ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

FOOD COMPOSITION AND SELECTIVITY OF JUVENILE PERCH (PERCA FLUVIATILIS L.) AGAINST FOOD RESOURCES IN THE MOUTH OF THE ODRA RIVER

Maria Wolska, Kinga Mazurkiewicz-Zapałowicz, Krzysztof Formicki
Division of Hydrobiology, Ichthyology and Biotechnology of Biotechnology of Reproduction,
West Pomeranian University of Technology in Szczecin, Szczecin, Poland

ABSTRACT

In the lower reaches of large rivers considerable densities of zooplankton, including large crustaceans, can successfully develop. We studied food composition and selectivity of juvenile *Perca fluviatilis*. The material was collected near the left bank of the western branch located in the estuarine part of the Odra. Quantitative and qualitative food composition of perch fry caught in June and July was assessed based on the content of their alimentary tracts. Also zooplankton samples were collected from the water column.

Both in June and July, copepods prevailed in the plankton of the shore zone in the river. In the diet of fry in June, however, the most common were cladocerans, while in July – copepods again. In the diet, the group of cladocerans were dominated by female *Daphnia* of 1.11 to 1.50 mm in length, whereas *in situ* smaller *Daphnia* prevailed. Among copepods, in June, mature stages were most common; in July, however, juvenile copepodits prevailed. Feeding juvenile perch have a narrow food selectivity. They preferred *Daphnia* and females of large copepods, avoiding *Bosmina*, *Diaphanosoma*, small *Thermocyclops*, and copepodits.

Key words: zooplankton, food selectivity, fry, perch.

INTRODUCTION

Zooplanktonic associations in rivers are usually scarce and generally predominated by rotifers and small crustaceans, like Bosminidae and larval stages of copepods, present around the year irrespective of the river type [7, 14, 34, 35, 37]. In some cases, the zooplankton may achieve considerable densities, and large cladocerans as well as adult stages of copepods may have a significant percentage in the population. It is not only river-lake continuum [1, 29], but also large, sluggish, lowland rivers of long-lasting water retention, where the reproduction of zooplankton is possible [8, 17]. Besides physical conditions, biological factors have a significant influence on the river plankton [7, 16]. Areas of extended water retention create environment for aquatic vegetation that in turn create substrate for specific associations of periphyton and a niche for free-living invertebrates [19]. Zooplankton is represented here by both organisms morphologically associated with macrophytes and planktonic species foraging in this zone [26] or seeking refuge against plankton eaters [3, 10]. The shore zone is also a place of fry feeding and covering to avoid fish predation [23, 27, 33]. The 0+ fry is characterized by weak food specialization and feed on the organisms that are available at a given time, are most abundant, have appropriate body size and shape, and move with the speed and manner allowing the juvenile fish to capture and eat them [28]. Zooplankton is the most important food item for juvenile stages of fish [22], and its availability is the key factor controlling the growth and survival rate of the fry [20].

As the fry grow, its dietary plankton species composition changes, the prey unit sizes grow, and the number of eaten zooplankton increases. As soon as the fry reaches certain size, the size of the consumed zooplankton ceases to change, however its amount increases rapidly. At this stage of life, one can expect the strongest pressure of the fry on large cladocerans. The impact of perch predation on *Daphnia* populations is the strongest from mid June until mid July, when *Daphnia* percentage in

the fry diet reaches 70% [15]. Also smelt and roach fry, for example, exerts the greatest pressure on the large forms of zooplankton at that time [28]. Basing on the theory of optimum feeding [30] we can evaluate the fish density and their predation pressure using species composition and size of zooplankton organisms [36]. In the mouth part of the Odra, like in other lowland rivers, adult stages of copepods and their copepodits, as well as cladocerans, coexist with much more abundant small zooplankton forms, such as rotifers and nauplii [36]. Flowing waters, due to their speed, turbulence, and turbidity, are usually classified as unfavorable as an environment for crustacean plankton growth and population development. We aimed to analyze the use of this reservoir by juvenile fish and the food selectivity by the fry of perch, *Perca fluviatilis* L., a common species of considerable economic importance.

MATERIAL AND METHODS

The material was collected near the left bank of the western branch of lower reaches of the Odra (Domiąża), on the 48.9 km. The quantitative and qualitative composition of perch fry diet was determined by analysis of the content of the alimentary tracts. Fry catches took place twice, in mid June and mid July.

The fry were caught using a landing net (mesh size 3 mm) near the shore, at about 4.00 pm. This time of the day was selected according to suggestions by Čikova [6], who demonstrated that juvenile perch feed mainly during the day, eating 90% of their daily ration between 8.00 am. And 4.00 pm. Consequently, their stomachs are maximally filled about 4.00 pm and their contents is the most reliable in terms of the composition analysis. In all, 100 alimentary tracts were examined, 50 specimens on either date. We analyzed the entire digestive tracts, as also undigested parts of animals were found in the intestines. This allowed a very detailed analysis and preparation of a detailed list of planktonic food organisms and their sizes.

