

Zooplankton and its Contribution to the Diet of European Perch (*Perca fluviatilis*) in Two Lowland Reservoirs in Northwestern Bulgaria

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Abstract: This study presents results on zooplankton composition of two lowland reservoirs in the Danube River Basin and gives insight into the trophic relationship between zooplankton and European perch (*Perca fluviatilis* Linnaeus, 1758). We found significant within-reservoir differences in the univariate and multivariate biological metrics between spring and autumn samples. Overall zooplankton densities and biomass were higher in spring, both being dominated by Cladocera, while zooplankton diversity was greater in autumn with Rotifera dominating the densities and Copepoda dominating the biomass. In addition, we examined the foregut content of 297 perch specimens. It consisted exclusively of crustacean zooplankters, small fish and benthic invertebrates. The zooplankton of the perch foregut content was dominated by cyclopoids in spring and by cladocerans in autumn. This mismatch between the relative abundance of zooplankton in the perch foregut content and in the reservoirs demonstrates the selective feeding of *Perca fluviatilis*. Given that zooplankton plays a major role in standing water bodies, *i.e.* linking the energy transfer between primary producers and secondary consumers, our findings may serve as a basis for future research on the within-reservoir trophic relationships, as well as for effective and sustainable management of aquacultures of Bulgarian reservoirs.

Keywords: Zooplankton composition, seasonality, perch selective feeding, lowland reservoirs, Danube River Basin

Introduction

Reservoirs provide numerous ecological services worldwide, *e.g.*, drinking water supply, flood alleviation, power generation, water abstraction for agriculture, aquacultures, sport fishing, recreation (PRUS *et al.* 1999, FITZPATRICK, BREE 2001, JACKSON *et al.* 2001). The importance of reservoirs in Bulgaria is unequivocal: while there are about 400 natural lakes, the number of reservoirs in the country is about 2200 (KOPRALEV 2001). Studies on the structure and functioning of reservoir ecosystems are, therefore, essential from both scientific and water management perspectives.

It is known that zooplankton plays a major role in lentic water bodies as it is linking the energy transfer between primary producers, *e.g.* phytoplankton, and secondary consumers, *e.g.* fish (DODDS 2002,

LIKENS 2010, MOSS 2010). Furthermore, studies on lakes and reservoirs recognise the within-system spatial heterogeneity in the distribution and relationships between zooplankton and fish as an important ecological issue (KUBECKA *et al.* 1998, HORPPILA *et al.* 2000, SEDA, DEVETTER 2000, SEDA *et al.* 2000, WINFIELD *et al.* 2002, VASEK *et al.* 2003, 2006). The existing knowledge of zooplankton communities in Bulgarian reservoirs, however, concerns mostly its composition and dynamics, as well as the importance of various environmental factors for zooplankton communities (*e.g.* NAIDENOV 1964a,b,c, 1976, 1977a,b, 1981, 1993, NAIDENOV, BAEV 1987, KOZUHAROV 1995a,b, KOZUHAROV *et al.* 2007, 2013, PANDOURSKI 2007).

Additionally, the European perch (*Perca fluviatilis* Linnaeus, 1758) is one of the most frequently

found species in Bulgarian reservoirs (TRICHKOVA *et al.* 2007). In most of them it is also a dominant predator among fish (TRICHKOVA *et al.* 2005) and, therefore, plays an important role in the trophic structure of standing water bodies. Moreover, studies investigating the relationship between zooplankton and fish for Bulgarian reservoirs are largely lacking. Consequently, this study aimed at (1) examining the qualitative and quantitative composition of zooplankton in two lowland reservoirs; (2) comparing the spring and autumn dynamics within and between reservoirs; and (3) investigating the selective feeding of perch on zooplankton.

Material and Methods

Study area

Drenovets (D) and Poletkovtsi (P) reservoirs are located in Northwestern Bulgaria (Fig. 1) and belong to the Danube River Basin. Drenovets Reservoir belongs to the Lom River Basin, while Poletkovtsi Reservoir belongs to the Voynishka River Basin. Both reservoirs have earthfill embankment dam and comparable surface areas, volumes and average depths (Table 1). The maximum water levels are registered usually between April and May (D & P) and the minimum in October (D) or in September (P). The reservoirs are used for irrigation, fisheries, commercial and sport fishing.

Sampling and laboratory analyses

The zooplankton was collected from the pelagial at six stations in Drenovets Reservoir and five stations in Poletkovtsi Reservoir (Fig. 1). A total of 84 zooplankton samples were collected during the investigation: 42 qualitative and 42 quantitative samples. Owing to bad weather condition on two occasions it was not possible to visit a total of three sampling sites. Qualitative samples were collected with Apstein plankton net. Composite quantitative samples were collected through direct filtering of 50 dm³ water of the superficial layer using a hand-held net (five subsamples x 10 dm³, European standard EN 15110:2006). Both nets had mesh size of 47 µm.

Moreover, we investigated the foregut content of 259 perch specimens from Drenovets Reservoir and 38 from Poletkovtsi Reservoir, including the content of the victims when it was well preserved. Samples were collected during spring and autumn turnovers: from Drenovets Reservoir in autumn 2002 (A1), 2003 (A2) and 2004 (A3), and in spring 2003 (S1) and 2004 (S2). Poletkovtsi Reservoir was sampled in autumn 2003 (A2) and 2004 (A3), and in spring 2004 (S2). The faunistic material was pre-

