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Long-term Changes in Zooplankton Community in Zhrebchevo Reservoir, Central Bulgaria

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Abstract: The present paper describes the long-term changes in the zooplankton community in Zhrebchevo Reservoir, Central Bulgaria. Zooplankton data from 2009-2011 were compared with those from 1977-1980. Overall 104 zooplankton taxa were recorded; only 30 of them were common for both investigation periods (29% of similarity). The similarity of the dominant species was 26.6%. In 2009-2011, the dominant species were *Daphnia pulicaria* Forbes, 1893, *Bosmina longirostris* (Müller, 1785), *Diaphanosoma lacustris* Korinek, 1981, *Eudiaptomus gracilis* (Sars, 1863) as well as copepodites and nauplii; rotifers were almost absent. In contrast, in 1977-1980, the rotifers *Keratella cochlearis* Gosse, 1851, *Asplanchna* sp., *Kellicottia longispina* (Kellicott, 1879) dominated the plankton community. The reason for the shift in the zooplankton community was most likely the invasive mussel *Dreissena polymorpha* (Pallas, 1771), a competitor for the filter feeders and a potential predator on the small zooplankters, such as rotifers.

Key words: zooplankton, veliger larvae, reservoir, eutrophication, ecotone zone

Introduction

Changes in the zooplankton community of reservoirs are caused by interactions between physical and biological processes, i.e. water movements and the input of organic matter by the inflowing river (Kozuharov 1995, Kozuharov *et al*. 2007). The community is also sensitive to anthropogenic impacts (Naidenow 1981b). During the periods of high flushing of the reservoir, the structure of the plankton can be influenced through loss of organisms as a consequence of their vertical distribution in the water column, swimming capacity and reproductive rates. The interference could be indirect, mediated by physical changes of the environment (Naidenow 1981a). Species richness of plankton in reservoirs is related to its trophic state (Gannon, Stemberger 1978) and biotic interactions. Furthermore, the zooplankton plays an important role within the trophic web of water ecosystems. Bacterioplankton and phytoplankton abundance are influenced by Cladocera and Rotifera predation (Jeppesen *et al.* 2000). Moreover, zooplankton organisms are food source for juvenile fish and planktivorous fish (Pehlivanov *et al.* 2006, Evtimova *et al.* 2015). The changes of zooplankton structure in Zhrebchevo Reservoir as a result of pollution and hydro-technical constructions were described by Naidenow (1981a). Thirty years later, Zhrebchevo Reservoir was invaded by the zebra mussel *Dreissena polymorpha* (Pallas, 1771). Kalchev *et al*. (2013) detected that the zebra mussel affected significantly the transparency, pH and concentrations of dissolved oxygen, NH_4-N, NO_2-N and NO_3-N. Moreover, the community structure of zooplankton was influenced by direct and indirect competitive interactions triggered by this invasive species (Stanachkova *et al.* 2010).

The aim of the present study is to analyse the structure of the zooplankton community of Zhrebchevo Reservoir in 2009-2011and to compare it with data from the same water body obtained in 1977-1980 (Naidenow 1981a).

Materials and Methods

*Sampling*The study was carried out in Zhrebchevo Reservoir at four sampling sites (Fig. 1, Table 1). Sampling was performed in different seasons (February, May, June, July and October) of 2009-2011. The samples were collected by using plankton net with mesh size of 55 micrometres (Wallace *et al.* 2006), taking vertical hauls of 5 m in areas of a depth between 5 and 41 m. Samples were preserved in 4% formaldehyde solution. The biomass calculation were done using the individual standard weights according to Zhadin (1949), Chislenko (1968), Korinek (1987), Prikril (1980), Kozuharov (2006) and Michaloudi (2005).

Statistical Analysis

Long-term changes of species similarity according to Jaccard (1901) were assessed using cluster analysis. The calculation was made with statistical package PAST version 2.17C (Hammer *et al.* 2001). The comparison of the dominant complexes of the two study periods was done by applying dominant analysis after De Vries (1937). In addition, the correlation between the total abundance of species and their biomass was done using the web-based software LIMNOS (www.limnoecology.com) to estimate which species contributed most for the community biomass. The vertical distribution of zooplankton was visualised using the statistic package Sigmaplot 11.0. The software environment R 2.5.1 (R Development Core Team 2007) was used to assess possible biotic interaction between the invasive *Dreissena* mussels and the zooplankton. To analyse the impact of *D. polymorpha*, Pearson's correlation coefficients were calculated.