Leptodora specimens were the only organisms in the stomach contents that were damaged; hence their sizes were estimated indirectly by the length of the furca. We used for this purpose the sizes of furcas and cephalothoraces of the specimens captured *in situ*. We proceeded similarly in the case of a small number of damaged exoskeletons of *Daphnia* found in the intestine (the spike was measured). Only the crustaceans were studied; nauplii, rotifers, or *Dreissena* larvae have not been found in the stomachs of the fry. The significance of differences between the composition of zooplankton in the contents of the digestive tracts and the composition of zooplankton captured in the water column were tested using the Duncan's test (Statistica PL v. 9.0). In order to depict food selectivity of perch fry in relation to particular food items and their size structure in the mouth of the Odra, we estimated the food selectivity indices using Ivlev's formula [18].

Along with the fry catches, qualitative and quantitative zooplankton samplings were performed in the water column within the shore zone of the river. Both samplings and analyses were carried out using standard methods [9].

RESULTS

It was found that the average length of fry was 37.18 mm ± 2.315 (June) and 46.08 mm ± 4.203 (July), while their unit weight, respectively, 0.887 g ± 0.201 and 1.992 g ± 0.455. Analysis of digestive tracts showed that filled stomachs contain completely digested prey. Their numbers remained in relation to the size of fish. In smaller fish (June), it averaged 153 ± 12.9 individuals, while in larger fish (July), a digestive tract contained an average of 570 ± 228.8 planktonic organisms. Comparison of the contents of the digestive tracts of juvenile fish with the species composition and size structure of prey in the environment has shown great differences in both the percentage of individual plankton species in the composition and their average size (Tab. 1, 2). The primary food of juvenile perch in June were cladocerans mainly daphnids (Tab. 1). Their share in the diet was 67%, while in the environment only 24%. Large cladocerans, *Leptodora kindti* (Focke), which occur in plankton in very small densities (in qualitative samples) and which have not been found in our quantitative plankton samples, occurred sporadically in the diet and reached a length of 7.095 mm. Apart from cladocerans, copepods were found in the diet representing 32% of the total, of which the most numerous were mature forms (males and females, 11%). Copepodits accounted for only 9%, despite the fact that their percentage *in situ* was as high as 54%. The most commonly eaten copepods were females of *Acanthocyclops robustus* (Sars) (8%), which have not been found in the quantitative plankton samples. The sizes of crustaceans present in the digestive tracts were larger than those of the plankton organisms, but the statistically significant differences were found only in the sizes of copepodits (p<0.05) (Tab. 1).

Table 1. Species composition of copepodes and cladocerans and their sizes [mm] in the diet of perch fry and in the plankton of the Odra estuary water column (means and standard deviations) in June

Species	In one digestive tract			*In situ* No l-1		
	No. of food organisms N	%N	Body length of food organisms	No. of food organisms N	%N	Body length of food organisms
Cladocera						
Daphnia cucullata ♀	58.7 ± 45.4	38	1.23 ± 0.228a	1.6	5	0.80 ± 0.312a
D. cucullata juv	15.7 ± 14.11	10		0.8	10	
Daphnia longispina ♀	22.1 ± 21.5	14	1.39 ± 0.249a	0.8	5	1.11 ± 0.532a
D. longispina juv	6.0 ± 6.41	4		0.0*	0	
Leptodora kindti	0.6 ± 1.088	0	5.02 ± 1.469a	0.0*	0	3.03 ± 2.336a
Bosmina longirostris	0.9 ± 5.406	1	0.38 ± 0.046a	0.6	4	0.29 ± 0.117a

Species	No. of food organisms N	%N	Body length of food organisms	No. of food organisms N	%N	Body length of food organisms
eggs Cladocera	250.0 ± 182.42			6.8		
Copepoda						
Acanthocyclops robustus ♀	11.6 ± 8.2	8	0.98 ± 0.164a	0.0*	0	0.82 ± 0.168a
A. robustus ♂	11.2 ± 9.986	7		1.2	8	
Cyclops vicinus ♀	0.7 ± 1.231	0	1.31 ± 0.214a	0.0*	0	1.09 ± 0.237a
C. vicinus ♂	0.38 ± 1.10	0		0.0*	0	
Mesocyclops leuckarti ♀	3.1 ± 3.163	2	0.88 ± 0.101a	0.0*	0	0.82 ± 0.114a
M. leuckarti ♂	4.1 ± 4.88	3		0.4	3	
Thermocyclops oithonoides ♀	1.3 ± 1.7	1	0.78 ± 0.088a	0.4	3	0.70 ± 0.021a
T.oithonoides ♂	1.9 ± 3.350	1		0.2	1	
Thermocyclops crassus ♀	0.5 ± 1.03	0	0.80 ± 0.072a	0.6	4	0.69 ± 0.121a
T. crassus ♂	0.3 ± 1.04	0		0.6	4	
copepodit	13.3 ± 13.53	9	0.83 ± 0.092b	8.4	54	0.56 ± 0.158a
Copepoda ♀	17.2 ± 12.208	11		1.0	7	
Copepoda ♂	18.2 ± 17.583	11		2.4	16	
eggs Copepoda	121.2 ± 97.64			22.8		

