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The diet and growth of larval and juvenile pikeperch (*Stizostedion lucioperca* (L.)): A comparative study of fishponds and a reservoir

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Abstract. Diet of larval and juvenile pikeperch (*Stizostedion lucioperca*) reared in ponds was investigated and compared with the diet of pikeperch from a reservoir. The standard length of first feeding pikeperch larvae in ponds was 6.1 mm, on average, and although rotifers were present in the diet, their numerical contribution can be considered as insubstantial. Rotifers were soon replaced by nauplii of cyclopoid copepods, which were highly positively selected and contributed largely to the diet up to a larval length of 10 mm. *Daphnia* spp. were consumed from the onset of exogenous feeding, but were not positively selected until 15 mm. Another smaller cladoceran *Bosmina longirostris* was highly negatively selected and did not contribute significantly to the diet. A clear positive selection for larger relatively to smaller prey and a preference for *Daphnia* from a body length of 15 mm onwards could be observed. In the reservoir, rotifers were not found in the diet of pikeperch larvae even in the smallest individuals. Dominant food items were nauplii and 1st copepodite instar of *Eudiaptomus gracilis* and *Cyclops* spp. Cladocerans – *Daphnia galeata* and to a lesser extent *Diaphanosoma brachyurum* appeared in the pikeperch diet at a length of about 10 mm. A shift from copepods to *Daphnia* spp. and especially *Leptodora kindtii* could be recognised in pikeperch at a length of 20 mm. When comparing our data from nursing ponds with the data from Římov reservoir, similar trends in diet composition were observed.

Growth of pikeperch was found significantly faster in nursing ponds than in the reservoir. Slow growth of reservoir pikeperch was probably an artefact due to the prolonged spawning period in the reservoir. Larvae and juveniles from later spawnings decreased the average size of the population over the studied period. In nursing ponds lowest average standard length at harvest was found in the pond with the highest numbers of fish, and vice versa in the pond with the lowest numbers the largest standard length was recorded. This result corresponds to the increased intracohort food competition among juvenile pikeperch with increasing stocking density.

Key words: Diet composition, Fishpond, Food selection, Growth, Reservoir

Introduction

The pikeperch, *Stizostedion lucioperca* (L.) has an important place in the fishery industry of the Czech Republic (Kokeš, 1993). It is a highly valued game fish, desired market fish and a useful species in biomanipulation activities of reservoirs. To ensure production of market fish and also juveniles for stocking of natural waters, the pikeperch is spawned semi-artificially and reared in ponds in monoculture to a size of 30–50 mm (so called advanced fry, Steffens, 1979). Because an appropriate food supply is crucial to the rearing of fish, we have focused on the diet composition and feeding selectivity in early life history of the 0+ pikeperch and compared the data from fishponds and the reservoir.

Materials and methods

During April 24–June 20 1995 young-of-the-year pikeperch ranging from 5.6 to 45 mm standard length were collected from four ponds (A, B, C, D) of the fish farm Ostrov-Čejkovice, Hluboká nad Vltavou. The water area of ponds used for breeding and rearing pikeperch was 0.46 ha (A) or 0.63 ha (B, C, D) with mean depth 0.7–1 m. Ponds were left without water over the winter period. In spring, quicklime (0.6–0.7 t per pond) was used to prevent development of parasites and also to adjust the buffering capacity of the bottom. A method of semi-artificial breeding was used to spawn mature pikeperch. Spawners stocking density was 9 females and 6 to 9 males at each pond. Fish were set to spawning on April 20 and fished out on May 15, with exception of pond D where they were left and fished out by fry fishing on June 26. On April 24 ponds A and C were treated with Soldep – 0.4 l per pond (containing 21–29% of active substance – trichlorphone) to reach optimal regime for growth of small zooplankton. Trichlorphone selectively eliminates filtering crustaceoplankton and so enables the mass development of rotifers (Tamás and Horvath, 1975, 1976; Svobodová, 1990). The fish spawned in the last week of April in pond A and in the first week of May in ponds B, C and D. The juveniles were fished out on June 20 (A, B, C) and 26 (D), respectively, at the size of 35–45 mm standard length. Initially zooplankton and fish were collected twice a week, later on just once a week. Sampling was carried out between 10 a.m. and 14 p.m. Zooplankton was collected by two 5 m long horizontal tows of plankton net (mouth diameter 20 cm, mesh size 100 μm). Both tows were pooled and preserved in 4–6% formaldehyde solution. In the laboratory at least three subsamples were counted and individuals were identified to genus level. Zooplankton volume was assessed after sample sedimentation in a calibrated tube. Zooplankton abundance and volume data were transformed to 1 m^{-3} of water. On early sampling days the fish larvae were captured using the above-described plankton net. Later on, when the moving abilities of the larvae improved, a fry seine (10 m length, 2 m depth, mesh size 1.7 mm) was used. Immediately after capture, the fish were preserved in 4–6% formaldehyde solution. In the laboratory the standard length for juveniles and the length from the snout tip to end of the *chorda dorsalis* for larvae was measured and the whole digestive tract content was extracted and analysed. Food organisms were identified to the genus level. The diet was evaluated using the numerical method (Hyslop, 1980). Altogether 21 samples of zooplankton and 102 diets of pikeperch larvae and juveniles were analysed.