Species Diversity

To estimate the changes in biodiversity, the Shannon-Weaver (1963) index, dominance index after Simpson (1949) and evenness index according to Pielou (1975) were applied.

Results and Discussion

Species Composition

The metazoan plankton community consisted mainly of eurybiont species with high tolerance to environmental factors. This lead to intense competitive interactions in the community (Protasov 2002). During the period 2009-2011, 71 taxa were found, compared to 64 taxa in the period 1977-1980 (Table 2). In addition molluscan veligers were found in the plankton during all seasons, including in winter

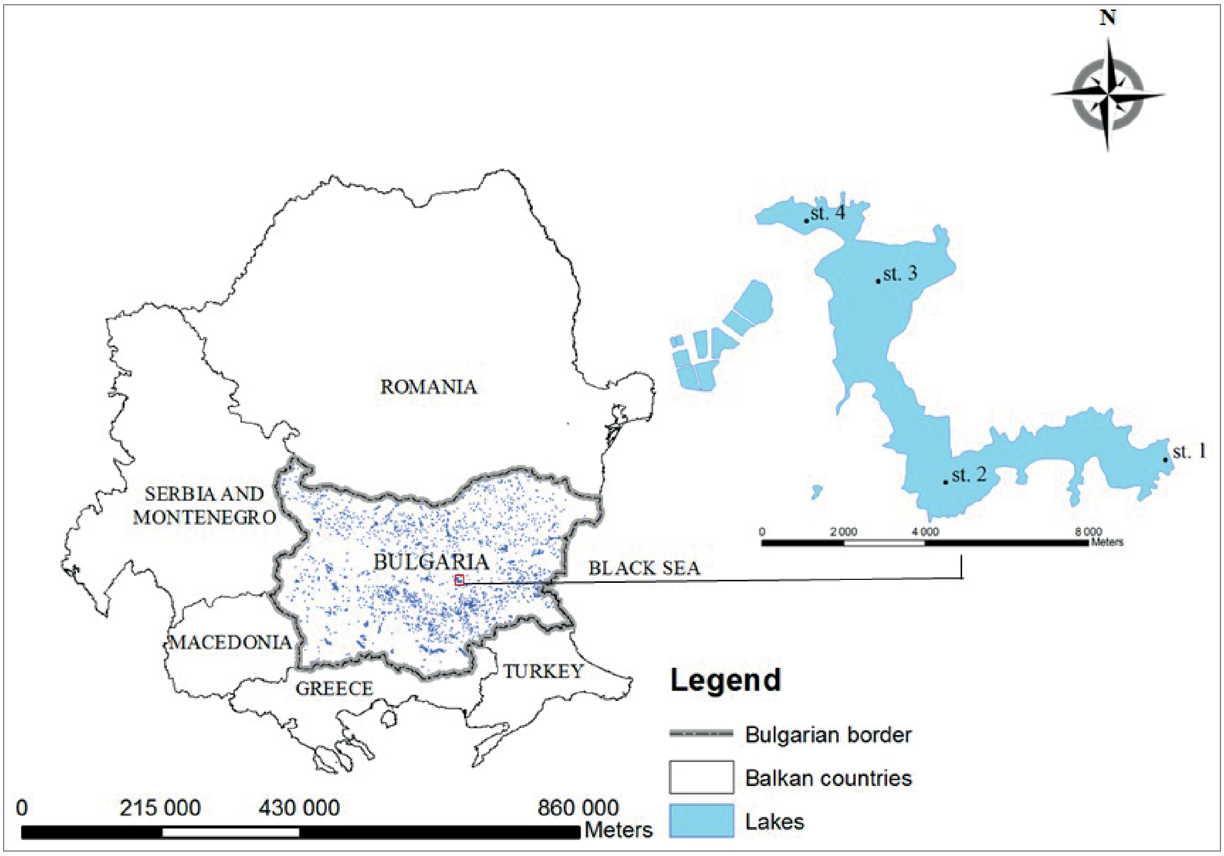

Fig. 1. Location of Zhrebchevo reservoir and sampling sites

Table 1. Geographic coordinates of the sampling sites and its measured depth in meters