The values marked with the same indexes do not differ significantly (p<0.05)
* found only in the samples qualitative

Table 2. Species composition of copepodes and cladocerans and their sizes [mm] in the diet of perch fry and in the plankton of the Odra estuary water column (means and standard deviations) in July

Species	In one digestive tract			In situ No 1-1		
	No. of food organisms N	%N	Body length of food organisms	No. of food organisms N	%N	Body length of food organisms
Cladocera						
Daphnia cucullata ♀	94.9 ± 64.819	17	1.24 ± 0.186a	0.9	1	1.14 ± 0.317a
D. cucullata juv	23.3 ± 17.034	4		0.3	3	
Daphnia longispina ♀	37.6 ± 27.227	7	1.40 ± 0.323a	0.4	1	0.82 ± 0.379a
D. longispina juv	6.8 ± 8.010	1		0.8	2	
Leptodora kindti	41.7 ± 29.249	7	5.31 ± 1.193a	2.8	9	3.39 ± 1.187a
eggs Cladocera	362.5 ± 77.201			4.4		
Copepoda						
Acanthocyclops robustus ♀	41.6 ± 29.740	7	0.98 ± 0.130b	0.0*	0	0.78 ± 0.066a
A. robustus ♂	80.6 ± 47.217	14		2.8	9	
Cyclops vicinus ♀	7.8 ± 8.401	1	1.37 ± 0.011b	0.0*	0	1.08 ± 0.021a
C. vicinus ♂	2.0 ± 4.259	0		0.0*	0	
Mesocyclops leuckarti ♀	12.8 ± 9.719	2	0.84 ± 0.122a	0.5	2	0.95 ± 0.134a
M. leuckarti ♂	15.2 ± 18.580	3		0.0*	0	
Thermocyclops oithonoides ♀	16.0 ± 17.184	3	0.78 ± 0.080a	0.4	1	0.68 ± 0.095a
T.oithonoides ♂	21.1 ± 18.091	4		1.2	4	
Thermocyclops crassus ♀	4.9 ± 5.550	1	0.79 ± 0.094a	0.6	2	0.69 ± 0.202a
T. crassus ♂	2.4 ± 5.664	0		0.0*	0	
copepodit	159.8 ± 78.337	28	0.85 ± 0.161a	22.8	70	0.64 ± 0.146a
Copepoda ♀	83.5 ± 49.281	15		1.5	5	
Copepoda ♂	121.9 ± 68.998	21		4.0	13	
eggs Copepoda	519.8 ± 66.259			10.4		

The values marked with the same indexes do not differ significantly (p<0.05)

In the later period (July) the percentage of copepods and cladocerans in the diet changed (Tab. 2). Cladocerans accounted for only 36% of stomach content. However, among these cladocerans, *Daphnia cucullata* females dominated, attaining sizes similar to those in June (up to 1.89 mm), but constituting only 17% of the content. In July, a significantly reduced contribution of *Daphnia longispina* (8%) of up to 2.4 mm in length was observed, but the percentage of large *Leptodora kindti* (7%), reaching a maximum of 10.2 mm in length, increased. In relation to June, not only did the share of copepods (64%) increase greatly in the digestive tracts, but also their structure changed; the percentage of copepodits (28%) and males (21%) increased. The most abundant were *Acanthocyclops robustus* males (14% of organisms in the food, Tab. 2). Their sizes as well as the sizes of Cyclops vicinus from the alimentary tracts and *in situ* showed statistically significant difference (Tab. 1).

