

Species dominating in fish food in consecutive stages of development (C1-G) from 14 April to 7 June 1994

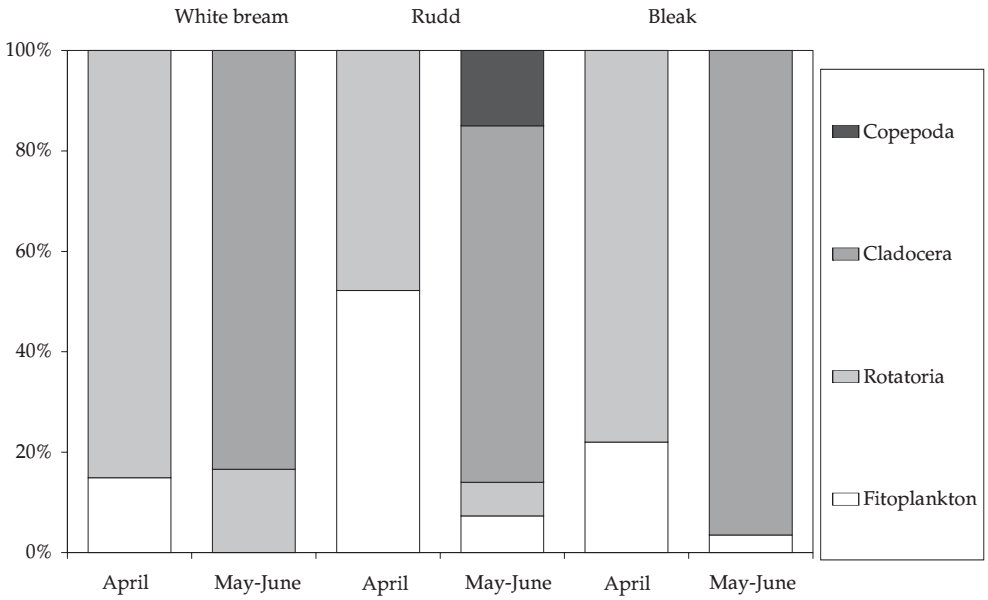
Date	Species	Stage	Station L1	Station L2		Station Gos
14.04	Roach	B-C1	Rot: Brachionus+ algae av. 1.8*	As L1+	Rot: Keratella, kopepodits av. 0.9* coniferous seeds	Only roach: Algae, veliger, kopepodits, Cla:Daphnia long. av. 0.2*
	Bleak	B-C1	Algae + Rotatoria			
	White bream	B				
26.04	Roach	C2-D2	Rot: Asplanchna, Keratella, av. 3.4* Coniferous seeds	As L1+	Rot: Lecane, Nematoda, kopepodits, algae 50-80%	Rotatoria
	Bleak	C1-C2				Cla: Polyphemus, veliger av. 4.6*
	Rudd	BC1	Nematoda + algae av. 9.0*			
	Bream	C1	Algae: diatoms Tabellaria, Synedra		Algae 100%	Algae, Rot: Brachionus, Asplanchna, Keratella 20% empty
	White bream	C1-C2	green algae – Closterium 80-90%			
4.05	Roach	C2-D2	Cla: Bosmina, Chydorus, kopepodits Ostracoda av. 2*	Ostracoda, kopepodits 2.8*		Rotatoria, Gammaridae av. 4.5*
	Roach	D2-E	Algae – diatoms, green algae 80%			lack
	Rudd	C2	Cladocera 66.6%	As L1+		lack
	Bleak	C2	Only algae (perifiton)			lack
	Bream	C2/D2	Algae; 50% empty	kopepodits		
	White bream	C2-D2	Algae	lack		Filamentors algae, diatoms
16.05	Roach	D2-E-F	Cla. phytophilic: Polyphemus, Sida, Alona, Ceriodaphnia – 27* pelagic: Bosmina, Chydorus – 23*	As L1+	Camptocercus, Daphnia av. 10.6*	Bosmina, veliger, detritus Harpacticoida – 20*, insect larvae
	Bleak	D-E-F	Cladocera, kopepodits, naupli			Bosmina, insect larvae, Chydorus, Copepoda
	White bream	D2	Cyclops, Cla: Camptocercus, Daphnia, Bosmina	Algae: diatoms and Padiastrum		lack
	Bream	C2-E	lack	lack		Rot: Brachionus, Copepods, Cladocera – 30*
	White bream II	C1-C2	Only zooplankton, Bosmina, Chydorus, av. 5.5*	lack		lack
7.06	Roach	E-F-G	Filamentors algae, veliger (up to 52*), larvae and pupae Chironomidae (27*) and Trichoptera	Alagae, detritus, Hydracarina av.1.9* Larvae Diptera and Trichoptera		Rot: Brachionus, insect larvae, Oligochaeta, zooplankton
	Bleak	D2-E	Pupae Diptera, kopepodits (up to 217*), veliger	Algae, veliger, Rotatoria, kopepodits 150*		- as above -
	Rudd	D2-E	lack			- as above -
	White bream	D2-F	lack			- as above-
	Rudd II	C1-C2	lack	lack		Zooplankton in this Bosmina 83%, 30% of weight
	Bleak II	C1-C2	Diatom perifiton, Rotatoria, Bosmina, Chydorus			lack