Geographic coordinates – datum WGS 84		Sampling period	2009	2010	2010	2011	2011
North	East	Sampling site	August	May	October	February	June
42°53'25.4"	25°56'58.6"	1	37.5	41.2	38.0	38.6	39.0
42°35'11.7"	25°53'04.0"	2	25.0	32.4	27.0	26.5	22.0
42°37'37.4"	25°51'30.7"	3	11.0	18.0	16.8	15.2	16.0
42°38'30.9"	25°57'04.0"	4	5.3	14.5	5.0	6.4	0.5

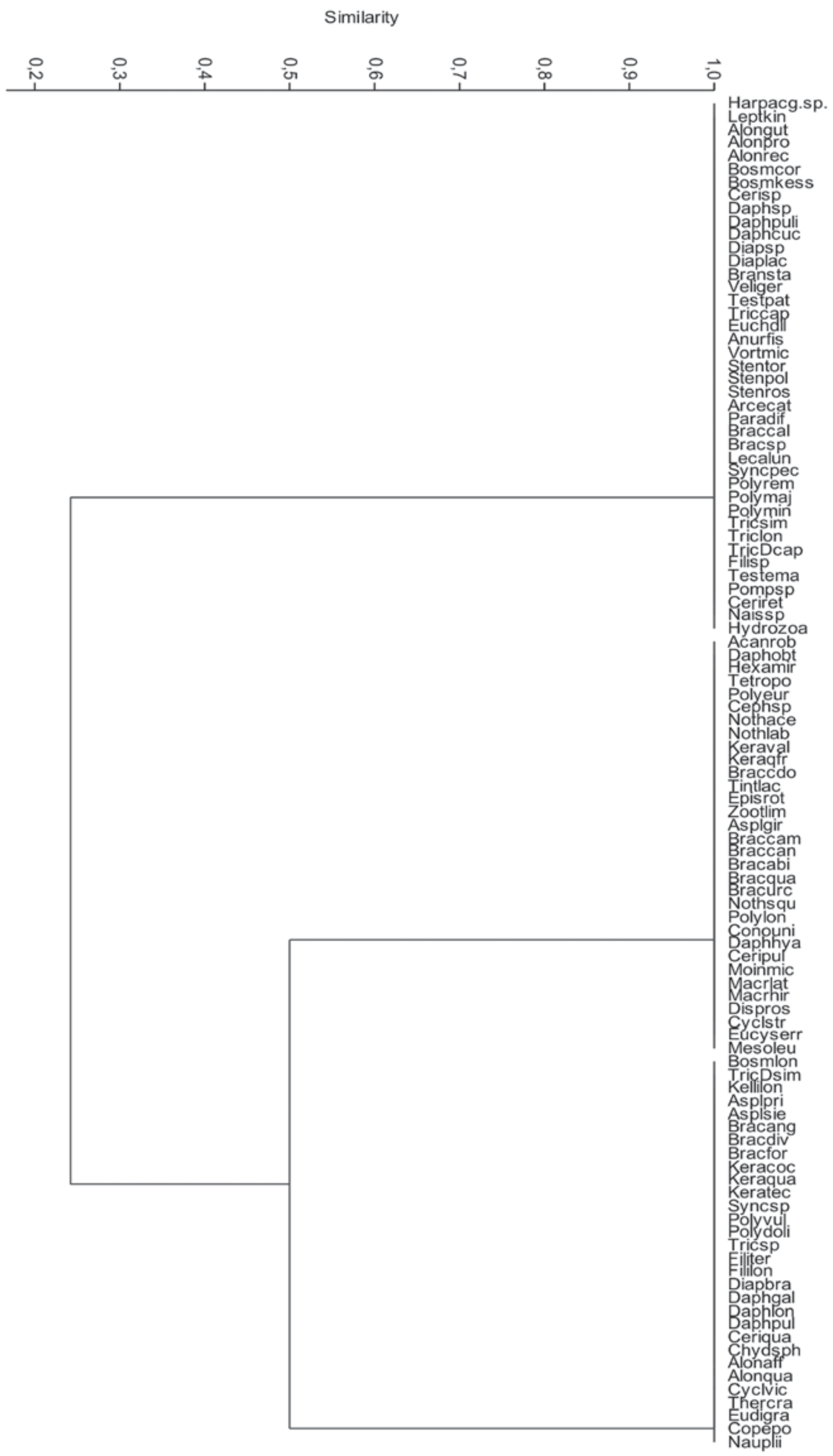

Fig. 2. Cluster analysis of the species similarity of the zooplankton within the two periods. For taxa code see Table 2

Table 2 List of the taxa found within both studied periods

code	Year	1977 1980	2009	2010	2010	2011	2011
	Month	all	July	May	October	February	June
	Taxa						
Arcecat	*Arcella catinus* Stepanek, 1942		+		+		
Tintlac	*Tintinnopsis lacustris* (Entz, 1901)	+					
Episrot	*Epistylis rotans* Svec, 1897	+					
Zootlim	*Zoothamnium limneticum* Svec, 1897	+					
Stenros	*Stentor roeseli* (Ehrenberg, 1834)		+				
Stenpol	*S. polymorphus* O. F. Müller, 1786		+				
Stentor	*Stentor* sp.		+				
Vortmic	*Vorticella microstoma* Ehrenberg, 1835		+				
Paradif	*Paradifflugia* sp.				+		
	Rotifera						
Asplpri	*Asplanchna priodonta* Gosse, 1851	+	+	+	+		+
Asplsie	*A. sieboldi* Leydig, 1854	+	+	+	+	+	+
Asplgir	*A. girodi* Guerne, 1888	+					
Anurfis	*Anuraeopsis fissa* Gosse, 1851				+		
Bracqua	*Brachionus quadridentatus* Herrman, 1783	+					
Braccal	*B. calyciflorus* Pallas, 1766			+		+	