Diet composition and growth of 0+ pikeperch were investigated at the Římov reservoir (Southern Bohemia, Czech republic) in 1993. The surface area of the reservoir is 210 ha, total volume 34×10^6 m^3, maximum depth 43 m, average depth 16 m, with a theoretical retention time of 90 days. It serves as a drinking water supply reservoir. Ichthyoplankton samples were taken from the central part of the reservoir. Pelagic tows were conducted during night above depths of 15–30 m. Conical ichthyoplankton townets, 1.0 and 2.0 m in diameter, 3.5 m long, with a mesh size of 1.5 mm were used. For sampling details see Matěna (1995). Quantitative zooplankton samples were taken concurrently with fish samples by vertical hauls from the epilimnetic layer using plankton nets equipped with Appstein cones, the mesh size was 100 μm. Two hauls were made on each occasion and pooled. All fish and zooplankton samples were immediately preserved in 6–10% formaldehyde solution. In the laboratory the fish were measured and processed as above described for the nursing pond fish.

Feeding selectivity of the fish was assessed using Ivlev's selectivity index (Ivlev, 1961):

$$E_i = (r_i - n_i) \cdot (r_i + n_i)^{-1}$$

where r_i is the relative abundance of prey category i in the diet of fish and n_i is the relative abundance of prey category i in the environment. This index can achieve values ranging from -1 to +1. Negative values indicate negative selectivity, whereas positive values show positive selectivity of a particular prey category by fish. Values between -0.3 and +0.3 are generally considered to be not significantly different from 0 and represent nonselective feeding (Lazzaro, 1987). The upper positive limit value (+1) indicates that a particular prey category found in fish diet was not found in the environment, which can be considered as a methodological sampling inaccuracy.

In the text, cyclopoid and calanoid copepods are evaluated separately as Cyclopidae and Diaptomidae prey categories, and include mature specimens and their copepodite stages. In contrast, the nauplii prey category includes representatives of both families.

Results

The zooplankton community development followed similar trends in all four ponds (Figure 2). Initially the share of rotifers in total zooplankton numbers was low, but increased to 49–84% at the end of the studied period (June 14). Nauplii of copepods constantly constituted about 1–10%, with occasional increases up to 70%. The numbers of cladocerans, mainly *Daphnia* spp., were generally low, but increased to 93–100% during May 19 through June 6. The abundance of copepods remained relatively stable during the investigated period, constituting no more than 35%, with a decline on May 19.

Data on feeding selectivity of 0+ pikeperch are summarised in Table 3. Data from all ponds were pooled because no substantial differences were found (one-way ANCOVA for every prey category, in all cases $p > 0.05$). Rotifers occurred in small numbers in the diet of only newly hatched larvae and were not positively selected. At the onset of exogenous feeding cyclopoid nauplii were positively selected or consumed proportionally to their presence in the environment. They composed 45.5–97% of the diet up to length of about 10 mm when they were replaced by cyclopoid copepods, which were highly positively selected by fish from a length of 6.5 mm onwards and constituted up to 97% of their diet. *Daphnia* spp. were consumed from a length of 5.6 mm with a maximal intake between 15 and 17.5 mm when they contributed 90% of the diet. However they were not positively selected until larvae were 15 mm long. Another cladoceran *Bosmina longirostris* was highly negatively selected and was found in negligible amounts in the diet.

