Diet Composition and Selectivity in O+ Perch (*Perca fluviatilis* L.) and its Competition with Adult Fish and Carp (*Cyprinus carpio* L.) Stock in Pond Culture

Zdeněk ADÁMEK [1,2]

Jiří MUSIL [2]

Ivo SUKOP [3]

SUMMARY

Food composition and selectivity of 0+ perch (*Perca fluviatilis*) were studied under the experimental pond conditions during the growing season in 2000. The diet of perch fry consisted mainly of chironomid larvae and pupae and zooplankton, mainly cladocerans (*Bosmina longirostris*, *Chydorus* sp., *Ceriodaphnia* sp., *Alona* sp.) and copepods. Both chironomids and cladocerans were consumed with positive selectivity. The food items of lesser importance were water beetles (genera *Rhantus*, *Hydrobius* and *Hydroporus*), water bugs *Corixa affinis* and mayfly larvae *Caenis* sp. Chironomid larvae were most important food items also in the diet of both adult perch and 2+ carp. Also 0+ perch contributed considerably to the diet of adult perch and benthic food resources (bryozoans and organic debris) including supplied feed cereals were of biggest importance for common carp. The perch competes with parental fish and common carp for approximately one third of available food items, whilst adult perch and carp compete for a half of them.

KEY WORDS

food composition, food selectivity, perch, fry, common carp, pond culture

[1] Research Institute of Fish Culture and Hydrobiology Vodňany, University of South Bohemia, Laboratory Pohořelice, Vídeňská 717, 691 23 Pohořelice, Czech Republic E-mail: adamek.zdenek@quick.cz

[2] Department of Fisheries, University of South Bohemia, Studentská 13, 370 05 České Budějovice, Czech Republic

[3] Department of Fisheries and Hydrobiology, Mendel University of Agriculture and Forestry, Nejdecká 400, 691 44 Lednice na Moravě, Czech Republic

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INTRODUCTION

The European perch (*Perca fluviatilis*) is a prospective fish species for pond fish culture under conditions of the temperate climate as it is in great demand for sport fishing and human consumption purposes. However the knowledge about its food composition in pond polycultures and competition with common carp (*Cyprinus carpio*) and other commercial pond fish species is very limited. Many studies were devoted to perch food pattern in various natural waterbodies, like lakes, reservoirs and rivers (e.g. Horoszewicz 1964, Prejs 1976, Popova, Sytina 1977, Losos et al. 1980, Adámek et al. 1987, Koli et al. 1988) but no available study dealt with perch food composition in a fishpond ecosystem.

Perch is quite common species throughout the Central Europe, where it is inhabiting almost all types of still and running waters except trout zones (Baruš and Oliva, 1995) and localities with poor environmental conditions. Perch often create local populations, which consist above all of fish of single age category (Vostradovský, 2001), which is a typical situation in some reservoirs. Thus they show a tendency to overpopulate and to become a food competitor for non-predatory fishes (Švátora, 1986).

Perch food is very variable and depends above all on the age and availability of food resources (Lohniský, 1960). The composition of perch diet was a topic of many studies, e.g. Kokeš and Sukop (1984), Nagy (1988), Matěna (1994), Ekloev and Diehl (1994), Person and Ekloev (1995) and Wang and Appenzeller (1998). The grazing pressure of perch towards macrozoobenthos under experimental conditions was studied by Giles et al. (1995). Matěna and Pešta (1996) described the food selectivity in perch fry in comparison to rudd fry under experimental laboratory conditions. The predation pressure and selectivity of adult perch under experimental conditions was studied by Adámek (2000) and food competition of 2+ perch with 2+ common carp (*Cyprinus carpio*) by Adámek and Sukop (2001).

The first food of perch fry consists above all of nauplii and copepodit stages of Cyclopidae and Calanoidae and of rotifers (Rotatoria) (Baruš and Oliva, 1995). Later on, the diet of perch fry consists mainly of larger zooplankton species (Lohniský, 1960), often together with zoobenthos (chironomid larvae – Horpilla et al., 2000). First prey fish appeared in perch diet at TL > 103 mm (Nagy, 1988) and subsequent fast growth of perch juveniles is given in coherence with food transition on predation strategy (Lohniský, 1960). Large perch forage on chironomids and fish, often small perch (Horpilla et al., 2000).