Braccam	*B. c. amphiceros* Pallas, 1766	+					
Braccan	*B. c. anuraeiformis* Brehm, 1909	+					
Braccdo	*B. c. dorcas* Gosse, 1851	+					
Bracang	*B. angularis* Gosse, 1851	+		+	+		
Bracabi	*B. a. bidens* Plate, 1886	+					
Bracdiv	*B. diversicornis* Daday, 1883	+	+				
Bracfor	*B. forficula* Wierzejeski, 1891	+		+			
Bracurc	*B. urceolaris* (Linnaeus, 1758)	+					
Bracsp	*Brachionus* sp.				+		
Keracoc	*Keratella cochlearis* Gosse, 1851	+		+	+	+	+
Keraval	*K. valga* (Ehrenberg, 1834)	+					
Keraqua	*K. quadrata* Carlin, 1943	+	+	+	+	+	+
Keraqfr	*K. q. frenzeli* (Ekstein, 1895)	+					
Keratec	*K. tecta* Gosse, 1851	+	+		+		
Kellilon	*Kellicottia longispina* (Kellicott, 1879)	+	+	+	+	+	+
Nothlab	*Notholca labis* Gosse, 1887	+					
Nothsqu	*N. squamula* O. F. Müller, 1786	+					
Nothace	*N. a. extensa* Oloffson, 1918	+					
Cephsp	*Cephalodella* sp.	+					
Euchdil	*Euchlanis dilatata* Ehrenberg, 1832				+		+
Lecalun	*Lecane luna* (Müller, 1776)	+					
Syncpec	*Synchaeta pectinata* Ehrenberg, 1832				+		
Syncsp	*Synchaeta* sp.	+	+	+	+	+	+
Polyvul	*Polyarthra vulgaris* Carlin, 1943	+		+	+		
Polydoli	*P. dolichoptera* Idelson, 1925	+	+	+	+		+
Polyeur	*P. euryptera* Wierz., 1891	+					
Polylon	*P. longiremis* Carlin, 1943	+					
Polyrem	*P. remata* Skorikov, 1896			+	+		+
Polymaj	*P. major* Burckhard, 1900			+	+		
Polymin	*P. minor* Voigt, 1904		+	+	+		