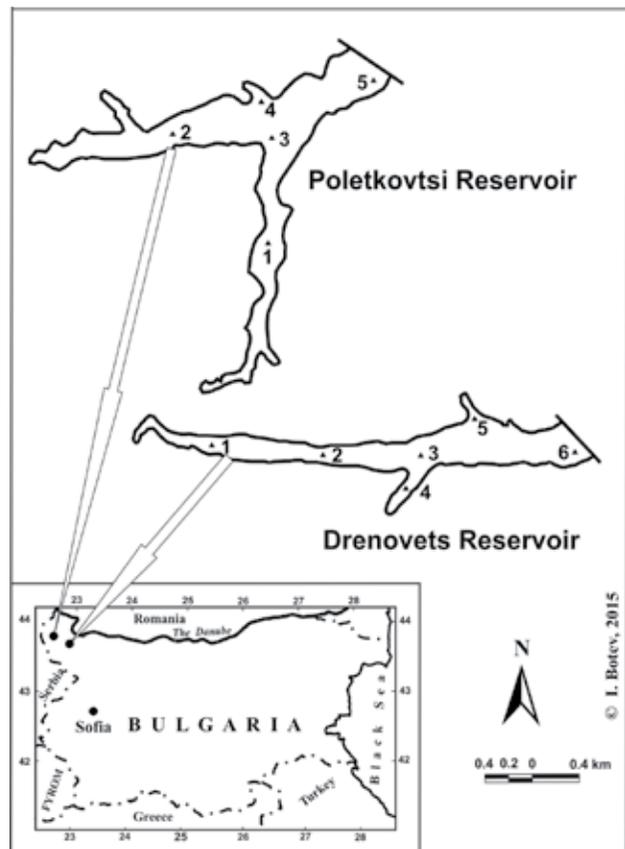


Fig. 1. Schemes and location of Drenovets and Poletkovtsi reservoirs. Drenovets Reservoir: Station 1 – 43°41'42" N, 22°52'49" E; Station 2 – 43°41'41" N, 22°53'18" E; Station 3 - 43°41'38" N, 22°53'53" E; Station 4 – 43°41'30" N, 22°53'47" E; Station 5 – 43°41'46" N, 22°54'17" E; Station 6 – 43°41'39" N, 22°5'54" E. Poletkovtsi Reservoir: Station 1 – 43°50'36" N, 22°30'19" E; Station 2 – 43°50'58" N, 22°29'34" E; Station 3 – 43°50'59" N, 22°30'20" E; Station 4 – 43°51'06" N, 22°30'14" E; Station 5 – 43°50'13" N, 22°30'52" E.

Table 1. Morphological and hydrological characteristics of Drenovets and Poletkovtsi reservoirs (Northwestern Bulgaria). The data were provided by "Irrigational Systems" EAD, Vidin branch

Features	Drenovets Reservoir	Poletkovtsi Reservoir
Altitude, m	176	205
Surface area (S), dka		
S _{max}	1070	1648
S _{average}	700	1170
Volume (V), m ³ x10 ⁶		
V _{max}	12	17.5
V _{operational storage}	11.5	16.2
V _{dead storage}	0.5	1.3
Depth (h), m		
h _{max}	28	36
h _{average}	14	15

served in 70% ethanol. The zooplankton taxa and the dominant phytoplankton taxa were identified to the lowest taxonomic rank. The zooplankton biomass was calculated following Morduhay-Boltovskoy (PAVLOVSKIY, ZHADIN 1956).

Data analyses

We tested for effects of spring or autumn on the univariate response variables (total taxa number, zooplankton density and biomass, and rarefied taxon richness) by means of analysis of variance (ANOVA). Total variation in response variables was partitioned using Type III sum of squares. The taxonomic resolution used in these analyses was genera, thus avoiding noise from very rare species. Variables were transformed, if necessary, prior to analysis to meet assumptions of normality and homoscedasticity. Taxon richness of zooplankton was rarefied to the minimum number of specimens found in a sample to remove the confounding influence of abundance on estimates of richness (HURLBERT 1971). Frequency of occurrence (pF) after DE VRIES (1937) was used as an additional descriptor of overall zooplankton structure.

The Bray-Curtis similarity coefficient was calculated with PRIMER® 6.1.8 (PRIMER-E Ltd., Plymouth, U.K.; CLARKE, GORLEY 2006, CLARKE, WARWICK 2001). The importance of season (spring or autumn) on the overall (*i.e.* multivariate) taxonomic structure of zooplankton was tested for both density and biomass using permutational multivariate analysis of variance (PERMANOVA; ANDERSON 2001), using PERMANOVA+ add-on for PRIMER. These analyses were based on the Bray-Curtis similarity matrices calculated from $\log(x+1)$ -transformed zooplankton density or biomass data and were done with 9999 permutations of the residuals under an unrestricted permutation model. We used similarity percentage species-contributions analysis (SIMPER; CLARKE, WARWICK 2001) to investigate the contribution of individual zooplankton taxa to the between-season or between-reservoir dissimilarities.

Results

Dominant phytoplankton taxa

In autumn 2002 (A1) the phytoplankton of Drenovets Reservoir was dominated by the peridinium dinoflagellates *Ceratium hirundinella* (O. F. Müller) Dujardin, 1841, and *Peridinium* sp. High algal densities were registered in autumn 2003 (A2) owing mainly to *C. hirundinella* and a few species of Dinophyta, while in spring 2004 (S2) *Microcystis* was recorded with

the highest density. In Poletkovtsi Reservoir with high densities were *C. hirundinella*, *Aphanizomenon* sp. and Cyanophyceae (A2). In spring 2004 we found a few individuals of *C. hirundinella*.

Qualitative zooplankton composition

We found a total of 42 zooplankton taxa in the two reservoirs (Table 2). In Drenovets Reservoir we recorded 38 zooplankton taxa, including 30 rotifers, five cladocerans, two cyclopoids (adult and juvenile forms), and one protozoan species. Seven were the common zooplankton taxa for Drenovets Reservoir over all sampling occasions. Very rare were *Notholca caudata* Carlin, 1943, *Brachionus angularis* Gosse, 1851, and *Lecane bulla* (Gosse, 1851). The cladoceran *Daphnia pulex* (De Geer, 1778) was found only in the perch foregut content in spring 2003 (S1).