The studies have shown that food preferences of perch fry modify the quantitative and size structure of zooplankton organisms, including *Daphnia* (Fig. 1). Differences between the composition of cladocerans and copepod associations in stomach contents and *in situ* were statistically significant ($p < 0.05$) for large species (*Daphnia*, *Leptodora kindti*, *Acanthocyclops robustus*, *Cyclops vicinus*).
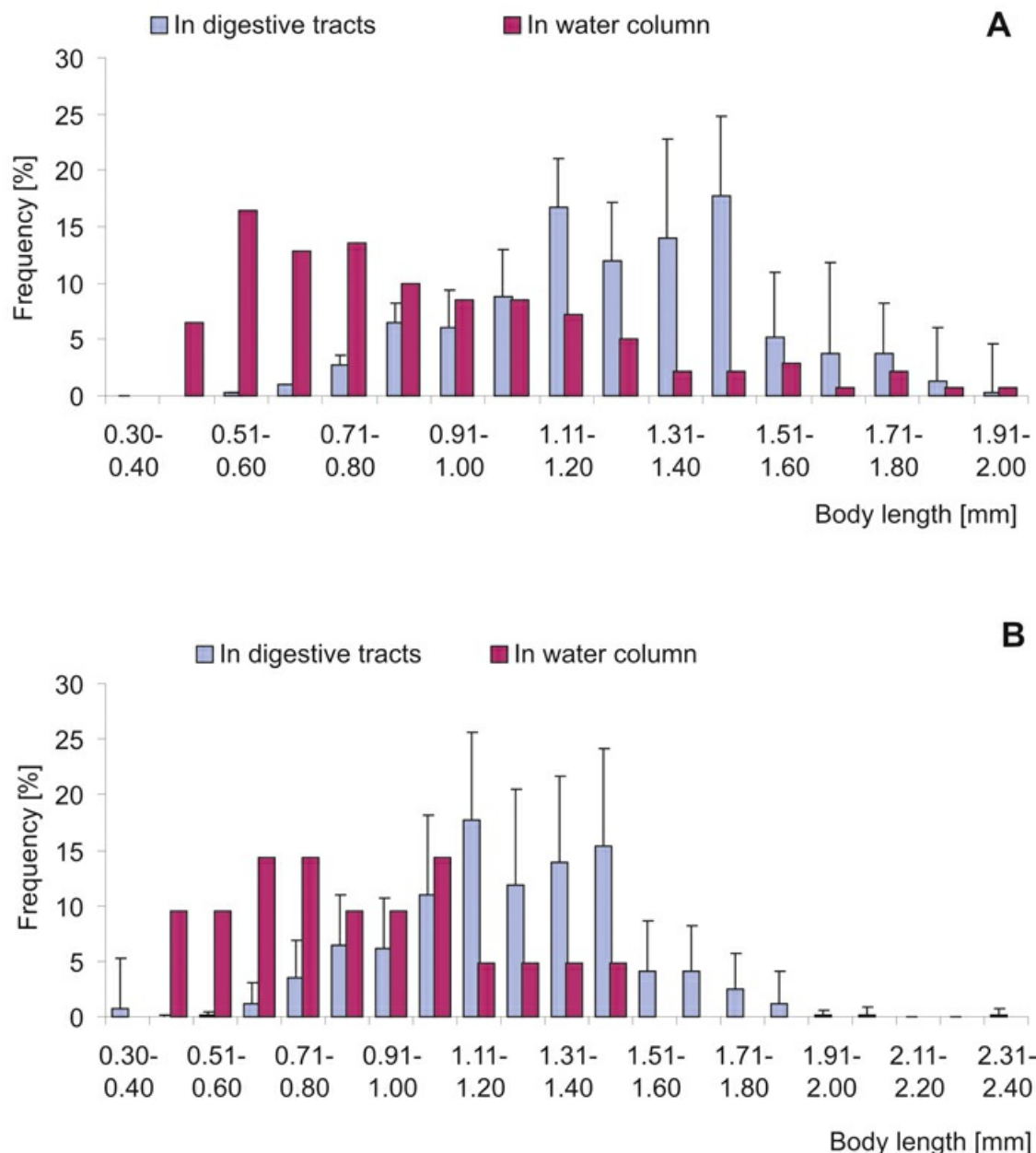
Fig. 1. Size structure of Daphnia in the mouth of the Odra and in digestive tracts of perch fry (means and standard deviations);
A: June, B: July

By the selectivity index E, the prey can be classified as "preferred" (E > 0) and "avoided" (E < 0). In June, the fry demonstrated the greatest preference for *Daphnia longispina*, followed by *Daphnia cucullata* and female copepods (*Acanthocyclops robustus* and *Mesocyclops leuckarti*). *Diaphanosoma, Bosmina, Leptodora,* copepodits and male copepods belonged to the "avoided" group. In July, the selectivity increased towards *Daphnia cucullata, Leptodora kindti* and copepods in general (Fig. 2).

Fig. 2. Coefficients of food selectivity, E, for each diet component of perch fry in the mouth of the Odra; M – male, F – female

In addition to preferences in respect of species, the selectivity in relation to certain size of prey were found within each taxon (Tab. 3, 4). It has been shown that the fry to a greater extent preferred the largest zooplankton individuals. This tendency was observed among both "preferred" and "avoided" prey animals. For organisms with the same size, the E index increased to approximately the same extent the increase in the size of prey.