** ind. per fish*

on crustaceans, but their composition was more diversified. Roach chose phytophilic (27 ind. per fish) and pelagic (23 ind. per fish) Cladocera. Bleak consumed all Cladocera and juvenile Copepoda. White bream fed on large *Cyclops* and Cladocera, but preferred different species than roach (Tab. 2). White bream larvae (C_1-C_2) captured only *Bosmina* and *Chydorus* (5.5 ind. per fish). Insect larvae and pupae appeared in the digestive tracts of larger fish (F-G, June 7). In roach Chironomidae (27 ind. per fish) and Trichoptera were observed, in bleak – Diptera. The two species fed also on *Dreissena veligers* (up to 52 in roach, and to 217 in bleak) and on copepodites. At he same time, new generation of bleak (C_1-C_2) fed on periphytic diatoms, Rotatoria, and small Cladocera (*Bosmina* and *Chydorus*) (Tab. 2).

At the site L2, fish larvae fed similarly as at L1; the observed differences might have resulted from different development rate within the same stage C_1-C_2, or different availability of certain food items. For example, *Keratella* appeared together with copepodites in the fish digestive tracts at site L2 already on Apr. 14 (0.9 ind. per fish), accompanied by conifer seeds. On Apr. 26, not only bream, but also rudd grazed on algae which comprised 100 and 50% of the sample content respectively. On the average, 5.9 food organisms per fish were found. At the beginning of May roach preyed on Ostracoda, and bream – on copepodites. The average number of prey organisms was 2.8 per fish, more than at L1 site. On May 16, similarly as at L1, roach and bleak fed on Cladocera but consumed more: 10.6 ind. per fish, and white bream consumed only algae. On June 7, roach digestive tracts contained, besides Diptera larvae and pupae, also Hydracarina and detritus. This indicates that fish fed near the bottom. In case of bleak, digestive tracts filled with algae, Rotatoria, copepodites and veligers suggest deficiency of other prey (Tab. 2).

In Gosławskie Lake fish food composition was slightly different. On Apr. 14 roach fed on *Daphnia*, veligers and copepodites (0.2 ind. per fish), and on Apr. 26 they consumed mainly Rotatoria (80-100% of the diet). At the same time, rudd and bleak captured *Polyphemus* and veligers. Both species of bream grazed on algae, with some addition of Rotatoria. Digestive tracts were empty in 20% of the fish. Also on May 4 roach preferred Rotatoria (4.5 ind. per fish), and both species of bream – algae. On May 16 the fish started to feed on Cladocera and insect larvae – in roach and bleak 15-20 ind. per fish were found, and in bream up to 30 ind. per fish. On June 7 older roach, rudd, bleak and white bream juveniles (EF) fed on planktonic crustaceans, insect larvae and pupae, and Oligochaeta. New generation (C_1-C_2) of rudd consumed small crustaceans, among which *Bosmina* comprised 83% of the total number and 30% of the biomass (Tab. 2).



Rys. 2. Food composition (% of the numbers) of early (April) and late (May) larvae in stages C1-C2

Comparison of fish food in successive samples revealed differentiation of its composition respective to fish items and size (Tab. 2). In case of the larvae beginning exogenous feeding (C_1-C_2), food composition depended on time: early hatch (April) fed on algae and rotifers, and late hatch (May-June) consumed almost exclusively crustaceans – mainly small Cladocera (*Bosmina*, *Chydorus*) (Fig. 2). Presence of *Chydorus sphaericus* in C_1 fish was observed also by Panov and Sorokin (1966) and Grigorash (1963).

Analysis of the composition of fish food and its dynamics over time (Tab. 2) allowed to distinguish 4 main groups of prey organisms: Rotatoria, Cladocera, Copepoda and Chironomidae (Tab. 1). Small Rotatoria were the first fish food, followed by small Cladocera (mainly *Bosmina* and *Chydorus*), juvenile Copepoda (nauplii and copepodites), while at the end of larval development (stage E-G) fish fed on insect larvae and pupae, mainly Chironomidae. The larvae fed also on phytoplankton, initially on periphytic diatoms and later on green algae. *Dreissena* larvae (veligers) were an additional component of the fish diet, accompanied by conifer seeds. Presence of the latter may indicate food deficiency, although, according to Grigorash (1963) these seeds are often eaten by fish at early larval stages.