We recorded 30 zooplankton taxa in Poletkovtsi Reservoir from which 21 rotifers, five cladocerans, two cyclopoid copepods (adult and juvenile forms) and two protozoans (Table 2). The number of the common taxa in Poletkovtsi Reservoir over all sampling occasions was nine, while ten of the components were found only in autumn 2003; one only in spring 2004 and four only in autumn 2004. The overall frequency of occurrence reached 100% only for six common for the two reservoirs taxa.

There were significant within-reservoir differences between the number of taxa in spring and in autumn in both Drenovets (D) and Poletkovtsi (P) reservoirs (D: ANOVA $F_{1,21} = 5.28$, $p = 0.032$ and P: ANOVA $F_{1,8} = 6.74$, $p = 0.031$). The zooplankton diversity was generally higher in autumn (Fig. 2). Moreover, the within-reservoir seasonal differences between spring and autumn samples were significant also for the rarefied richness in both reservoirs (D: ANOVA $F_{1,25} = 4.49$, $p = 0.044$ and P: ANOVA $F_{1,8} = 5.53$, $p = 0.046$). Furthermore, the between-reservoir similarity, calculated using the frequency of occurrence of each species, was relatively high: the Bray-Curtis coefficient of similarity reached 77%.

Quantitative zooplankton composition

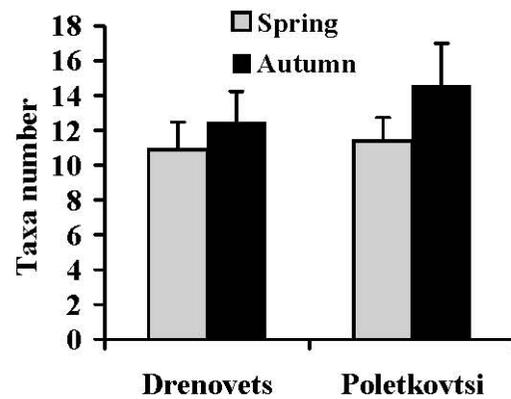
Abundance and biomass of the zooplankton

The mean zooplankton density and biomass were greater in spring than in autumn (Figs. 3 and 4). These between-season differences were highly significant for the log-transformed densities in Poletkovtsi Reservoir (P: ANOVA $F_{1,8} = 32.55$, $p = 0.0005$), and for the log-transformed biomass in both reservoirs (D: ANOVA $F_{1,21} = 10.06$, $p = 0.005$ and P: ANOVA $F_{1,8} = 35.54$, $p = 0.0003$).

The highest mean density in Drenovets Reservoir, owing mostly to the contribution of rotif-

Table 2. Qualitative composition of zooplankton taxa in Drenovets (D) and Poletkovtsi (P) reservoirs and frequency of occurrence pF

№	Zooplankton taxon	pF %	
		D	P
Rotifera			
1	<i>Cephalodella</i> sp.	20	33
2	<i>Trichocerca (Diurella) similis</i> (Wierzejski, 1893)	20	33
3	<i>Trichocerca (Diurella)</i> sp.		33
4	<i>Trichocerca (s. str.)</i> sp.1	20	33
5	<i>Trichocerca (s. str.)</i> sp.2	20	
6	<i>Trichocerca</i> sp.	80	33
7	<i>Synchaeta oblonga</i> Ehrenberg, 1831	20	
8	<i>Polyarthra vulgaris</i> Carlin, 1943	20	
9	<i>Polyarthra dolichoptera</i> Idelson, 1925	100	100
10	<i>Polyarthra</i> sp.	40	
11	<i>Asplanchna priodonta</i> Gosse, 1850	20	
12	<i>Asplanchna sieboldi</i> (Leydig, 1854)	20	
13	<i>Asplanchna</i> sp.	100	67
14	<i>Lecane (s. str.)</i> sp.	20	33
15	<i>Lecane (Monostyla) bulla</i> (Gosse, 1851)	20	
16	<i>Lecane (Monostyla)</i> sp.	20	33
17	<i>Proales</i> sp.	20	
18	<i>Lepadella</i> sp.	40	33
19	<i>Euchlanis</i> sp.	20	33
20	<i>Brachionus homoceros</i> (Wierzejski, 1891)	20	33
21	<i>Brachionus diversicornis</i> (Daday, 1883)	40	67
22	<i>Brachionus angularis</i> Gosse, 1851	20	
23	<i>Keratella cochlearis</i> (Gosse, 1851)	80	100
24	<i>Keratella tecta</i> (Gosse, 1851)	100	100
25	<i>Keratella quadrata</i> (O. F. Müller, 1786)	60	67
26	<i>Notholca caudata</i> Carlin, 1943	20	
27	<i>Anuraeopsis</i> sp.	60	100
28	<i>Testudinella</i> sp.	20	33
29	<i>Pompholyx complanata</i> Gosse, 1851	20	33
30	<i>Pompholyx</i> sp.	40	67
31	Rotifera gen. spp.	20	67
Cladocera			
32	<i>Daphnia pulex</i> (De Geer, 1778)	20	
33	<i>Daphnia cucullata</i> Sars, 1864	100	100
34	<i>Daphnia</i> sp.	20	67
35	<i>Bosmina (Bosmina) longirostris</i> (O. F. Müller, 1785)	80	100
36	<i>Bosmina (Eubosmina) longispina</i> Leydig, 1860		33
37	<i>Bosmina (Eubosmina) coregoni</i> Baird, 1857	40	
38	<i>Alona cf. costata</i> Sars, 1862		33
Copepoda			
39	<i>Cyclops vicinus</i> Ulyanin, 1875	60	67
40	<i>Thermocyclops oithonoides</i> (Sars, 1863)	100	100
41	Copepodites	100	100
42	Nauplii	100	100
Varia			
43	<i>Testacea</i> gen. sp.		33
44	<i>Tintinnopsis lacustris</i> (Entz, 1901)	60	67