In the Římov reservoir rotifers were relatively abundant at the beginning (May 26) and the end (August 6) of the studied period, constituting 32 and 20% of total zooplankton abundance, respectively, but the remained scarce between these dates. The proportion of copepod nauplii ranged consistently from 7–17%. The numbers of copepodite stages and adults of *Eudiaptomus gracilis* and *Cyclops* spp. were found also generally constant. *E. gracilis* was mostly abundant from June 8 to June 23, when the numerical share was 26–37%, but decreased to 6–14% during July 8 through August 6. The numbers of *Cyclops* spp. were not higher than 26% with a decline to 6% on June 23. The proportion of *Daphnia* spp. was constantly between 22 and 37% with an increase up to 60% on July 21. Other cladocerans (*Bosmina longirostris*, *Leptodora kindtii*, *Diaphanosoma brachyurum*, *Polyphemus pediculus* and Chydoridae) were found in negligible amounts.

At the onset of exogenous feeding nauplii and 1st copepodite instar of *Eudiaptomus gracilis* and *Cyclops* spp. were the dominant food items of reservoir fish. Both calanoid and cyclopoid copepods were highly positively selected (Table 4) and constituted about 80% of the pikeperch diet on May 26 and June 8. Rotifers were not found in the diet of 0+ pikeperch on

Table 1. Total abundance of zooplankton (thousands ind m^{-3}) in nursing ponds (A–D) and the Římov reservoir (E) from 5th May to 6th August

Pond	5.5.	12.5.	17.5.	19.5.	26.5.	30.5.	6.6.	8.6.	14.6.	23.6.	21.7.	6.8.
A	654.1	70.3	67.0	2.0		41.3	1.2	676.1				
B			45.1	7.5		35.8	35.3		2090.9			
C			86.2	0.3		22.4	34.3		660.2			
D			81.9	7.1		57.3			623.5			
E					274.4			151.4		74.8	45.4	89

Table 2. Total volume of zooplankton (ml m^{-3}) in nursing ponds from 5th May to 14th June

Pond	5.5.	12.5.	17.5.	19.5.	30.5.	6.6.	14.6.
A	26	13	46	4	2	2	41
B			38	17	11	89	73
C			25	1	13	64	78
D			32	23	45		11

any sampling date. Cladocerans – *Daphnia galeata* and to a lesser extent *Diaphanosoma brachyurum* appeared in the fish diet at a length of about 10 mm. A clear shift from copepods to *Daphnia* spp. and particularly to *Leptodora kindtii* could be recognised on June 23 at a standard length of about 20 mm. Both cladoceran species contributed to the diet by more than 85% on June 23, July 21 and August 6, respectively. The positive preference for *L. kindtii* was high. Changes in zooplankton development and diet composition of 0+ pikeperch in ponds and Římov reservoir are presented in Figure 2.

The size of first feeding pikeperch larvae in ponds was 6.1 mm and their guts contained 4.3 zooplankton individuals, on average. The gut fullness increased about ten times for every 10 mm standard length, e.g. at 19.4 mm 36.0 zooplankton ind. and at 29.3 mm 316.6 zooplankton ind. were found on average. On the first sampling date, May 26, pikeperch larvae in the Římov reservoir measured 11.1 mm and their guts contained a mean of 4.8 zooplankton individuals. With increasing length up to June 23 (20.8 mm) the gut fullness increased in the same way as in the fish from ponds, but later on lower gut fullness was reported (one-way ANCOVA, $F = 4.15$, $p = 0.0044$). On July 21 and August 6 the fish measured 16 and 28.33 mm on average and their guts contained only 8.8 and 19.3 zooplankton individuals, respectively.