DISCUSSION

Changes in the composition of fish larvae diet observed over time were related not only to fish size, but also to availability (abundance) of food in the environment. Relative densities of the 4 main groups of plankton over the study period (Apr. 14 – June 6) are shown in Fig. 3-5, together with developmental stages of the fish. Densities (ind. l^{-1}) and biomass (mg l^{-1}) of zooplankton are shown in Table 3.

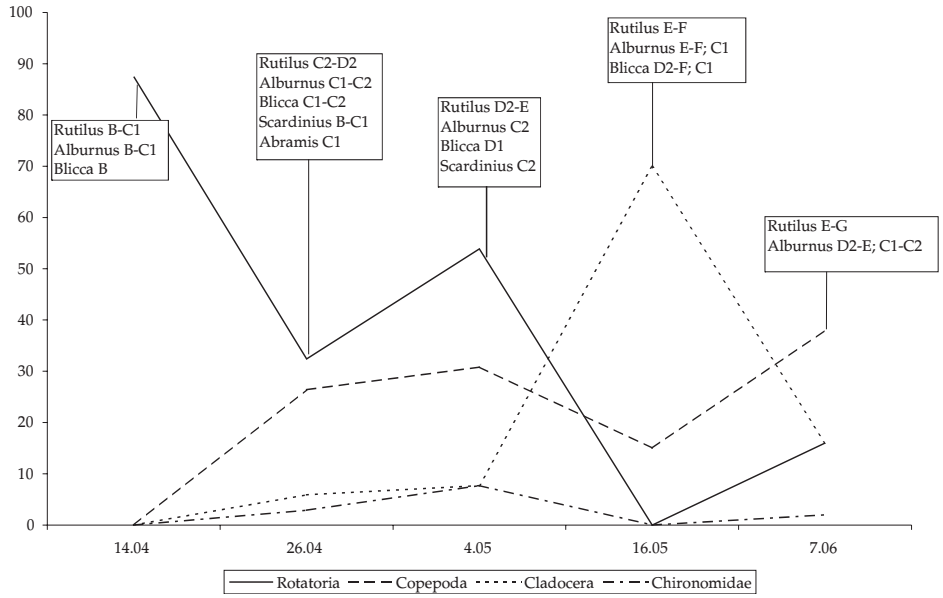
TABLE 3

Numbers (ind. l^{-1}) and weight (mg l^{-1}) of zooplankton at the sampling stations in 14 April -7 June of 1994

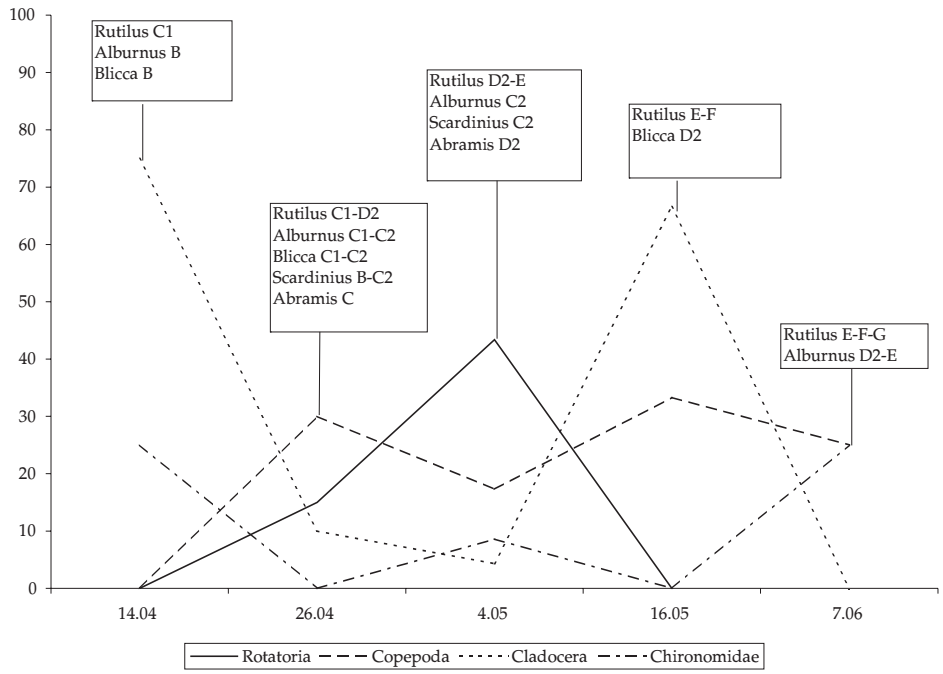
Date	Lake Licheńskie				Lake Gosławskie	
	L1		L2			
	ind. l^{-1}	mg l^{-1}	ind. l^{-1}	mg l^{-1}	ind. l^{-1}	mg l^{-1}
14.04	499	0.2	249	0.2	237	0.2
26.04	2123	0.9	1250	0.3	450	0.2
4.05	748	1.2	1062	0.8	811	0.4
10.05	1250	1.6	187	0.8	1123	0.8
7.06	2998	0.9	248	0.6	251	0.5
Mean	1523,6	1.0	599.2	0.5	574.2	0.4