**Fig. 2.** Mean spring (grey bars) and autumn (black bars) zooplankton taxa number in Drenovets and Poletkovtsi reservoirs. Untransformed data are shown for clarity

ers, was established in spring 2004 (365 200 ind. m⁻³). On three of the sampling occasions the genus *Keratella* dominated the mean zooplankton density in the reservoir: *Keratella tecta* (Gosse, 1851) in autumn 2003 and 2004 (20 600 and 58 633 ind. m⁻³); *Keratella cochlearis* (Gosse, 1851) in spring 2004 (138 600 ind. m⁻³). In autumn 2002 dominant was *Polyarthra* with 21 000 ind. m⁻³. Only on one occasion (spring 2003) dominant was the cladoceran *Bosmina (Bosmina) longirostris* (O. F. Müller, 1785) representing 50% of the mean zooplankton density in Drenovets Reservoir. Overall, rotifers were dominant by mean density over four of the sampling occasions, representing 65.6% in autumn 2002; 74.6% in autumn 2003; 77.6% in spring 2004 and 88.80% in autumn 2004. During our investigation the highest abundance of Rotifera was registered in spring 2004 with an average value for the reservoir of 283 000 ind. m⁻³. About 30 times lower was the value in spring 2003 (10 367 ind. m⁻³). The highest mean abundance of Cladocera in Drenovets Reservoir was recorded in spring 2003, with 89 900 ind. m⁻³ representing 59.7%. At that time *B. (B) longirostris* reached an exceptionally high density of 248 400 ind. m⁻³ on station 4. In autumn 2004 when cladocerans were registered only at one of the stations, their mean abundance was more than 1300 times lower.

The highest mean biomass in Drenovets Reservoir was registered in spring 2003 when it reached 2351 mg m⁻³ (Fig. 4), owing mostly to the relatively large *B. (B) longirostris* (32.4%), *Daphnia cucullata* Sars, 1864 (29.1%) and copepodites (26.1%). During this period the overall contribution of Cladocera was 61.5% (1445 mg m⁻³) of the total biomass. The highest registered mean rotifer biomass in Drenovets Reservoir (A3: 496 mg m⁻³) was owing

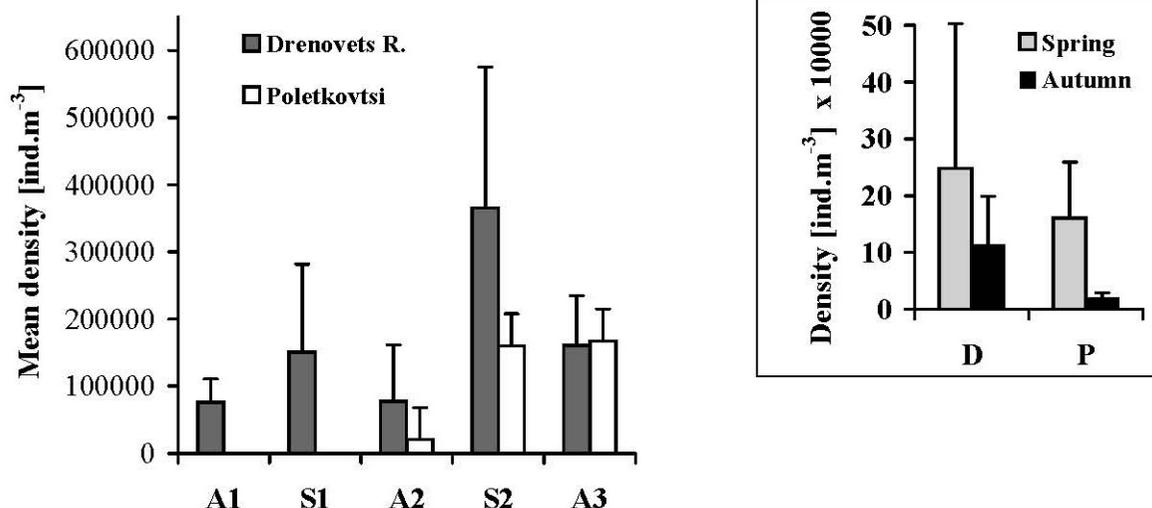


Fig. 3. Mean zooplankton densities in Drenovets Reservoir (dark grey bars) and Poletkovtsi Reservoir (white bars). Legend: A 1 – September 2002; S 1 – May 2003; A 2 – September 2003; S 2 – May 2004; A 3 – September 2004. With an inset are shown the overall mean spring and autumn densities. Untransformed data are shown for clarity

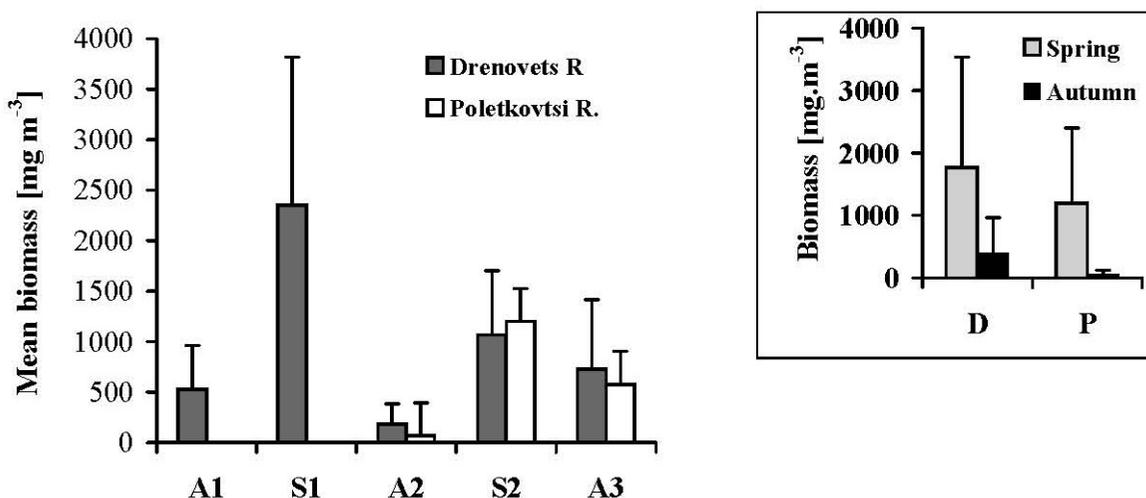


Fig. 4. Mean zooplankton biomass in Drenovets Reservoir (dark grey bars) and Poletkovtsi Reservoir (white bars). Legend: A 1 – September 2002; S 1 – May 2003; A 2 – September 2003; S 2 – May 2004; A 3 – September 2004. With an inset are shown the overall mean spring and autumn biomass. Untransformed data are shown for clarity