Table 3. Changes in food selectivity coefficients, E, in relation to prey size in June; body length of prey [mm] above the horizontal line, E coefficient below the line

Daphnia cucullata	0.45	0.55	0.65	0.75	0.85	0.95	1.05	1.15	1.25	1.35	1.45	1.55	1.65	1.75	1.85
	-1.0	-0.962	-0.846	-0.629	-0.235	-0.402	0.052	0.446	0.490	0.809	0.825	0.142	1.0	0.038	1.0
Daphnia longispina	0.55	0.65	0.75	0.85	0.95	1.05	1.15	1.25	1.35	1.45	1.55	1.65	1.75	1.85	2.15
	-0.96	-0.771	-0.841	0.044	0.1	0.241	0.240	0.105	0.327	0.566	1.0	0.182	0.123	-0.372	1.0
Leptodora kindti	2.65	2.75	2.95	3.05	4.05	4.35	5.15	5.35	5.45	5.75	5.95	6.05	6.35	6.55	6.95
	-1.0	-1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-1.0
Acanthocyclops robustus	0.75	0.85	0.95	1.05	1.15	1.25	1.35								
	-0.462	0.014	0.1	0.276	1.0	1.0	-0.84								
Bosmina longirostris	0.25	0.35	0.45	0.55											
	-1.0	0.02	0.612	-1.0											
Cyclops vicinus	0.95	1.05	1.35	1.45	1.55										
	1.0	1.0	1.0	1.0	-0.998										
Mesocyclops leuckrti	0.75-	0.85	0.95	1.05	1.15										
	0.044	0.06	0.108	0.121	0.972										
Thermocyclops crassus	0.55	0.65	0.75	0.85	0.95										
	-0.679	-0.598	0.174	0.174	0.8										
Thermocyclops oithonoides	0.55	0.65	0.75	0.85	0.95	1.05									
	-0.946	0.011	-0.056	0.033	0.213	0.831									
Eurytemora afinis	1.15	1.25	1.45												
	1.0	1.0	1.0												
copepodit	0.35	0.45	0.55	0.65	0.75	0.85	0.95	1.05	1.25						
	-0.980	-0.988	-0.766	0.297	0.278	0.762	0.65	0.377	1.0						
Copepoda♀	0.75	0.85	0.95	1.05	1.15	1.25	1.35	1.45	1.55	1.75					
	-0.744	0.291	-0.413	0.023	1.0	1.0	-0.561	1.0	-0.88	1.0					
Copepoda♂	0.55	0.65	0.75	0.85	0.95	1.05	1.15								
	-0.884	-0.495	-0.052	0.011	0.483	0.457	0.753								

Table 4. Changes in food selectivity coefficients, E, in relation to prey size in July; body length of prey [mm] above the horizontal line, E coefficient below the line

Species														
Daphnia cucullata	0.55 / -0.959	0.65 / -0.899	0.75 / -0.596	0.85 / -0.361	0.95 / -0.337	1.05 / 0.283	1.15 / 0.493	1.25 / 0.287	1.35 / 0.331	1.45 / 1.0	1.55 / 1.0	1.65 / 1.0	1.75 / 1.0	1.85 / 1.0
Daphnia longispina	0.45 / -0.994	0.55 / -0.994	0.65 / -0.829	0.75 / -0.749	0.85 / -0.495	0.95 / -0.4	1.05 / 0.105	1.15 / 0.338	1.25 / 0.33	1.35 / 1.0	1.45 / 1.0	2.05 / 1.0	2.35 / 1.0	
Leptodora kindti	2.65 / -0.899	3.05 / -0.711	3.55 / -0.547	3.65 / 1.0	3.85 / 0.377	3.95 / 0.377	4.15 / 0.799	4.35 / 0.197	4.75 / 1.0	4.95 / 1.0	5.55 / 1.0	7.75 / 1.0	7.95 / 1.0	8.25 / 1.0	8.45 / 1.0
Diaphonosoma brachyurum	0.55 / -1.0	0.75 / -1.0	0.85 / -0.71	0.95 / 0.9										
Acanthocyclops robustus	0.75 / -0.391	0.85 / 0.134	0.95 / 0.803	1.05 / 0.683	1.15 / 0.373	1.25 / 1.0								
Cyclops vicinus	0.95 / 1.0	1.05 / 0.868	1.15 / 1.0	1.25 / 1.0	1.35 / 1.0	1.45 / 1.0	1.55 / -0.701	1.65 / -0.583						
Mesocyclops leuckarti	0.65 / 1.0	0.75 / 0.164	0.85 / 1.0	0.95 / -0.208	1.05 / -0.401									
Thermocyclops crassus	0.55 / -0.95	0.65 / 0.042	0.75 / -0.103	0.85 / 0.09	0.95 / 1.0									
Thermocyclops oithonoides	0.55 / -1.0	0.65 / 0.983	0.75 / 0.811	0.85 / 0.982	0.95 / 1.0									
copepodit	0.35 / -0.951	0.45 / -0.843	0.55 / -0.512	0.65 / -0.116	0.75 / 0.75	0.85 / 0.705	0.95 / 0.850	1.05 / 0.883	1.15 / 1.0					
Copepoda ♀	0.55 / 1.0	0.65 / 1.0	0.75 / -0.534	0.85 / 0.579	0.95 / 0.863	1.05 / 0.861	1.15 / 0.63	1.25 / 1.0	1.35 / 1.0	1.45 / 1.0	1.55 / 1.0	1.65 / -0.154	1.75 / -1.0	
Copepoda ♂	0.55 / -1.0	0.65 / 0.663	0.75 / 0.297	0.85 / 0.487	0.95 / 1.0	1.05 / -0.307	1.15 / -0.04	1.25 / 1.0						