Table 2 Continued

code	**Year**	**1977 1980**	**2009**	**2010**	**2010**	**2011**	**2011**
	Month	all	July	May	October	February	June
	Taxa						
Tetropo	*Tetramastix opolensis* Zacharias, 1898	+					
Tricsim	*Trichocerca* (s. str.) *similis* (Wierz., 1893)				+		
Triclon	*T.* (s. str.) *longiseta* (Schrank, 1802)				+		
Triccap	*T.* (s. str.) *capucina* (Wierz. et Zach., 1893)				+		
Tricsp	*Trichocerca* (s. str.) sp.				+		
TricDsim	*Trichocerca (D.) similis* (Wierz., 1893)				+		+
TricDsp	*Trichocerca (D.)* sp.				+		
Conouni	*Conochilus unicornis* Rousslet, 1892	+					
Fililon	*Filinia longseta* (Ehrenberg, 1834)	+	+			+	
Filiter	*F. terminalis* Plate, 1886	+					+
Filisp	*Filinia* sp.			+	+		
Hexamir	*Hexarthra mira* (Hudson, 1871)	+					
Testpat	*Testudinella patina* (Herrman, 1783)				+		
Testema	*T. emarginula* (Stenroos, 1898)				+		
Pompsp	*Pompholix* sp.				+		
	Mollusca						
Veliger	Veliger larvae		+	+	+	+	+
	Crustacea						
	Anostraca						
Bransta	*Branchipus stagnalis*			+			
	Cladocera						
Diapbra	*Diaphanosoma brachyurum* (Lievin, 1848)	+	+		+		
Diaplac	*D. lacustris* Korinek, 1981		+	+	+		+
Daphgal	*Daphnia galeata* Sars, 1864	+	+	+		+	+
Daphcuc	*D. cucullata* Sars, 1864		+	+	+		+
Daphlon	*D. longispina typica* Müller, 1785	+		+	+	+	+
Daphhya	*D. hyalina* Leydig, 1860	+					
Daphpul	*D. pulex* (Leydig, 1860)	+	+	+	+		
Daphpuli	*D. pulicaria* Forbes, 1893		+	+		+	
Daphobt	*D. obtusa* Kurz, 1874	+					
Daphsp	*Daphnia* sp.			+			
	Daphnia sp. juv		+	+			
Ceriret	*Ceriodaphnia reticulata* (Jurine, 1820)	+					
Ceriqua	*C. quadrangula* (Müller, 1785)	+			+		
Ceripul	*C. pulchella* Sars, 1862	+					
Cerisp	*Ceriodaphnia* sp.			+			
Moinmic	*Moina micrura* Kurz, 1874	+					
Macrlat	*Macrothrix laticornis* Jurine, (1820)	+					
Macrhir	*M. hirsuticornis* Norman et Brady, 1867	+					
Bosmlon	*Bosmina longirostris* (Müller, 1785)		+	+	+	+	+
Bosmkes	*B. kessleri* Uljanin, 1872		+	+	+	+	
Boscor	*B. coregoni* Baird, 1857		+	+	+	+	+
	Bosmina sp.juv.			+			
Chydsph	*Chydorus sphaericus* (Müller, 1785)			+	+		+
Alonrec	*Alona rectangula* Sars, 1862		+		+		
Alonaff	*A. affinis* Leidig, 1860	+			+		+