exclusively to *Asplanchna* sp. (84.9%). The lowest mean biomass (182 mg m⁻³) was observed in autumn 2003 when the naupliar stages of Cyclopoida accounted for 44% of the mean biomass and dominant was the tiny *K. tecta*. In spring (both 2003 and 2004) in Drenovets Reservoir the biomass was dominated by crustaceans with Cladocera contributing most to the biomass: 61.5 % in 2003 and 68.9 % in 2004. Prevailing was *B. (B) longirostris*, especially in May 2004 when it accounted for 57.4% of the total mean biomass. In autumn, *Asplanchna* sp. contributed significantly to the total biomass, *i.e.* 44.9 % in 2002; 26.3 % in 2003, when naupliar stages of Copepoda dominated (58.6%); and 68.09% in 2004.

In autumn the zooplankton consisted mainly of Rotifera and Copepoda, with respectively 46.9 % and 38.3 % in 2002; 38.1 % and 58.6 % in 2003, and 80.2% and 19.7% of the mean reservoir biomass in 2004. The maximum copepod reservoir density (50 300 ind. m⁻³) and biomass (759 mg m⁻³) were reached in spring 2003. Almost three times lower was the copepod density in autumn 2004, and the lowest registered biomass was 106 mg m⁻³ (autumn 2003), which was about seven times lower than the highest biomass of Copepoda. During all the sampling occasions abundance and biomass of Drenovets Reservoir were largely formed by juvenile stages of Cyclopoida.

Table 3. Results of SIMPER analyses identifying the densities of the six zooplankton taxa, which contributed most strongly to the significant ($p < 0.05$) within-reservoir differences found between spring and autumn samples. Untransformed data are shown for clarity

Reservoir	Zooplankton taxon	Mean density (ind. m ⁻³)		Contribution (%)
		Spring	Autumn	
Drenovets	<i>Bosmina (Bosmina) longirostris</i>	66636	125	24.0
	<i>Keratella tecta</i>	21691	33638	12.8
	<i>Keratella cochlearis</i>	64727	800	9.8
	Copepodites	21200	3425	8.3
	<i>Pompholyx complanata</i>	27818	0	8.3
	Nauplii	15782	15425	6.4
Poletkovtsi	<i>Bosmina (Bosmina) longirostris</i>	56400	1760	25.0
	Nauplii	25600	35960	16.7
	<i>Keratella cochlearis</i>	27280	5080	12.8
	<i>Keratella quadrata</i>	14640	200	10.4
	<i>Trichocerca</i> sp.	0	19320	8.1
	Copepodites	13120	3520	6.4

Table 4. Results of SIMPER analyses identifying the biomass of the six zooplankton taxa which contributed most strongly to the significant ($p < 0.05$) within-reservoir differences found between spring and autumn samples. Untransformed data are shown for clarity

Reservoir	Zooplankton taxon	Mean biomass (mg m ⁻³)		Contribution (%)
		spring	autumn	
Drenovets	<i>Bosmina</i> sp.	666.58	4.40	32.6
	<i>Daphnia cucullata</i>	422.73	17.50	17.9
	Copepodites	360.40	58.23	14.3
	<i>Asplanchna</i> sp.	93.52	234.56	14.0
	Nauplii	70.99	69.41	6.2
	<i>Pompholyx</i> sp.	61.36	1.97	4.9
Poletkovtsi	<i>Bosmina</i> sp.	564.00	17.60	36.1
	<i>Daphnia cucullata</i>	228.00	2.00	23.5
	Copepodites	223.04	59.84	15.3
	Nauplii	115.20	61.82	12.5
	<i>Asplanchna</i> sp.	0.00	63.60	4.7

The zooplankton density in Poletkovtsi Reservoir was extremely low in autumn 2003. In September 2003 the rotifers prevailed with the highest abundance of 11 040 ind. m⁻³ or 54.1% of the total mean abundance, mainly due to *Polyarthra dolichoptera* Idelson, 1925 (8720 ind. m⁻³ or 42.8%). The role of the naupliar stages of Cyclopoida was also considerable: 7360 ind. m⁻³ or 36.1% in 2003, and 64 560 ind. m⁻³ or 38.7% in 2004. In autumn maximum biomass was registered for Copepoda (73.8%) and was only 51 mg m⁻³ in 2003, and 395 mg m⁻³ or 68.4% in 2004. In spring we found slight predominance of cladocerans with 38.06% (60 960 ind. m⁻³) over Rotifera with 36.86% (59 040 ind. m⁻³) in Poletkovtsi Reservoir. However, dominant by biomass in May 2004 was Cladocera with 66.1% or 792 mg m⁻³.

Horizontal distribution of the zooplankton

The zooplankton was unevenly distributed along the stations in Drenovets Reservoir. The maximal density of 945 000 ind. m⁻³ was registered at station 1 in spring 2004, of which 581 000 ind. m⁻³ were *K. cochlearis*. The lowest abundance was registered at station 5 in spring 2003 (4600 ind. m⁻³). It was formed only by five components with dominance of *B. longirostris* (2600 ind. m⁻³). In Drenovets Reservoir maximal biomass was registered at station 4 in spring 2003, mainly due to *B. longirostris* (45.5%), Copepodites (28.1%) and *D. cucullata* (19.4%). The lowest biomass was found at station 5 in autumn 2003 when crustaceans were scarce and the rotifers comprised 74.3% of the biomass.