The food spectrum of perch (concerning above all fry and juveniles) is often identical with the most of commercial non-predatory fishes. Thus the aim of this study was, besides evaluation of 0+ perch diet, also to assess the level of food competition between the adult perch and their progeny and between perch and common carp stock under pond polyculture conditions.

MATERIAL AND METHODS

The observations were performed in an experimental pond No.51 (0.08ha), which belongs to the experimental pond facility of the Research Institute of Fish Culture and Hydrobiology (University of South Bohemia) at Vodòany during April – September 2000. The monitoring of basic environmental parameters (Table 1) using DO meter Horiba OM14 and pH meter WTW MultiLine P4, and sampling of zooplankton, macrozoobenthos and fish were performed monthly. Macrozoobenthos was sampled by means of doubled pooled sample using small Ekman–Birge grab ($85 cm^2$) and zooplankton was collected by means of Patalas sampler (2 l) as a pooled 10-l sample.

The pond was stocked on 18 April 2000 with adult perch (2500 $ind.ha^{-1}$ and 18.8 $kg.ha^{-1}$) and 2+ common carp (2500 $ind.ha^{-1}$ and 75 $kg.ha^{-1}$). Since June, fish (carp) were supplied with cereal feed in irregular intervals. The examined 0+ perch specimens originated from natural spawning of stocked adults.

Fish were sampled by means of electroshocking gear (300V, Smith-Root Inc., USA). Each fish was measured (TL and SL) and weighed (W) to nearest mm and g (0.1g in 0+ perch) respectively. Examined fish were sacrificed by narcosis overdosing and samples were preserved in 4 % formaldehyde solution as a whole fish (0+ perch) or the whole alimentary tract (adult perch and 2+ carp).

The analyses of food composition were performed with three-month delay. The contents of alimentary tracts were removed, blotted on a phosphorous-bronze sieve using filter paper and weighed. The values obtained were used to calculate the indices of fullness (in $^0/_{000}$) as the proportion of the weight of ingested food (w) on the total weight of fish (W): IF = w . 10000/W (Holčík and Hensel 1972).

The separable food items were identified and their proportion on total amount of ingested food was assessed by indirect volumetric estimation (Hyslop 1980). The Costello's (1990) graphical method was used for the interpretation of the role of particular food items in the diet of examined fish (see Figure 1) in individual sampling periods. The food items of animal origin except for chironomids were identified to species where possible. Cyclopidae and Calanoidae (including their larval stages) were declared together as copepods (Copepoda).

Table 1. Mean values (± S.D.) of environmental parameters

Parameter	Unit	Mean ± SD	Range
Water temperature	°C	21.14 ± 4.09	17.3 – 27.9
O_2	mg.l^{-1}	12.41 ± 3.9	9.66 – 19.2
Saturation	%	135.68 ± 37.21	106.4 – 200
pH		8.02 ± 0.96	7.57 – 9.43
Transparency	cm	32 ± 9.9	16 – 43

Table 2. Fish stock composition at stocking (April 2000) and harvesting (September 2000)

Fish category	Abundance (individuals ha^{-1})	Biomass (kg ha^{-1})
Stocking		
2+ carp	2500	75.25
Adult perch	2500	18.75
Harvesting		
2+ carp	2013	524.4
Adult perch	300	39
0+ perch	7600	17.75

Altogether 52 perch fry (0+) were examined for the content of their alimentary tracts. Feeding selectivity was calculated using the Ivlev's selectivity index E (Jacobs, 1974):

$$E = (r - p)/(r + p),$$

where r – proportion of certain prey item taken by perch, p – proportion of that prey item present in the offer. Positive values (0 to +1) mean that the item is preferred, whilst negative values mean that the particular food item is avoided. The values about zero show that the item is consumed in accordance with its density in the surrounding environment.

The same methodological approach was applied in samples of gut content of adult perch (n = 2) and 2+ common carp (n = 15). To assess the level of food competition between individual fish species and year classes, Shorygin' s (1952) index of food similarity was applied as a sum of lowest percentages of individual food items in the diet of the two compared fish groups (i.e. 0+ perch, adult perch and 2+ carp).