DISCUSSION

The impact of plankton feeders on the density and biomass of zooplankton has been studied most intensively in lakes [4, 11, 25]; information on the riverine plankton in this aspect are, on the other hand, fragmentary [2, 10, 15]. The composition of fry food depends on the composition of zooplankton in the water column, availability of particular planktonic forms, and the ability of the young fish to capture and swallow its prey. Clear seasonality is a characteristic of predatory pressure, which also changes with the age of the fish. For example, Akopian et al. [1] demonstrated that selective predation of perch fry of 30–40 mm in length in June and 45–80 mm in July against *Daphnia* and adult copepods was one of the main factors of the change in the species composition and size structure of zooplankton during early summer and resulted in 75-% reduction in its resources in the river Marne. With the growth of fry, the species composition of prey changes, individual size of eaten food item increases, and the numbers of consumed zooplankton increases as well. Rotifers are eaten by the tiniest fry, whereas for larger fish they are of little importance as food. Cladocerans and copepods, on the other hand, are important not only for juvenile fish, but for adult forms of a number of fishes as well [2, 20]. Perch fry of 7 mm in length, for instance, feeds exclusively on rotifers and nauplii. At length 7–20 mm, the young perch does not eat rotifers any more, switching to tiny cladocerans and copepods, followed by large cladocerans, and chironomid larvae and pupae [6]. Also roach exceeding 18 mm of length only sporadically eats rotifers [23]. In the of the Odra, rotifers and the larvae of zebra mussel, *Dreissena polymorpha*, represent the greatest densities. Cladocerans and copepods, on the other hand, are less common. Most often, *Bosmina longirostris* (Müller) and small nauplii are found here [36]. Our results show, however, that large cladocerans of the genus *Daphnia*, which give maximum energy gain, were found within the shore zone of the river in June and July.

The fish fry exerted the highest pressure on large cladocerans and copepods. Hammer [11] reported similar food preferences of juvenile perch in June and July; cladocerans (mainly *Bosmina*) represented 39–100%, whereas copepods 0 to 50% of its food. If we consider food preferences of juvenile perch, we must take into account that the attack of the fish on a copepod is likely to be less successful than such on a cladoceran, since copepods have the ability to quickly and abruptly leap away when endangered by a predator [5]. This may also be reflected in the diet composition of perch fry from the Odra as shown in our studies. In June, we found more cladocerans than quick and agile copepods, whereas the proportion of these in zooplankton was opposite. Among the copepods in the diet, adult forms prevailed over copepodits. In July this pattern was reversed and copepods represented a higher percentage in the stomach contents compared to cladocerans. Copepodits are the most common *in situ*, although known as the form with the greatest ability to escape among copepods [32], outweighed mature copepods also in stomach contents. The cause of the shift in the diet was a decrease in *Daphnia* densities resulting from an increased intensity of predation by fish fry. According to optimal foraging theory, the amount of food contributed by a particular prey organism is linked to the abundance of other potential prey items in the penetrated environment. In our study, in July there was a "switch" in this behavior; more abundant prey organisms were more intensively hunted. Terlecki [33] also observed in lake Zegrzyński that fry consumed relatively more copepods, when there were more of these in the environment.

A very important factor influencing the selectivity of fish food is the pigmentation of prey organisms. *Leptodora,* otherwise very demanded prey item due to its size, is almost transparent, so that it becomes less visible to fish especially in the eutrophic, turbid flowing waters [13]. In this study, we occasionally found *Leptodora in situ,* however primarily juvenile and more transparent individuals, while in digestive tracts content we observed specimens with a maximum length of 1.020 cm. Number of eggs carried in the brood chambers of cladocerans, or sizes of egg bags in copepods, are important factors of the pigmentation of

prey too; individuals with eggs are eliminated to the extent significantly greater than those without eggs [21, 31]. It is suggested that females with eggs are better visible than those without eggs or males. Egg sacks in copepods can also hamper the freedom of movement, which in turn can facilitate piscine predation. Our results on fry food preferences match those of other authors. *Daphnia* are very willingly eaten by juvenile fish [12, 15, 24] and so are mature copepods [4, 12, 32] while copepodits are rather avoided [25].

Daphnia in July were smaller *in situ* than in digestive tracts, which may indicate a strong predation pressure of the fry. But the mere fact that large fry ate *Daphnia* cladocerans and not e.g. small *Bosmina*, as in the research of Hammer [11], may indicate under-utilization of the food base.

CONCLUSION

During the season of the most intensive feeding, perch fry consumed mainly planktonic crustaceans (mainly *Daphnia*), modifying the quantitative composition and size structure of zooplanktonic organisms *in situ*. The presence of large cladocerans in the shore zone of the river shows, however, that the fish only partly exploit the food reservoirs. The research suggests that fish feeding pressure is one of the major factors that affects the zooplankton structure in the mouth section of a large lowland rivers.