Table 3. Feeding selectivity of 0+ pikeperch from nursing ponds: pooled data from all four ponds with exception of May 5 and 12, when data were available just from pond A; Ivlev's index, bold values indicate significant positive or negative selectivity

Prey category	5.5.	12.5.	17.5.	19.5.	30.5.	6.6.	14.6.
Cyclopidae	**–0.78**	**–0.52**	**0.64**	**0.99**	0.27	**0.81**	**0.52**
Nauplii	0.30	**0.39**	–0.16	**0.32**	**–0.95**	**–0.96**	**–0.93**
Daphnia spp.		**–0.58**	**–0.57**	**–0.77**	**0.37**	–0.24	**0.63**
Bosmina longirostris		**–1.00**	0.29		**–0.84**		**–0.88**
Rotatoria	**–1.00**	–0.29	**–0.42**	**–1.00**	**–0.95**	**–0.83**	**–0.88**
Chironomidae						**1.00**	**1.00**

Table 4. Feeding selectivity of 0+ pikeperch from Římov reservoir: Ivlev's index, bold values indicate significant positive or negative selectivity, category other Cladocera represents Chydoridae, *Diaphanosoma brachyurum* and *Polyphemus pediculus*

Prey category	26.5.	8.6.	23.6.	21.7.	6.8.
Diaptomidae	**0.82**	0.16	**–0.54**	0.17	–0.18
Cyclopidae	**0.30**	**0.51**	**–0.72**	**–0.60**	**–1.00**
Nauplii	–0.05	**–1.00**	**–1.00**	**–1.00**	**–1.00**
Daphnia spp.	**–1.00**	–0.25	**0.43**	–0.15	0.29
Bosmina longirostris	0.14	**–1.00**	**–0.33**	**–1.00**	**–0.82**
Leptodora kindtii	**–1.00**	**0.82**	**1.00**	**0.98**	**1.00**
Other Cladocera	**0.50**	**–1.00**	0.08	**–1.00**	**–0.65**
Rotatoria	**–1.00**	**–1.00**	**–1.00**	**–1.00**	**–1.00**

Growth of 0+ pikeperch differed significantly among ponds (one-way ANCOVA, $F = 25.26$, $p < 0.000001$) and between ponds and the Římov reservoir (one-way ANCOVA, $F = 7.07$, $p = 0.00004$) (Figure 1). The largest pikeperch were harvested from pond D, the smallest one from pond A (one-way ANOVA, $F = 26.96$, $p = 0.0000027$). Pond D had the lowest (52 000 inds ha^{-1}), pond A the highest (228 000 inds ha^{-1}) fish density as was assessed by fishing on June 26. In pond A (and particularly also in pond C) a general decline in zooplankton abundance (Table 1) and zooplankton volume (Table 2) was recorded from May 19 to June 6. Therefore artificially caught zooplankton was added to avoid starvation of the fish. Zooplankton was added at two days intervals between May 26 to June 20, June 11 to 20 and June 16 to 20 into ponds A, C and D, respectively. The total amounts of added zooplankton were 1180 kg, 280 kg and 120 kg, respectively.