In autumn 2003 and 2004 the zooplankton of Poletkovtsi Reservoir was unevenly distributed. In

2003 the zooplankton density peaked at stations 3 and 1 (28 000 ind. m⁻³ and 25 600 ind. m⁻³, respectively) and at station 2 in 2004 (255 600 ind. m⁻³). The lowest numbers in autumn were counted at station 2 in 2003 (6400 ind. m⁻³) and at station 1 in 2004 (86 000 ind. m⁻³). The highest autumn biomass for Poletkovtsi Reservoir (967 mg m⁻³) was registered in 2004 at one of the side arms (station 5) where *Asplanchna* reached 382 mg m⁻³ and the naupliar stages of Copepoda - 376 mg m⁻³. The highest biomass in 2003 was recorded also at station 5, mainly owing to the naupliar stages of Copepoda (48.3% of the total biomass at the station). The lowest values were measured at station 4: 11 mg m⁻³ in 2003 and 229 mg m⁻³ in 2004. In spring 2004 the zooplankton was relatively evenly distributed along the different stations. An exception was station 5 where the abundance reached 329 600 ind. m⁻³ and the biomass 2370 ind. m⁻³, with *B. (B) longirostris* being the dominant species.

Zooplankton structure

We found highly significant overall differences between the taxonomic structure of zooplankton communities in spring and autumn (abundance: PERMANOVA pseudo- $F_{1,38} = 6.41, p \leq 0.0001$ and biomass: PERMANOVA pseudo- $F_{1,38} = 9.52, p \leq 0.0001$). The between-reservoir differences in the zooplankton communities along the seasonal gradient were not significant (abundance: PERMANOVA pseudo- $F_{1,38} = 1.46, p = 0.15$, log(x + 1)-transformed; and biomass: PERMANOVA pseudo- $F_{1,38} = 0.82, p = 0.61$, log(x + 1)-transformed). The within-reservoir zooplankton communities were significantly different in spring and autumn as measured by the zooplankton log(x + 1)- transformed abundance (D: PERMANOVA pseudo- $F_{1,25} = 3.62, p = 0.04$; and P: PERMANOVA; pseudo- $F_{1,13} = 3.05, p = 0.02$) and log(x + 1)- transformed biomass (D: PERMANOVA pseudo- $F_{1,25} = 6.77, p \leq 0.0001$; and P: PERMANOVA pseudo- $F_{1,13} = 4.69, p = 0.0008$). SIMPER analysis revealed that the taxa densities contributing most to the dissimilarity between within-reservoir abundance between spring and autumn samples in both reservoirs comprised *Bosmina longirostris*, *Keratella cochlearis* and the copepodite stages of Cyclopoida. The density of these taxa was reduced significantly from spring to autumn (Table 3). SIMPER analysis on biomass revealed that *Bosmina*, *Daphnia cucullata*, *Asplanchna* and the juvenile stages of Cyclopoida contributed most to the dissimilarity between the within-reservoir biomass between spring and autumn samples in both reservoirs (Table 4).

Zooplankton components in the diet of perch (*Perca fluviatilis*)

We investigated the foregut content of 279 perch specimens, including some of the better preserved victims from Drenovets Reservoir. A total of 11 zooplankton taxa were found in the foregut content from the two reservoirs. Zooplankton was found in 50 of the foreguts from Drenovets Reservoir, mostly in the younger fish. A total of 10 zooplankters were established. The larger-sized crustaceans *Cyclops vicinus* Ulyanin, 1875 (juvenile and adult) and *Daphnia cucullata* were with the highest overall relative abundance and frequency of occurrence in the foregut content (Table 5). They were followed by the copepod *Thermocyclops oithonoides* (Sars, 1863) and the cladoceran *B. coregoni*. *Daphnia pulex* was found only in the foregut content of the perch and not in the zooplankton samples from the reservoir (Tables 2 and 5).

Cyclops vicinus had a high abundance and frequency of occurrence in the food of perch in spring, while in autumn we detected only single specimens of *C. vicinus* in the foregut content. Overall, cyclopoids dominated amongst all zooplankters in the perch food content in Drenovets Reservoir. *Daphnia pulex* had the highest percentage of dominance, but it was most rarely found in the foreguts (Table 5). The cladoceran *Bosmina longirostris* (found only in spring 2003) had the lowest relative abundance and frequency of occurrence in the foregut content. In autumn the number of Cladocera in the food of the perch in Drenovets Reservoir was greater than the one of Cyclopoida. The latter was mostly represented by *Thermocyclops oithonoides*. The density of cyclopids in spring was several times higher than the one of Cladocera, and they were mostly represented by *Cyclops vicinus*. The genus *Bosmina*, such

Table 5. Zooplankton taxa found in the foregut content of perch in Drenovets Reservoir. RP (%) – relative abundance, pF (%) – frequency of occurrence, DF (%) - frequency of dominance, N=126 individuals

Zooplankton taxa	RP (%)	pF (%)	DF (%)
<i>Cyclops vicinus</i>	39.4	19.1	75.0
<i>Cyclops</i> sp.	19.9	2.4	33.3
<i>Daphnia cucullata</i>	10.5	20.6	38.5
<i>Thermocyclops oithonoides</i>	9.8	11.1	42.9
<i>Bosmina coregoni</i>	6.3	10.3	15.4
<i>Daphnia pulex</i>	4.9	2.4	66.7
Cyclopoida gen. sp.	4.4	9.5	41.7
<i>Daphnia</i> sp.	2.0	5.6	14.3
<i>Bosmina</i> sp.	1.9	3.2	50.0
<i>Bosmina longirostris</i>	0.9	5.6	0.0

as *Bosmina coregoni* Baird, 1857, and *B. longirostris*, were present in the foregut content as well.

In Poletkovtsi Reservoir the foregut content of 38 perch specimens was investigated. Zooplankton was found in three of them, namely larger *Daphnia* sp. and juvenile and adult stages of *C. vicinus*. Larvae of Insecta were found in two foreguts, fish in the foreguts of eight specimens.