RESULTS

Food environment

The abundance of zooplankton fluctuated between 664 (30 Aug 2000) and 2115 (23 May 2000) individuals per litre with the average value of 1530 ind l^{-1}. The abundance of zoobenthos varied between 118 (30 Aug 2000) and 3071 individuals per square meter (23 May 2000) with the mean value of 1134ind. m^{-2} and its biomass was between 0.35 (30 Aug 2000) and 14.75g.m^{-2} (23 May 2000). Chironomid larvae highly predominated in all samples except for September, when only oligochets (*Limnodrilus* sp.) and phantom fly (Chaoboridae g.sp.) larvae occurred in macrozoobenthos.

0+ perch

In May (Figure 2), the diet of 0+ perch (TL 25 ± 2.9mm, n = 10) consisted of zooplankton with 66.83% and zoobenthos (33.17%). The dominating zooplanktonic organisms were represented by cladoceran genera as *Daphnia*, *Chydorus*, *Scapholeberis*, *Moina*, *Alona* and *Ceriodaphnia* with the most important item *Bosmina longirostris*, which proportion in 0+ perch diet amounted to 50.39% with 100% frequency of occurrence. All cladoceran species showed positive values of Ivlev's selectivity index. The proportion of cyclopids was only 2.8%. The benthic food items included only larvae and pupae of chironomids with relative proportion 33.17% and 80% frequency of

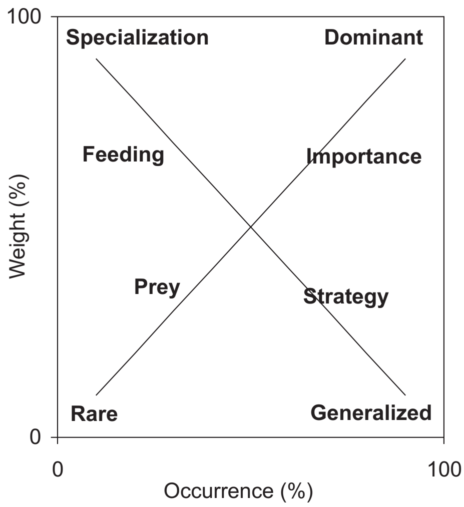

Figure 1. Guide to the interpretation of the Costello (1990) graphical method, showing axes and important diagonals positioning

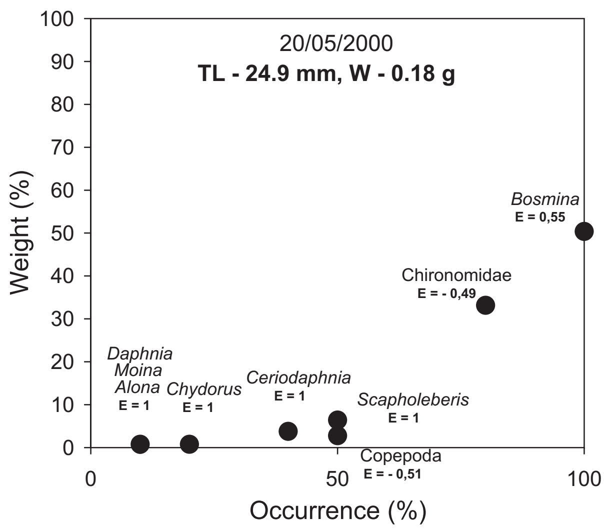

Figure 2. The importance of prey items in the diet of perch fry on 20 May 2000

occurrence. The index of fullness of the alimentary tract amounted to 481 ± 269.5$^{0}/_{000}$.

In June (Figure 3), the contribution of zooplankton to 0+ perch (TL 36 ± 2.0 mm, n = 10) diet varied between 1.13 (*Chydorus* sp.) and 3.79% (*Bosmina longirostris*). All cladoceran species in the diet showed positive selectivity indices. Total proportion of zooplankton including Cyclopidae was 9.17%. Zoobenthos, mainly larvae and pupae of chironomids, was the major food item with 74.21% proportion and 100% frequency of occurrence. The bigger benthic animals like *Caenis* sp., Ceratopogonidae, *Naucoris cimicoides* and water beetle *Hydrobius* sp., were represented in the diet of perch fry from 0.38 (*Hydrobius* sp.) to 13.75% in case of mayfly larvae *Caenis* sp. The index of fullness of the alimentary tract was 203 ± 101.9$^{0}/_{000}$.