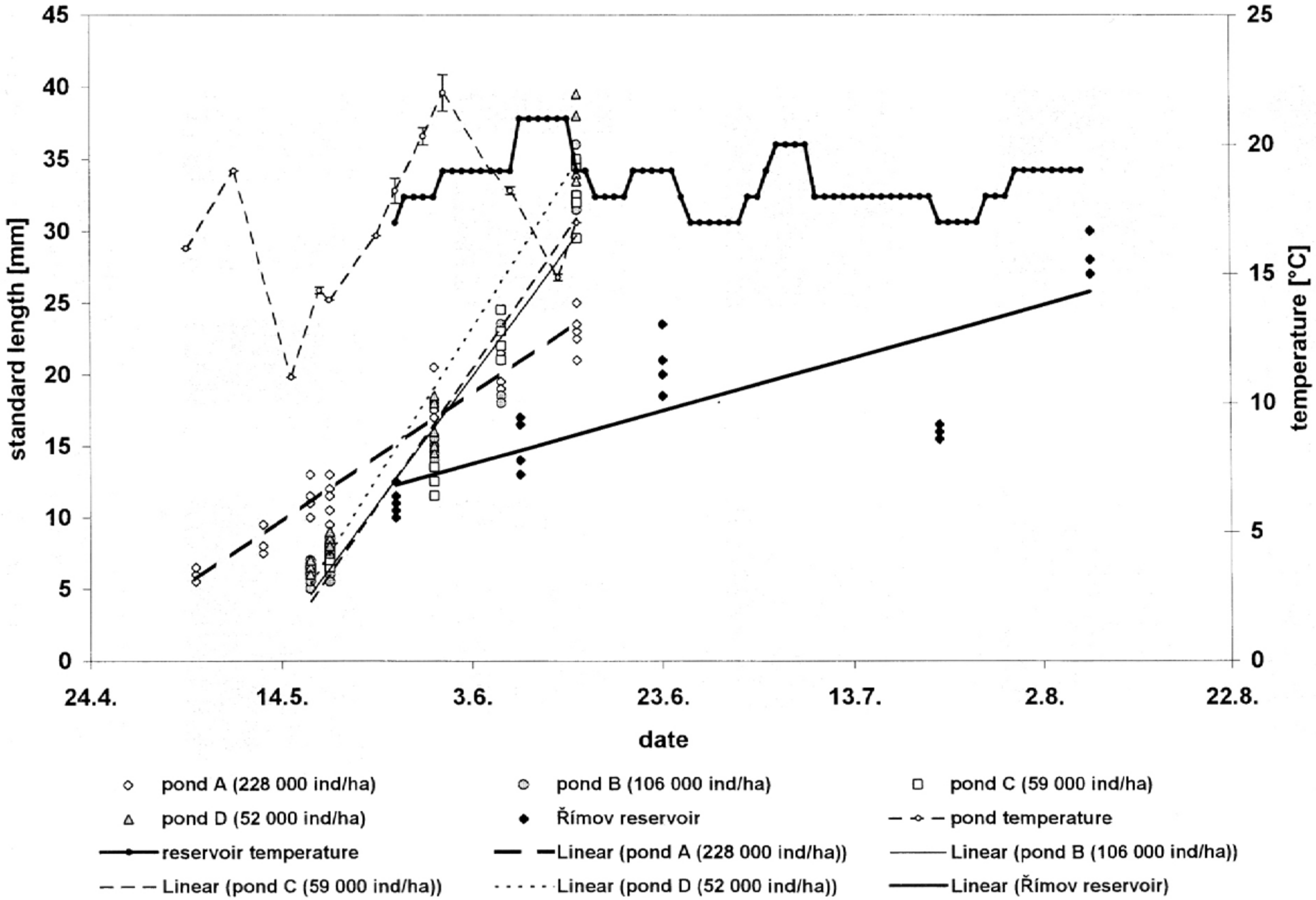

Figure 1. Growth of 0+ pikeperch: linear regressions; pond A – $y = 0.4506x + 5.2236$, $r^2 = 0.9541$; pond B – $y = 0.8991x + 3.6553$, $r^2 = 0.9498$; pond C – $y = 0.9548x + 3.1698$, $r^2 = 0.9357$; pond D – $y = 1.0499x + 4.3424$, $r^2 = 0.9592$; Římov reservoir – $y = 0.1853x + 12.057$, $r^2 = 0.675$; temperature data from all four ponds were pooled, error bars indicate ± 1 SE.