Discussion

This paper presents a study on the qualitative and quantitative zooplankton composition of two lowland reservoirs and the importance of different zooplankton taxa as a food source for *Perca fluviatilis*. We recorded greater within-reservoir zooplankton densities and biomass in spring and higher diversity in autumn for both Drenovets and Poletkovtsi reservoirs. The zooplankton communities in the two reservoirs were not significantly different as demonstrated by our analyses. The dominant phytoplankters for the two reservoirs were similar, as well. Upon identifying the zooplankton taxonomic structure in the reservoirs, the zooplankton from the foregut content of 279 perch specimens was investigated. Overall, perch fed on larger crustaceans from Cyclopoida and Cladocera. We registered a shift from cyclopid-dominated diet in spring to cladoceran-dominated diet in autumn.

The total number of zooplankton taxa found in the two reservoirs was 42: 38 for Drenovets and 30 for Poletkovtsi Reservoir. These data are comparable, though slightly higher, with the ones registered by KOZUHAROV *et al.* (2013): 34 taxa for Drenovets Reservoir and 24 taxa for Poletkovtsi Reservoir. Generally, the mean zooplankton abundance in Poletkovtsi Reservoir was lower compared to the one in Drenovets Reservoir. During our investigation the mean zooplankton densities varied between 77 267 and 365 200 ind. m⁻³ in Drenovets Reservoir, and between 20 400 and 167 040 ind. m⁻³ in Poletkovtsi Reservoir. When compared to the zooplankton densities in other Bulgarian reservoirs, *e.g.* Aleksandar Stambolijski Reservoir (NAIDENOV, BAEV 1987) and Mandra Reservoir (NAIDENOV, unpublished data), the mean values for the zooplankton abundance of the present investigation were higher.

We registered mean zooplankton biomass between 182 and 2351 mg m⁻³ in Drenovets Reservoir and between 68.86 and 1198.96 mg m⁻³ in Poletkovtsi Reservoir. In a study of lowland reservoirs PANDOURSKI (2007) found higher mean zooplankton biomass (160 to more than 4200 g m⁻³). An explanation could be the higher percentage of the

relatively small rotifers in the water bodies we studied. This phylum is known to have high reproductive rates and occasionally to numerically dominate zooplankton communities (WALLACE, SMITH 2009). The mean biomass in Drenovets Reservoir was generally higher or with close values to the ones in Poletkovtsi Reservoir as demonstrated also by the results of KOZUHAROV *et al.* (2013).

We found significant within-reservoir differences between spring and autumn values for both taxon number and rarefied richness. The zooplankton densities and biomass were higher in spring while diversity was higher in autumn. The build-up of herbivorous zooplankters in May is likely a consequence of the rapid growth in early spring and the high availability of algae, *i.e.* food sources for many zooplankton taxa (SOMMER *et al.* 1986, LIKENS 2010, SOMMER *et al.* 2012). The spring peak in zooplankton abundance was followed by a decrease or exhaustion of algae and, therefore, a reduction of zooplankton densities in late summer and early autumn (SCHEFFER *et al.* 1997). Furthermore, fish-induced predation pressure tends to be lower in spring and to gradually increase towards autumn. The latter was demonstrated by our results on the perch foregut content and conforms the plankton ecology group model of seasonal succession (SOMMER *et al.* 1986, SOMMER *et al.* 2012).

Overall, in spring the highest zooplankton densities in both reservoirs were recorded for Cladocera. Cladocerans are mostly herbivorous, supplementing their diet with detritus and bacteria (HAVEL 2009). In autumn the larger crustaceans were replaced by the smaller rotifers which reached highest densities in both Drenovets and Poletkovtsi reservoirs. Smaller taxa are less vulnerable to fish predation and are less affected by potential interference with their food collecting apparatus caused by some inedible algae which are more abundant in autumn (SOMMER *et al.* 1986). Moreover, algal blooms were registered in autumn due mainly to *Ceratium hirundinella* and a few species of Dinophyceae in Drenovets Reservoir and *C. hirundinella*, *Aphanizomenon* sp. and Cyanophyceae in Poletkovtsi Reservoirs. They could be triggered by silica depletion and replacement of diatoms by large Dinophyceae and Cyanophyceae. This might have contributed additionally to the decrease of zooplankton densities and biomass in both reservoirs as the above algae can interfere with the feeding of crustaceans (SOMMER *et al.* 1986, OKOGWU, UGWUMBA 2006).

The seasonal changes in the biomass of zooplankton in Drenovets and Poletkovtsi reservoirs followed similar pattern to the ones described by

NAIDENOV, BAEV (1987) for Aleksandar Stamboljiski Reservoir where the biomass in spring was formed mostly by Cladocera while in autumn the share of the different groups depended on the operational storage volume of the reservoir. We found that Cladocera dominated the biomass in spring, while Copepoda or Rotifera were dominant in autumn. Therefore, there was a reduction in both density and biomass of Cladocera when comparing spring and autumn samples from both reservoirs, concurrent on most occasions with an increase in abundance of rotifers and copepods. A possible explanation of this decrease in cladoceran abundance and biomass is the reduction of resources congruent with the increased competition with larger copepods, as well as the top-down control of fish.

We recorded high temporal and spatial diversity of zooplankton communities in both Drenovets and Poletkovtsi reservoirs. Aeolian processes likely are responsible for the uneven horizontal distribution as a result of zooplankters' low individual weights (LIKENS 2010). Thus, our findings underline the importance of multiple sampling sites and multiple sampling campaigns, in order to unravel in detail the taxonomic structure of zooplankton. Possible criticism of the sampling strategy we adopted would be that our quantitative samples might not be representative of the reservoir pelagial as they were collected through direct filtering of reservoir water from the upper layer and not through sampling numerous zooplankton horizons. As the samples were collected in spring and autumn this should not cause any bias owing to the spring and autumn turnovers that are typical of temperate continental dimictic water bodies. Regardless of the great temporal and spatial diversity of zooplankton, multivariate analyses on zooplankton community revealed that Drenovets Reservoir and Poletkovtsi Reservoir are not only of similar altitude and hydromorphological features, but there are significant similarities in community structure based on both the densities and biomass of zooplankton taxa.