REFERENCES

1. Akopian M., Garnier J., Pourriot R., 1999. A large reservoir as a source of zooplankton for the river: structure of the populations and influence of fish predation. J. Plankton Res., 21, 2, 285–297.
2. Bass J.A.B., Pinder L.C.V., Leach D.V., 1997. Temporal and spatial variation in zooplankton populations in the River Great Ouse: An ephemeral food resource for larval and juvenile fish. Regul. River, 13, 3, 245–258.
3. Burks R.L., Jeppesen E., Lodge D.M., 2001. Littoral zone structure as *Daphnia* refugia against fish predators. Limnol. Oceanogr., 46, 2, 230–237.
4. Christoffersen K., Riemann B., Klysner A., Søndergaard M., 1993. Potential role of fish predation and natural populations of zooplankton in structuring a plankton community in eutrophic lake water. Limnol. Oceanogr., 38, 3, 561–573.
5. Confer J.L., Blades P.I., 1975. Omnivorous zooplankton and planktivorous fish. Limnol. Oceanogr., 20, 571–579.
6. Čikova V.M., 1970, Pitanije okunja (*Perca fluviatilis* L.)v osušnoj zone priplotinnogo plesa Kujbyševskogo vodochranilišča. [Food of perch (*Perca fluviatilis* L.) in the dry area of dam reach of the Kuibyshev Reservoir. Vopr. Ichtiol., 10, 3, 62, 462–468 [in Russian].
7. Czerniawski R., Pilecka-Rapacz M., Domagała J., 2013. Zooplankton communities of inter-connected sections of lower River Oder (NW Poland). Cent. Eur. J. Biol., 8, 18–29.
8. de Ruyter van Steveninck E.D., Admiraal W., Breebaart L, Tubbing G.M.J., van Zanten B., 1992. Plankton in the River Rhine: structural and functional changes observed during downstream transport. J. Plankton Res., 14, 10, 1351–1368.
9. Greenberg A.E., Clesceri L.S., Eaton A.D., 1992. Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, Water Environment Federation.
10. Grenouillet G., Pont D., 2001. Juvenile fishes in macrophyte beds: influence of food resources, habitat structure and body size. J. Fish Biol., 59, 939–959,
11. Hammer C., 1985. Feeding behaviour of roach (*Rutilus rutilus*) larvae and the fry of perch (*Perca fluviatilis*) in Lake Lankau. Arch. Hydrobiol., 103, 1, 61–74.
12. Hoffman J.C, Smith M.E., Lehman J.T., 2001. Perch or plankton: top-down control of Daphnia by yellow perch (*Perca flavescens*) or *Bythotrephes cederstroemi* in an inland lake? Freshwater Biol., 46, 6, 759–775.
13. Horppila J., Liljendahl-Nurminen A., Malinen T., 2004. Effects of clay turbidity and light on the predatorprey interaction between smelts and chaoborids, Can. J. Fish. Aquat. Sci., 61, 1862–1870.
14. Ietswaart T., Breebaart L., van Zanten B., Bijkerk R., 1999. Plankton dynamics in the river Rhine during downstream transport as influenced by biotic interactions and hydrological conditions. Hydrobiologia, 410, 1–20.
15. Jachner A., 1991. Food and habitat partitioning among juveniles of three fish species in the pelagial of a mezotrophic lake. Hydrobiologia, 226, 81–89.
16. Jack J.D., Thorp J.H., 2002. Impacts of fish predation on an Ohio River zooplankton community. J. Plankton Res., 24, 2, 119–127.
17. Kim H.-W., Joo G.-J., 2000. The longitudinal distribution and community dynamics of zooplankton in a regulated large river: a case study of the Nakdong River (Korea). Hydrobiologia, 438, 171–184.
18. Lampert W., Sommer U., 2001. Ekologia wód śródlądowych. [Ecology of inland waters] Wydawnictwo Naukowe PWN, Warszawa [in Polish].
19. Lauridsen T.,L., Pedersen L.J., Jeppesen E., Sondergaard M., 1996. The importance of macrophyte bed size for cladoceran composition and horizontal migration in a shallow lake. J. Plankton Res., 18, 2, 2283–2294.
20. Mann R.H.K., 1997. Temporal and spatial variations in the growth of 0 group roach (*Rutilus rutilus*) in the River Great Ouse, in relation to water temperature and food availability. Regul. River., 13, 277–285.
21. Mehner T., 2000. Influence of spring warming on the predation rate of underyearling fish on *Daphnia* – a deterministic simulation approach. Freshwater Biol., 45, 2, 253–263.
22. Mehner T., Thiel R., 1999. A review of predation impact by 0+ fish on zooplankton in fresh and brackish waters of the temperate northern hemisphere. Environ. Biol. Fish., 56, 169–181.
23. Mikheev V.N., 1984. Razmiery potrebljajemych žertv i izbiratelnost pitanija u molodi ryb. [Body sizes of eaten prey organisms and food selectivity of juvenile fish] Vopr. Ichtiol., 24, 2, 243–252 [in Russian].
24. Mikheev V.N., Pavlov D.S., 1993. Spatial distribution and movement of young fishes in relation to food availability in a reservoir on the Rositsa river. Pol. Arch. Hydrobiol., 40, 1, 31–45.
25. Nielsen D.J., Hillman T.J., Smith F.J., Shiel R.J., 2000. The influence of a planktivorous fish on zooplankton assemblages in experimental billabongs. Hydrobiologia, 434, 1–9.
26. Nurminen L.K.L., Horppila J.A., 2002. A diurnal study on the distribution of filter feeding zooplankton: Effect of emergent macrophytes, pH and lake trophy. Aquatic Sci., 64, 198–206.
27. Okun N., Mehner T., 2005. Distribution and feeding of juvenile fish on invertebrates in littoral reed (*Phragmites*) stands. Ecol. Freshw. Fish., 14, 2, 139–149.
28. Opuszyński K., 1997. Wpływ gospodarki rybackiej, szczególnie ryb roślinożernych, na jakość wody w jeziorach. [Impact of fisheries, particularly of herbivorous fish, water quality in lakes] Biblioteka Monitoringu Środowiska, PIOŚ, Zielona Góra, 1–156 [in Polish].
29. Pourriot R., Rougier C., Miquelis A., 1997. Origin and development of river zooplankton: example of the Marne. Hydrobiologia, 345, 2–3, 143–148.
30. Pyke G.H.,Pulliam H.R., Charnov E.L., 1977. Optimal foraging: a selective review of theory and tests. Quar. Rev. Biol., 52, 2, 137–154.
31. Rajasilta M., Vuorinen I., 1983. A field study of prey selection in planktivorous fish larvae. Oecologia, 59, 65–68.
32. Szlauer L., 1974. Wykorzystanie do karmienia narybku siei – *Coregonus lavaretus* (Linnaeus, 1758) zooplanktonu, wynoszonego z jezior