In July (Figure 4.), the total length of 0+ perch (n = 10) was 49 ± 7.3 mm and its index of alimentary tract fullness was 155 ± 64.2$^{0}/_{000}$. Zoobenthos prevailed in food with 64.65% proportion, and with the dominance of chironomid larvae and pupae (60.00% proportion and 100% frequency of occurrence). Despite this, their selectivity index was however slightly negative E = -0.20. The other benthic animals (Hydracarina g.sp.div., *Hydroporus* sp., *Rhantus* sp., Ostracoda g.sp.div.) composed only remaining 4.65% altogether, however with positive selectivity indices. The dominant cladoceran species were represented by *Chydorus* sp. (30.32% with 70% frequency of occurrence, *Ceriodaphnia* sp. (2.21%), *Bosmina longirostris* (0.95%) and *Alona* sp. (0.67% of food ingested). All cladoceran species except of *Bosmina longirostris* showed positive selectivity indices. The proportion of cyclopids in the diet of perch fry was 3.71% with 60% frequency of occurrence and positive selectivity index. Only occasionally, *Argulus* sp. and statoblasts were registered in stomachs of perch fry.

In August (Figure 5), fish (n = 11) TL amounted to 55 ± 5.1 mm and their index of fullness was 57 ± 21.9$^{0}/_{000}$. The major food item was macrozoobenthos, with 70.58 and 0.44% proportion, and 91 and 9% frequency of occurrence in case of chironomids and ceratopogonids respectively. The dominant zooplanktonic food items were represented mainly by copepods with proportion in the diet amounting to 11.68% with 82% frequency of occurrence. In cladocerans, the proportions in 0+ perch diet were 4.38, 3.89 and 1.51% for *Chydorus*, *Alona* and *Ceriodaphnia*, respectively. Their frequency of occurrence ranged from 27 to 55% in *Chydorus* and *Ceriodaphnia*, respectively.

In September (Figure 6), the TL value of 0+ perch (n = 11) was 62 ± 6.0mm and the index of fullness amounted to 51 ± 27.8$^{0}/_{000}$. Zooplankton, which was represented mainly by copepods (E = 0.85) with