When the fish started exogenous feeding, Rotatoria predominated (87%) at the site L1 (Fig. 3). Later on their number decreased, and share of crustaceans (Cladocera and Copepoda) increased from 32.3% (Apr. 26) to 85% (May 16). At this time majority of the fish completed their larval development and reached the fry stage. New generations of white bream and bleak (stage C_1-C_2, May 16 and June 7) took advantage of abundant (70%) small crustaceans (*Chydorus sphaericus*, Tab. 2, Fig. 3). Thus, it seems that most larvae at this site developed under good feeding conditions. This is also confirmed by average zooplankton density, which amounted to 1523.6 ind. l^{-1} and 1 mg l^{-1} (Tab. 3). The results by Panov and Sorokin (1966) showed that zooplankton density of 1000-1500 ind. l^{-1} was quite sufficient for larval development. Moreover, high density of prey brings about a reflex of capture, accelerating the development of fish mouth, thus increasing food availability (Michaev 1984, Strielnikova 1987, 1988, 1989).

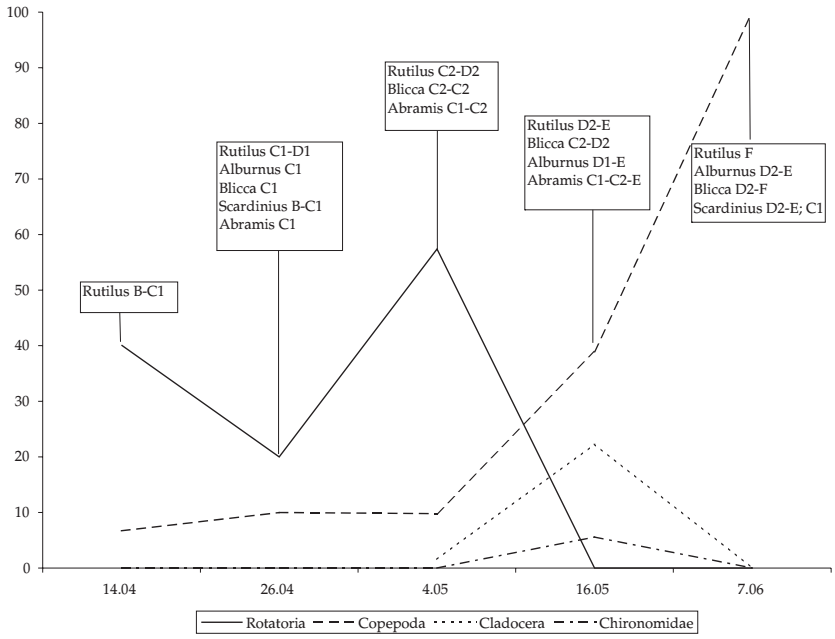
At site L2 (Fig. 4), on Apr. 14, small Cladocera predominated, mainly *Chydorus sphaericus*, available only to roach larvae (stage C_1). Larvae of bleak and white bream commencing exogenous feeding (stage B/C) had to consume conifer seeds (Tab. 2).



Rys. 3. Dynamics of the numbers (%) of zooplankton groups versus larvae developmental stages at ststion L1 in 14 April -7 June 1994



Rys. 4. Dynamics of the numbers (%) of zooplankton groups versus larvae developmental stages at station L2 in 14 April - 7 June 1994



Rys. 5. Dynamics of the numbers (%) of zooplankton groups versus larvae developmental stages in Lake Gosławskie in 14 April - 7 June 1994.

Scarce Rotatoria and Copepoda appeared on Apr. 26, and more numerous Cladocera – on May 16 (Fig. 4), this being quite beneficial for roach.