przez odpływy. [Use of zooplankton carried out from the lakes through drains for feeding fry of whitefish, *Coregonus lavaretus* (Linnaeus, 1758)] Rocz. Nauk Rol., 96-H-2, 80–107 [in Polish].

33. Terlecki J., 1993. Zależności pokarmowe u małych ryb na przykładzie przybrzeżnej strefy nizinnego zbiornika zaporowego. Rozprawa habilitacyjna. [Food dependencies of small fish by example of the shore area of a lowland dam reservoir. Habilitation dissertation] Acta Acad. Agricult. Techn. Olsten., Protec. Aquar. Piscat., 19, 1–59. Suppl. C [in Polish].

34. Viroux L, 1997. Zooplankton development in two large lowland rivers, the Moselle (France) and the Meuse (Belgium), in 1993. J. Plankton Res., 19, 11, 1743–1762.

35. Viroux L, 2002. Seasonal and longitudinal aspects of microcrustacean (Cladocera, Copepoda) dynamics in a lowland river. J. Plankton Res., 24, 281–292.

36. Wolska M., Mazurkiewicz-Zapałowicz K., 2006. Zooplankton and its effect on phytoplankton in a delta channel of the River Odra mouth. Pol. J. Environ. Stud., 15(5D), 2, 507–512.

37. Wolska M., Piasecki W.G., Mazurkiewicz-Zapałowicz K., 2009. Using mean zooplankton sizes in evaluation of fry feeding pressure in various bodies of water and the estuarine part of the Odra River. [In: Trudy Analiz i Prognozirovanije Sistem Upravlenija], Sankt-Peterburg, Izdatielstwo SZTU, 295–300.

Maria Wolska
Division of Hydrobiology, Ichthyology and Biotechnology of Biotechnology of Reproduction,

West Pomeranian University of Technology in Szczecin, Szczecin, Poland
K. Królewicza 4
71-550 Szczecin
Poland
email: Maria.Wolska@zut.edu.pl

Kinga Mazurkiewicz-Zapałowicz
Division of Hydrobiology, Ichthyology and Biotechnology of Biotechnology of Reproduction,

West Pomeranian University of Technology in Szczecin, Szczecin, Poland
K. Królewicza 4
71-550 Szczecin
Poland
email: Kinga.Mazurkiewicz-zapalowicz@zut.edu.pl

Krzysztof Formicki
Division of Hydrobiology, Ichthyology and Biotechnology of Biotechnology of Reproduction,

West Pomeranian University of Technology in Szczecin, Szczecin, Poland
K. Królewicza 4
71-550 Szczecin
Poland
email: Krzysztof.Formicki@zut.edu.pl

Responses to this article, comments are invited and should be submitted within three months of the publication of the article. If accepted for publication, they will be published in the chapter headed 'Discussions' and hyperlinked to the article.