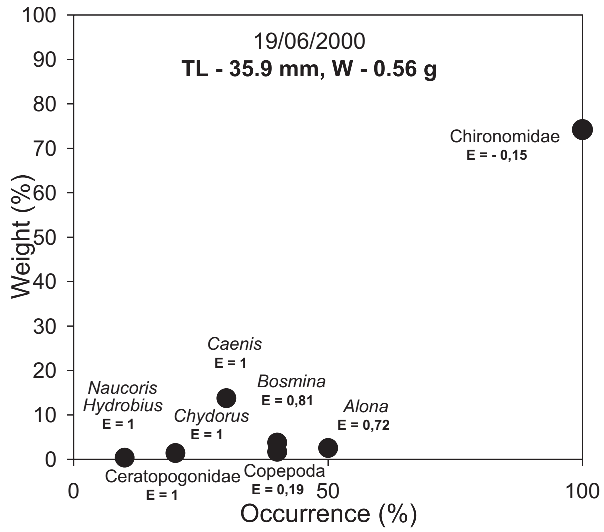

Figure 3. The importance of prey items in the diet of perch fry on 19 June 2000

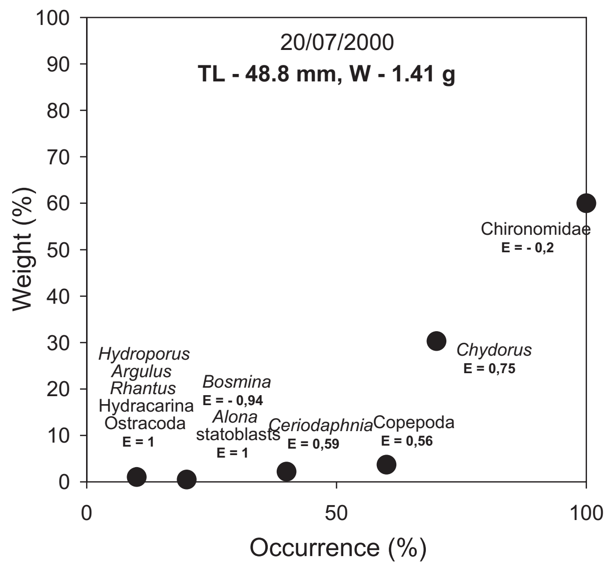

Figure 4. The importance of prey items in the diet of perch fry on 20 July 2000

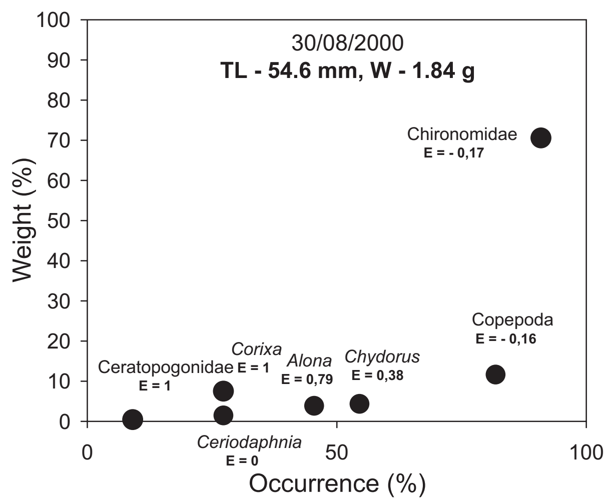

Figure 5. The importance of prey items in the diet of perch fry on 30 August 2000

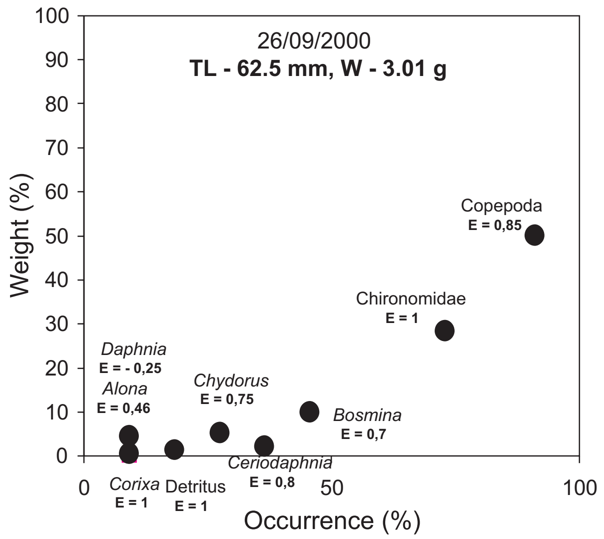

Figure 6. The importance of prey items in the diet of perch fry on 26 September 2000

50.29% proportion and 91% frequency of occurrence and by cladocerans *Bosmina longirostris* (10.13%), *Ceriodaphnia* (2.37%), *Chydorus* (1.46%), *Alona* (0.73%) and *Daphnia* (0.38%), prevailed in the stomach content of 0+ perch. Its frequency of occurrence varied from 9 (*Daphnia* and *Ceriodaphnia*) to 45% (*Bosmina longirostris*) and all of them except *Daphnia* showed positive selectivity indices. The zoobenthos food item was represented only by chironomids with 28.54% proportion and 73% frequency of occurrence (E = 1.00). Detritus (1.58% proportion with 18% frequency of occurrence) appeared also in the food bulk of 0+ perch from September.

Adult perch

Chironomid larvae and perch fry dominated with 36.8 and 33.3% respectively in the diet of adult perch in May (Table 3). The proportion of other food items was rather low, amounting from 3 (water bug *Corixa*) to 13% (caddisfly *Ironoquia* larvae and detritus).