Perca fluviatilis uses diverse food sources. We found in its foregut content 11 zooplankton components, eight fish species and 12 benthic invertebrate taxa. Our previous results on the food composition of *P. fluviatilis* in Drenovets Reservoir demonstrated that there were differences in food intake between different age classes of fish: perch juveniles (0+) were entirely planktivorous, individuals at age from 1+ to 3 - omnivorous, and those over 3 year - mostly predators (TRICHKOVA *et al.* 2005). In spring the perch specimens from Drenovets Reservoir between 70 and 100 mm in length fed exclusively on

zooplankton and insect larvae, while the individuals above 100 mm fed on other fish (cyprinids or perch). In autumn smaller perch specimens (35-60 mm) fed exclusively on zooplankton, while the specimens with length 90- 110 mm fed selectively mostly on smaller cyprinids and zooplankton. The perch within 140-190 length range fed mostly on smaller perch and larger cyprinid specimens, to a smaller extent on zooplankton and rarely on macroinvertebrates belonging to class Insecta (TRICHKOVA *et al.* 2005).

Our analyses of the zooplankton in the foregut content revealed that perch fed selectively on larger lower crustaceans, such as *Daphnia* sp. and Cyclopoida (juvenile and adult forms). *Cyclops* had the highest relative abundance in the foregut content, followed by *D. cucullata* and *Thermocyclops oithonoides*. It appears that perch selected preferably *C. vicinus* between the two cyclopoids, most likely because of its larger size. In Drenovets Reservoir *T. oithonoides* had comparable densities and biomass in spring and autumn water samples. However, in the foregut content we found it with higher relative abundance in autumn, while only single specimens were found in spring. In spring, when *C. vicinus* appeared in comparatively high densities and biomass in the reservoir, it had a high abundance and frequency of occurrence in the foregut content as well. In autumn it was not found in the reservoir, but nevertheless single specimens were detected in the perch food content. It has been recorded that there is a shift in the selective feeding of perch from cyclopoids to cladocerans from spring through autumn (KRATOCHVÍL *et al.* 2008, PETERKA, MATĚNA 2009), which was confirmed also by our results.

Daphnia pulex had the highest percent of dominance in the foregut content, but it was most rarely found in the samples. Regardless of the high number of sampling sites (six) for a reservoir with such a surface area, *D. pulex* was recorded only in the foregut content of a few perch specimens in Drenovets Reservoir and not in the water column. Therefore, perch selected actively the larger *D. pulex* instead of *D. cucullata*, even though the latter ranked second in abundance and biomass in the water samples from Drenovets Reservoir. We recorded the lowest relative abundance and frequency of occurrence in the foregut content for *Bosmina longirostris*. Nevertheless, in the zooplankton of the reservoir this species had the highest abundance and biomass. Most likely because of its small sizes, it was not preferred for food by perch.

These findings are an indication of the selective feeding of perch and potential top-down control (*i.e.* fish predation) as demonstrated by ČERNÝ, BYTEL

(1991), SEDA *et al.* (2000), LAZZARO *et al.* (2003), FRANKIEWICZ, WOJTAL-FRANKIEWICZ (2012). In a long-term study of Rimov Reservoir SEDA, KUBECKA (1997) demonstrated that there was a negative relationship between fish stocks and the biomass of *Daphnia* but no such pattern was observed for cyclopoids. In addition they found a decrease in the relative proportion of *Daphnia* and an increase of *Bosmina* occurrence in spring peaks when fish stocks were high. Similar prey preferences, regardless of the abundance of the zooplankton specimens in the reservoir, was observed by KUBECKA *et al.* (1998) and by PEHLIVANOV (1994). In addition, benthic invertebrate components and fish were registered in the food of perch (TRICHKOVA *et al.* 2005). It has been demonstrated that the share of macroinvertebrates increases as a function of size of perch (HJELM *et al.* 2001).

In Poletkovtsi Reservoir the foreguts of 47% of the perch specimens were empty. Zooplankton was recorded only in three of them, namely the large-bodied *Daphnia* sp. and juvenile and adult stages of *C. vicinus*. In a previous study (TRICHKOVA *et al.* 2005) we found that the perch in Drenovets Reservoir had higher growth rate corresponding to the higher overall density and biomass as compared to Poletkovtsi Reservoir. Moreover, rotifers were not found in the foregut content of perch, although they had high taxa

richness and quantities in the two reservoirs. They are too small, in general, for fish to capture them and in addition many rotifer taxa have morphological or behavioural adaptations against predation (DODDS 2002).

In conclusion, our study presents results on the zooplankton structure and seasonal dynamics of two lowland reservoirs in the Danube River Basin and gives insight into the relationship between zooplankton and European perch. Given that zooplankton plays a major role in standing water bodies, linking the energy transfer between primary producers and secondary consumers, our findings may serve as a basis for future research on the within-reservoir trophic relationships and can contribute to the effective and sustainable management of aquaculture in Bulgarian reservoirs.

Acknowledgements: The study was funded by the National Science Fund, Projects B-1108/01 and DO 02-283/2008. The authors are grateful to the National Agency of Fishery and Aquaculture – Vidin District and Mr Milen Metodiev for the assistance during field work. The authors are also grateful to “Irrigational Systems” EAD – Vidin and “Beluga Akvafarm” AD – Vidin for providing data on morphological and hydrological characteristics of Drenovets and Poletkovtsi reservoirs (NW Bulgaria). The authors thank Eng. Ivan Botev for preparation of the schemes of the reservoirs.

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Received: 02.05.2014
Accepted: 08.09.2014