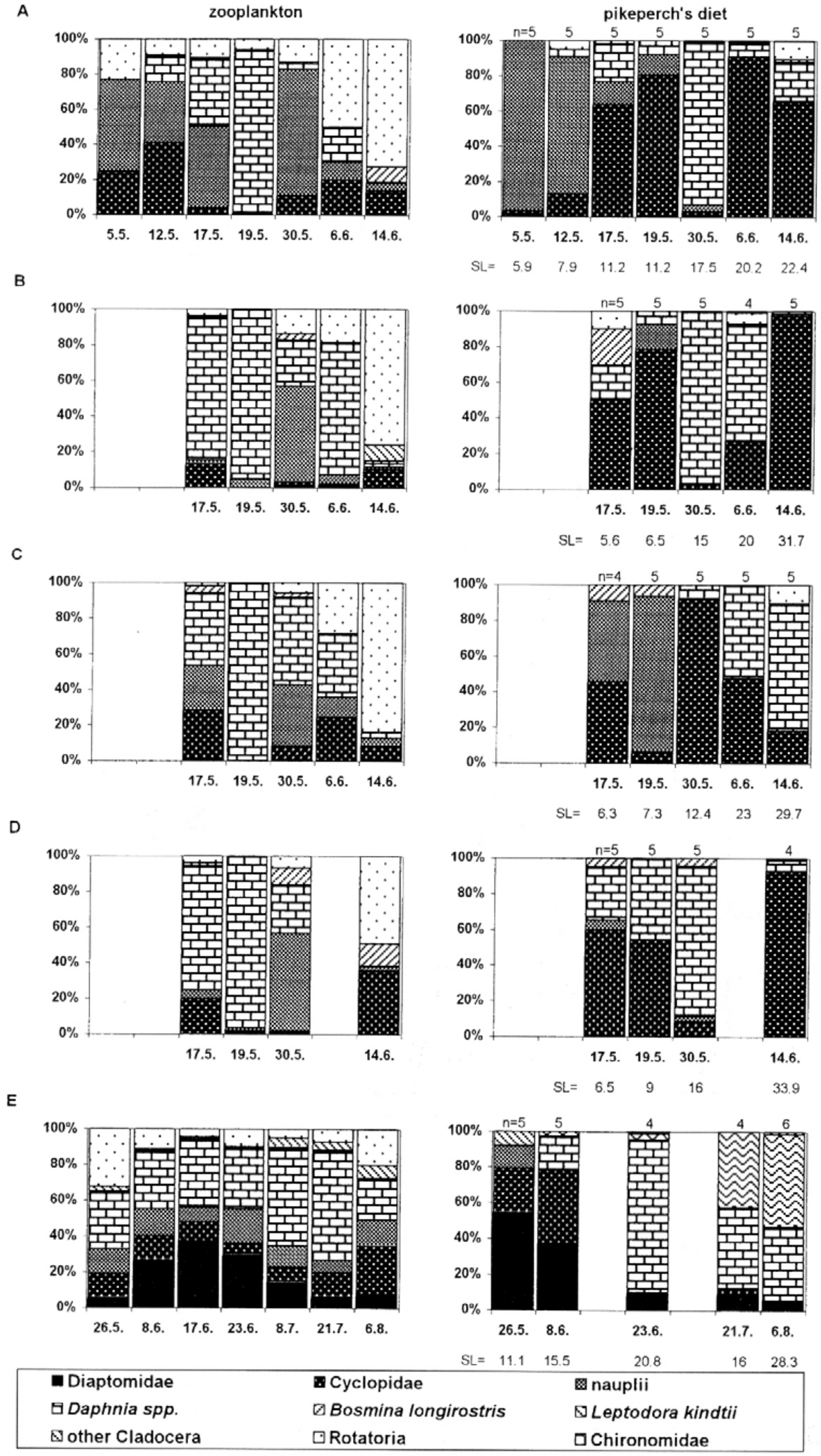

Figure 2. Zooplankton (left column) and diet (right column) composition of 0+ pikeperch in ponds (A–D) and Římov reservoir (E): percentages were calculated from numbers of individuals; category "other Cladocera" represents Chydoridae, *Diaphanosoma brachyurum* and *Polyphemus pediculus*; the figures above the columns of pikeperch's diet composition indicate the numbers of investigated fish; the figures below indicate the average standard length in mm of these fish.