Table 3. Diet composition of adult perch and 2+ common carp

Food item	24/05/2000 perch		24/05/2000 2+ carp		20/06/2000 2+ carp		21/07/2000 2+ carp	
	F	O	F	O	F	O	F	O
Bryozoa g.sp.			+	17			23.5	50
Moina sp.			32.4	17				
Bosmina longirostris			+	17				
Alona sp.					0.2	20		
Ironoquia dubia	13.4	50						
Limnephilidae g.sp.							1.7	25
Corixa affinis	3.3	50						
Chironomidae g.sp.	36.8	100	45.0	83	2.1	60	6.7	100
Perca fluviatilis	33.3	100						
terrestrial insects					4.2	80	1.3	25
macrophytes			1.0	50	2.1	60	16.2	75
detritus	13.2	50	21.6	83	6.2	80	35.6	75
cereals					85.2	80	15.0	25
n fish	2		6		5		4	
TL/SL (mm)	195/164		171/142		191/156		222/177	
W (g)	86.4		91.2		127.5		182.2	
IF ($^{o}/_{ooo}$)	107 ± 53.8		71 ± 78.7		499 ± 280.7		188± 89.8	

F = food item proportion in food bulk (%), O = frequency of occurrence (%); TL = total length, SL = standard length, W = weight, IF = index of alimentary tract fullness; all figures as mean ± S.D.

Table 4. Food similarity (Shorygin 1954) as a determinant of competition between individual fish species and categories in the pond

Species/category	Date	0+ perch	Adult perch	2+ carp		
			23-24/05/00	23-24/05/00	19-20/06/00	21/07/00
0+ perch		-	33.2	34.8	2.3	6.7
Adult perch	23-24/05/2000	*33.2*	-	50.0		
2+ carp	23-24/05/2000	*34.8*	*36.8*			
	19-20/06/2000	*2.3*				
	21/07/2000	*6.7*				

Food similarity excluding detritus *in italics*

The mean index of alimentary tract fullness was $107^{0}/_{000}$.

2+ common carp

Chironomid larvae were a regular part (2.1 to 45.0%) of the diet of 2+ carp with high frequency of occurrence from 60 to 100% (Table 3). In May, one fish (73,1 g) was registered to consume selectively high amounts of cladocerans with 90% predominance of *Moina* (32.4%) but in general, the benthic food resources were of highest importance. Besides chironomids, these were composed of bryozoans (23.5% in July) and of organic debris (detritus and plant fragments – 8.3 to 51.8%). Cereals supplied in irregular intervals were ingested in considerably high proportions (15.0 – 85.2%). The indices of gut fullness followed the proportion of cereals on the food bulk being lowest in absence of cereals ($71 \pm 78.7^{o}/_{ooo}$) whilst highest in June ($499 \pm 280.7^{o}/_{ooo}$) with 85.2% proportion on food ingested.

DISCUSSION

Zooplankton and chironomid larvae are the most important items in the diet of small perch (Horpilla et al. 2000). When applying Costello (1990) graphical plotting on our results, than chironomids, *Bosmina*, copepods and *Chydorus* can be considered as important and dominant food items, whilst remaining food items belonged rather among rare ones. Ivlev's indices of selectivity for cladocerans were almost always in positive figures which means that they belong among preferred food items of the perch fry. However in case of *Bosmina*, a hardly explainable high avoidance (E= –0.94, see Figure 4) was noticed in July despite of its dominance (30.55%) in zooplankton. Perch fry showed high preference for other, however less numerous crustaceoplankton species like *Chydorus*, *Ceriodaphnia*, *Alona* and copepods with selectivity indices ranging between 0.56 to 1.00. Not a one rotifer individual was found in the stomach of 0+ perch in spite of their regular dominance in zooplankton. Rotifers are not mentioned in the other studies of perch fry food either (Horpilla et al. 2000), which indicates their probably negligible role, if any, in its nutrition.