Table 2 Continued

code	**Year**	**1977 1980**	**2009**	**2010**	**2010**	**2011**	**2011**
	Month	all	July	May	October	February	June
	Taxa						
Alonqua	*A. quadrangularis* (O.F.Müller, 1785)	+		+			
Alonpro	*A. protzi* Hartwig, 1900					+	
Alongut	*A. guttata* Sars, 1862					+	
Dispros	*Disparalona rostrata* (Koch, 1841)	+					
Leptkin	*Leptodora kindti* (Focke, 1844)		+	+	+		+
	Copepoda						
Cyclvic	*Cyclops vicinus* Uljanin, 1875	+	+	+		+	+
Cyclstr	*Cyclops strenuus* Fisher,1851	+					
Acanrob	*Acanthocyclops robustus* (Sars, 1863)	+					
Eucyserr	*Eucyclops serrulatus* (Fisher,1851)	+					
Mesoleu	*Mesocyclops leuckarti* Claus, 1857	+					
Thercra	*Thermocyclops crassus* Ficher, 1853	+	+	+	+		+
Eudigra	*Eudiaptomus gracilis* (Sars,1863)	+	+	+	+	+	+
Copepo	Copepodites	+	+	+	+	+	+
Nauplii	Nauplii	+	+	+	+	+	+
	Varia						
Naissp	*Nais* sp.			+			
Hydrozoa	Hydrozoa						+

at a temperature of 3.5°C (Stanachkova *et al.* in press).

Cluster analysis (Fig. 2) described the similarity in the species composition between the two studied periods. The analysis included a total of 103 taxa. The juvenile forms of *Daphnia* spp. and *Bosmina* spp. were excluded from the analysis. As already noted, 71 species were detected and 41 of them were new for the period 2009-2011 (upper group of species in Fig. 2), while out of the 64 taxa found in the period 1977-1980, 32 taxa were not found in the more recent period. Thirty taxa were common for the two periods (the second group of species clustered in Fig. 2). The low similarity of 29 % was an indication of a great change in the zooplankton community over the last thirty years.

The taxonomic structure revealed a reduction of rotifer species. According to Stanachkova *et al.* (2010), the presence of *D. polymorpha* was one of the most probable reasons for the decrease in microzooplankton. *Dreissena* had a direct influence on the rotifer community and an indirect effect on larger zooplankton species. As active filter feeders, mussels may suppress the zooplankton by competing for food resources (Thorp, Casper 2002, Wong *et al.* 2003, Wong, Levinton 2006, Kissman *et al.* 2010). These results corroborate the work of Kalchev *et al.* (2013), who investigated the influence of zebra mussel, *D. polymorpha*, on physical and chemical characteristics of Zhrebchevo Reservoir comparing the periods before (1977-1980) and after (2009-2011) its invasion. They concluded that in the epilimnion of sampling site №1 (in proximity to the dam), in the period after the invasion, the pH was significantly higher; while the concentrations of NH_4-N and NO_2-N were significantly lower than before the invasion. In the hypolimnion of the same site, the concentration of dissolved oxygen and NO_3-N was significantly higher after than before the invasion. For the same period, Kozuharov *et al.* (2013) compared the three main groups of zooplankters of Zhrebchevo Reservoir to other zooplankton communities and assessed the trophic conditions by applying the newly established RCC index. It was confirmed that the increase in water transparency was the result of the filtering activity of the zebra mussels. As a consequence, a larger photic zone was established. On the other hand, the rotifers were negatively influenced by *D. polymorpha*. The presence of new protozoan species and high quantities and biomass of bacterioplankton (Kalcheva 2011) indicated an advanced eutrophication processes in the reservoir. Actually, the trophic state of the reservoir was determined as mesotrophic (Kenderov *et al.* 2014). Significant differences were observed in the rotifer community, e.g. nine species of the genus *Brachionus* occurred between 1977-1980, and 30 years later only four species were detected (Table 2).