Discussion

The diet of pikeperch larvae under natural conditions was described in detail by Kovalev (1976). According to this author pikeperch goes through a number of developmental stages during the larval period, each of which is characterised by specific anatomical and morphological features, behaviour, spatial distribution and also diet. Kovalev (1976) has reported that nauplii and copepodite stages of copepods constituted 98.85% of the weight of the digestive tract content in larvae shortly after the onset of exogenous feeding (6.1 mm). In larger fish (8.0 and 9.3 mm) the share of copepods decreased slightly whereas the share of small cladocerans increased. Only single specimens of rotifers were found in the diet. Similarly to these findings Pavlov et al. (1988) have found cyclopoid nauplii, early copepodites and *Bosmina* as the first food of pikeperch larvae at developmental stage C_1 (6.4 mm body length), while rotifers were completely avoided. In our data, the length at first feeding for pikeperch larvae was 6.1 mm on average, and although rotifers were present in the diet, they were not positively selected and, because of their small size their contribution to the biomass can be considered as insignificant. In the Římov reservoir the pikeperch larvae were significantly larger on the first sampling date, but similarly to findings of Pavlov et al. (1988) no rotifers were found in the diet, although their numerical share in the environment was relatively high (mainly the genera *Keratella* and *Polyarthra*). Growth of pikeperch larvae is fast (Kovalev, 1976; Verreth and Kleyn, 1987) and they shift rapidly to larger prey (Woynárovich, 1960; Rogowski and Tesch, 1960; Verreth, 1984). Kovalev (1976) found that at a length of 15 mm cladocerans (mainly *Sida crystallina*, *Daphnia cucullata* and *Leptodora kindtii*) constituted 57.12% and copepods 42.88% of the weight of the stomach and gut contents of the fish in Il‘men lake. In our nursing ponds nauplii of cyclopoid copepods contributed largely to the diet until a length of 10 mm. Later on predominantly copepodite stages and adult copepods and at larger size also Cladocera contributed nearly exclusively to the diet. *Daphnia* spp. were consumed from the onset of exogenous feeding, but were not positively selected until a length of 15 mm. In the reservoir cladocerans (*Daphnia galeata*, *Diaphanosoma brachyurum*) appeared in the fish diet at a length of about 10 mm. At about 20 mm standard length a clear positive selection of larger prey organisms (*L. kindtii*) can be observed in young pikeperch similar to that reported by van Densen (1985). He found that in lake Tjeukemeer the diet of pikeperch changed gradually from copepodites through large daphnids towards *Neomysis integer* and/or *Leptodora kindtii*. Verreth and Kleyn (1987) observed similar shift in pikeperch reared in nursing ponds, but instead of *N. integer* or *L. kindtii* the fish selected chironomid larvae and Corixidae. In our nursing ponds chironomid larvae were found in the diet of juvenile pikeperch in ponds B and C on last two sampling dates, June 6 and 14. The chironomid larvae constituted about 1% of the total numbers of prey organisms in the diet of fish, but their contribution in terms of biomass was much higher due to their high individual weight compared with planktonic prey. Positive feeding preference for chironomid larvae was evaluated as maximal (Ivlev index = +1, Table 3) because they were not reported in the environment due to sampling inaccuracy (open water sampling).

Before harvest, the lowest average standard length was found in the pond with the highest numbers of 0+ fish and vice versa, in the pond with the lowest numbers the largest standard length was found. The growth of 0+ pikeperch was found to be influenced by temperature (van Densen et al., 1996; Buijse and Houthuijzen, 1992), but over our studied period temperature did not differ among ponds (one-way ANOVA, $F = 0.24$, $p = 0.87$) and therefore more probably, this result corresponds to the concept of increasing intracohort food competition among juvenile pikeperch with increasing stocking density (Johnston, 1999). The growth of pikeperch in the Římov reservoir was found to be significantly slower. Comparing the regression slopes (equations listed in the legend of Figure 1), growth in reservoir was about four times lower than in the nursing ponds with lower fish density (B, C and D) and about two times lower than in the pond A, where the fish density was the highest. Surface temperature of the Římov reservoir was significantly higher than in nursing ponds (one-way ANOVA, $F = 10.2$, $p = 0.002$) and although we reported a decrease in total zooplankton abundance, it was not as dramatic (from 270 000 to 45 000 ind m^{-3}) as that reported in the ponds, where the numbers decreased to 300–7000 ind m^{-3} (Tables 1 and 2). It seems that the spawning period in the Římov reservoir is quite prolonged, because even in mid July young larvae at the developmental stage C_1 were found. Therefore the simultaneous occurrence of pikeperch of different ages may decrease the average length and lower the estimated growth of pikeperch juveniles as observed.

Conclusions

Comparison of the diet composition of 0+ pikeperch under natural conditions in a reservoir and in nursing ponds suggest general similarities in feeding preferences of the fish in these two biotopes. In accordance with other authors (Woynárovich, 1960; Rogowski and Tesch, 1960; Kovalev, 1976; Pavlov et al., 1988), we have found that pikeperch larvae do not require rotifers as starting food, but from the onset of exogenous feeding prefer nauplii of copepods, which are soon replaced by the copepodite stages and mature copepods. Cladocerans contribute widely to the diet from about 15 mm standard length and at 20–40 mm selection for larger prey (*L. kindtii*, chironomid larvae) occurs. According to Kleinbreteler (1980) the first four weeks after onset of exogenous feeding appear to be critical for the survival of 0+ pikeperch. Therefore, well-prepared nursing ponds with a proper food supply of appropriate size are probably the most important factor in the successful rearing of 0+ pikeperch.

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