Zooplankton dynamics was similar as at the site L1, but the density (599.2 ind. l^{-1} and 0.5 mg l^{-1} – Tab. 3) was 2.5 fold lower, indicating that feeding conditions, except for roach, were poorer than at L1 station.

Zooplankton dynamics in Gosławskie Lake was different than in Licheńskie, and unfavourable for the larvae. From Apr. 14 to May 4 only Rotatoria were abundant, Copepoda being scarce (<10%). The latter predominated in the lake from May 16 to June 7. Cladocera were present only on May 16 (Fig. 5). Moreover, average share of these groups of plankton reached only 65%, while in Licheńskie Lake they comprised 82% at the site L1, and 96% at L2, at similar density (574 ind. l^{-1}, Tab. 3). The larvae, lacking appropriate food, fed mainly on algae with Rotatoria, copepodites and veligers. Only new generation of rudd (June 7) took advantage of high density of Copepoda (Fig. 5).

Food deficiency resulted in prolonged duration of developmental stages, for example bream remained at the stage C_1 from Apr. 26 to May 16.

Feeding conditions at all sampling sites were related to species composition and density of zooplankton. For example, at the site L1 the densities of 4 successive samples were

over 1000 ind. l^{-1}, at L2 such densities were observed only twice, and at the site Gos – once. Also zooplankton biomass at L1 was twice higher compared to other sites, due to the presence of planktonic young larvae of Chironomidae, and large phytophilic Cladocera (*Polyphemus, Camptocercus, Eurycercus* – Tab. 1), and copepods. The differences between sites L1 and L2 might have resulted from location of L2 station near the channel. Sand and abundant suspension in the samples suggest water mixing which might have limited crustacean development at this site. In the environments affected by the power plants, mechanical destruction of crustaceans was reported and destruction of the wintering stages of Cladocera due to washing out from the bottom by the current (Mordukhaj-Boltovskoj 1974, 1975). Aggregation of pelagic Cladocera and Copepoda near the bottom, under the layer of heated water, was also observed (copepodites of *Cyclops vicinus, C. strenuus, Daphnia cucullata, D. longispina, Leptodora kindtii, Diaphanosoma brachyurum*). Abnormal conditions of feeding and living may reduce their density (River 1974).

In Gosławskie Lake all fish larvae started exogenous feeding at very low absolute and relative density of Cladocera and Copepoda, thus had to consume algae. This resulted in extended duration of the successive developmental stages. For example, bream remained at the stage C_1 from Apr. 26 to May 16.

Summarising the results of the present study it should be stressed that in 1994 not all fish larvae developed under favourable feeding conditions. Beginning of exogenous feeding did not always coincide with abundant prey and this reduced in ecological and morphological availability of the food resources for C_1-C_2 larvae.

Moreover, interspecific relations regulated by different time of spawning, hatching and beginning of exogenous feeding, were disturbed. For example, under natural conditions bream starts exogenous feeding when roach already completes stage 3 of larval development, changes its feeding grounds and includes larger organisms in the diet. In Gosławskie Lake, however, the larvae of all analysed species at the stage C_1 started exogenous feeding at the same time, which resulted in strong feeding competition. Under natural conditions diversity of age structure of fish juveniles reduces competition. This is particularly important in the reservoirs in which species diversity and density of zooplankton depend on external factors, as in Konińskie lakes.

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STRESZCZENIE

ODŻYWIANIE SIĘ WYLĘGU WYBRANYCH GATUNKÓW RYB KARPIOWATYCH W JEZIORACH LICHEŃSKIM I GOSŁAWSKIM W 1994 ROKU

Celem pracy było poznanie odżywiania wylęgu płoci, uklei, krąpia, wzdręgi i leszcza od momentu przechodzenia na pokarm egzogenny do stadium narybku. Badania prowadzono w 1994 r. na 3 stanowiskach w jeziorach podgrzewanych w okresie od 14.04-7.06 (rys. 1). Skład gatunkowy pokarmu ogółem zestawiono w tabeli 1, tylko gatunki dominujące w kolejnych próbach w tabeli 2 a skład prób zooplanktonu w tabeli 3. Wyróżniono 4 grupy pokarmu: pierwszymi ofiarami wylęgu były drobne Rotatoria. Następnie w miarę wzrostu i rozwoju wylęgu, drobne Cladocera, Copepoda oraz larwy i poczwarki Chironomidae (rys. 2-5). Zooplankton uzupełniały glony – perifiton okrzemkowy i zielenice. Synchronizacja dynamiki liczebności tych grup z pojawieniem się wylęgu decydowała o jego wzroście i rozwoju (rys. 3-5).

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