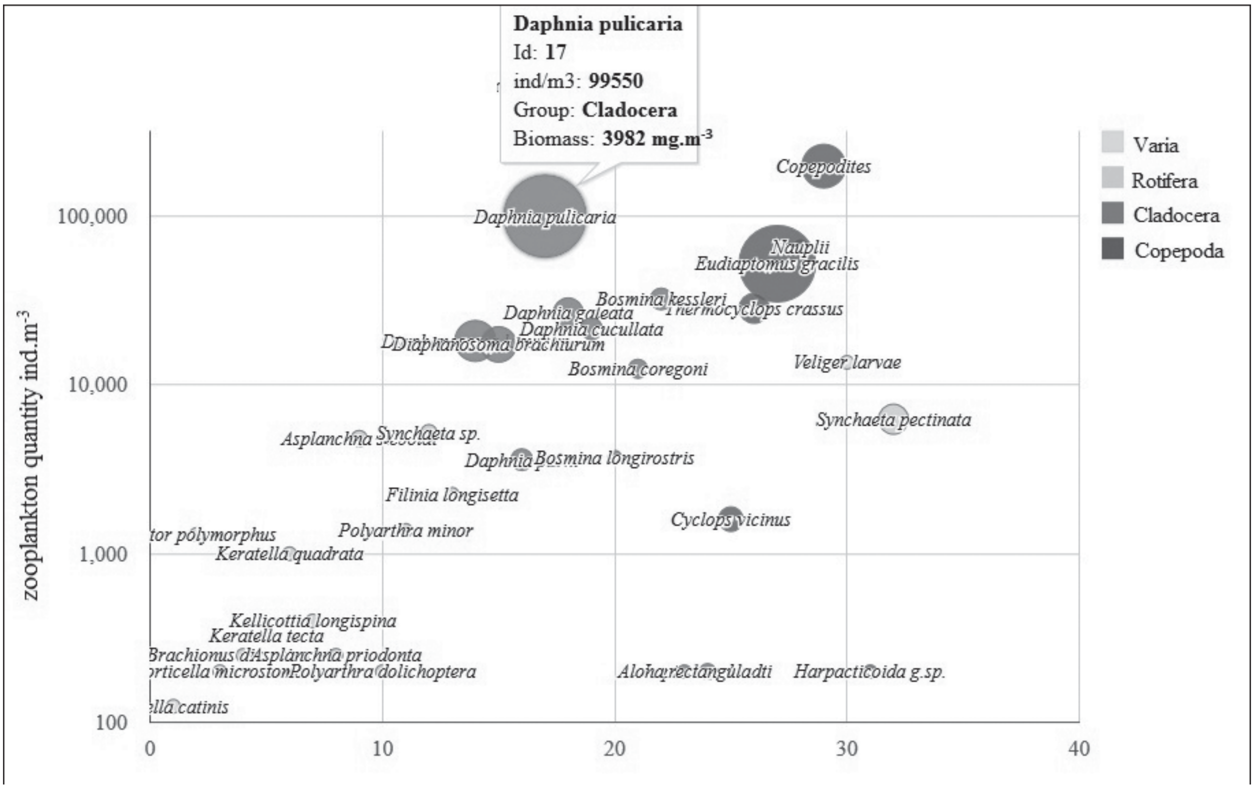

Fig. 3. Correlation between total number of species and their biomass within July 2009

Six taxa of the genus *Trichocerca* were new for the period 2009-2011 (Table 2). The calculation of the species ratio *Brachionus* : *Trichocerca* (Slàdeček 1983) revealed QB/T=0.8 for the period 2009-2011, which indicated mesosaprobity for Zhrebchevo Reservoir. Naidenow (1981a) obtained similar results: he calculated the saprobity status of the reservoir as ß-mesosaprobity. The new occurrence of the thermophile species *Leptodora kindti* (Focke, 1844) and *Thermocyclops crassus* Fischer, 1853 was an indication of community changes owing to climate warming. Moreover, the presence of veliger larvae in February 2011 (Table 1) could also be the result of climate change. Naidenow (1981a) reported only *Bosmina longirostris* while, in 2009-2011, *Bosmina coregoni* Baird, 1857 and *Bosmina kessleri* Uljanin, 1872 were found in addition.