In spite of high proportion of chironomid larvae in the diet of perch fry, the indices of selectivity for them were always slightly negative (E = -0.15 to -0.20). In May, their values indicated rather avoidance (E = -0.49) but the fish were probably too small (TL 25 ± 2.9mm) to ingest bigger chironomid larvae. It must also be understood that chironomid larvae were almost exclusive animals in macrozoobenthos, which increased inadequately their percentage as a food item and simply could not be consumed by young perch in corresponding amounts. The same was true for adult perch, which index of selectivity for chironomid larvae was also negative (E=–0.13). However in September, chironomids made a considerable part of perch food bulk despite no chironomid larvae were found in macrozoobenthos samples (E=+1.00).

The index of alimentary tract fullness continuously declined with 0+ perch age and size during the growing season ($481>203>155>57>51^{o}/_{ooo}$ in May>June>July>Augus>September, respectively).

Large perch forage on chironomids and fish (small perch in particular) as shown e.g. by Horpilla et al. (2000). The results from pond culture of adult perch and their progeny are in good agreement with their observations because 36.8 and 33.3% of food ingested by adult perch were just chironomids and small perch respectively.

From the feeding biology point of view, the joint culture of adult perch with their progeny resulted in 33.2% food coincidence – just in chironomid larva consumption. Young fish as the second most important food item in the nutrition of adult perch were not consumed by 0+ perch, and zooplankton as dominating food item of the fry was not ingested by adult fish, which means, that there was zero competition for these two food resources. The shift in food composition from zooplankton predominance in perch <8cm to piscivory in fish >16 cm was documented also in the study of Tolonen et al. (2000).

Two-year-old carp are predominantly benthic feeders because planktonic food resources are usually unable to cover their nutrition requirements due to inconvenient (too small) size structure. Under the pond conditions, the intensity of carp benthivorous nutrition raises with their age, and when fed with supplementary feeds, they concentrate considerably upon them. Cereals, as the most common supplementary feed in semi-intensive carp pond culture, dominate in carp food with high proportion depending upon the time interval after the last feeding and regularly exceed 50% with 100% frequency of occurrence (Adámek and Sukop 2001). The same was noticed in these investigations when the percentage of cereals in carp diet fluctuated between zero and 85.2% with respect to the time delay from the last feeding with maximum frequency of occurrence 80%. The diet similarity in adult perch and carp concerned mostly the competition for chironomid larvae (36.8%) because detritus, which was identically consumed in the extent of 13.2% need not to be necessarily considered as a matter of competition.

The food similarity in perch fry and carp concerned always chironomid larvae, which were recorded in 2.1 to 33.2% congruity. Some other food organisms (cladocerans *Moina* and *Alona*) appeared also in both species together but their contribution to the diet overlapping was rather occasional not exceeding 1.6 and 0.2% respectively.

CONCLUSIONS

Food composition and selectivity of 0+ perch (*Perca fluviatilis*) were studied under experimental pond conditions during the growing season 2000. The diet of perch fry consisted mainly of zoobenthos dominated by chironomid larvae and pupae, which composed 28.54 – 74.21% of food ingested with the frequency of occurrence ranging between 73 – 100%. Also zooplankton, mainly cladocerans (*Bosmina longirostris*, *Chydorus* sp., *Ceriodaphnia* sp., *Alona* sp.) and copepods, with 7.46 – 64.08 and 1.71 – 50.29% proportion of food ingested respectively, was an important food item of 0+ perch. Both chironomids and cladocerans were consumed with positive selectivity, which indicated a strong grazing pressure of perch fry. When applying Costello (1990) graphical plotting, chironomids, *Bosmina*, copepods and *Chydorus* can be considered as important and dominant food items, whilst remaining food items belonged rather among rare ones. The food items of lesser importance were water beetles (genera *Rhantus*, *Hydrobius* and *Hydroporus*), water bugs *Corixa affinis* and mayfly larvae *Caenis* sp. Perch fry (>25 mm TL) did not consume rotifers. Chironomid larvae were the most important food items also in the diet of both adult perch and 2+ carp. Also 0+ perch contributed considerably to the diet of adult perch and benthic food resources (bryozoans and organic debris) including supplied feed cereals were of biggest importance for common carp. The food similarity (= competition) in food items between 0+ perch and adults, and 0+ perch and 2+ carp amounted to 33.2 and 2.3 – 34.8% respectively but between adult perch and 2+ carp it was already 50.0%.

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