*Dominant Species*A comparison of the two investigation periods with respect to the dominant species revealed a similarity of only 26.6%. In 2009-2011, *D. pulicaria*, *B. longirostris*, *D. lacustris*, *E. gracilis*, copepodites and nauplii dominated; rotifer species were almost absent. In contrast, in 1977 – 1980, rotifers *Keratella cochlearis, Asplanchna* sp., *Kellicottia longispina* dominated the zooplankton community. The prevailing cladocerans in Zhrebchevo Reservoir reflected changes in the environmental conditions. As filter feeders, they depend on the size structure of the food source and might be sensitive indicators (Brooks, Dodson 1965). There is evidence that the relative abundance of the filter-feeding types varies with the trophic state of the water body (Geller, Müller 1981). The structure of the filtering apparatus is well-known and species can be grouped according to their mesh-sizes. The "fine-mesh filter feeders" *Diaphanosoma brachyurum*, *Ceriodaphnia quadrangula* and *Chydorus sphaericus* prevailed in the cladoceran community 30 years ago. *Daphnia pulicaria* and *B. coregoni*, classified as "medium-mesh filter feeders", dominated in the summer of 2009 (DF= 26.67% DT= 28.57%) and in the spring of 2010 (DF= 5%; DT= 5.26%), respectively. The change of the dominant species corresponded to the altered size structure of the food source. *B. longirostris*, *E. gracilis*, copepodites and nauplii were common for the two studied periods.

Quantitative Parameters

Zooplankton abundance and biomass were analysed seasonally. The highest zooplankton abundance (54282 ind.m^{-3}) and maximum biomass (1254 mg.m^{-3}) occurred in May 2010. The correlation analysis between the total number and the biomass of the various species revealed that *D. pulicaria*, *D. longispina typica* and *E. gracilis* were responsible for the zooplankton biomass at that time (Fig. 4).

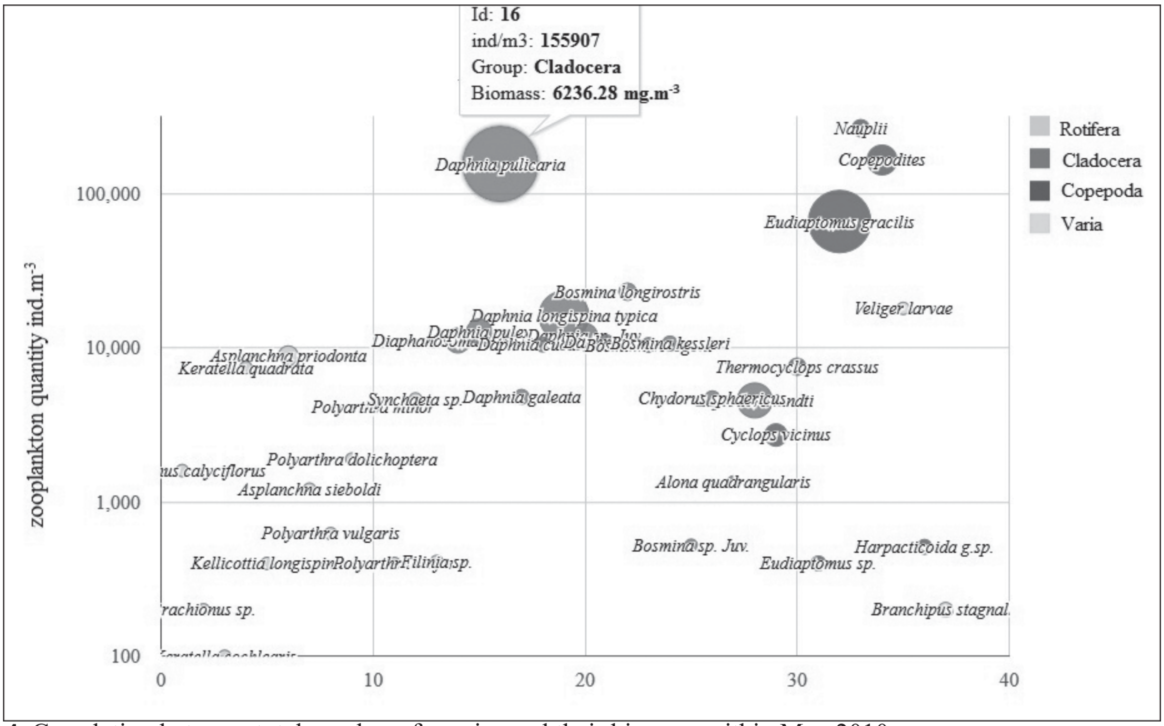

Fig. 4. Correlation between total number of species and their biomass within May 2010

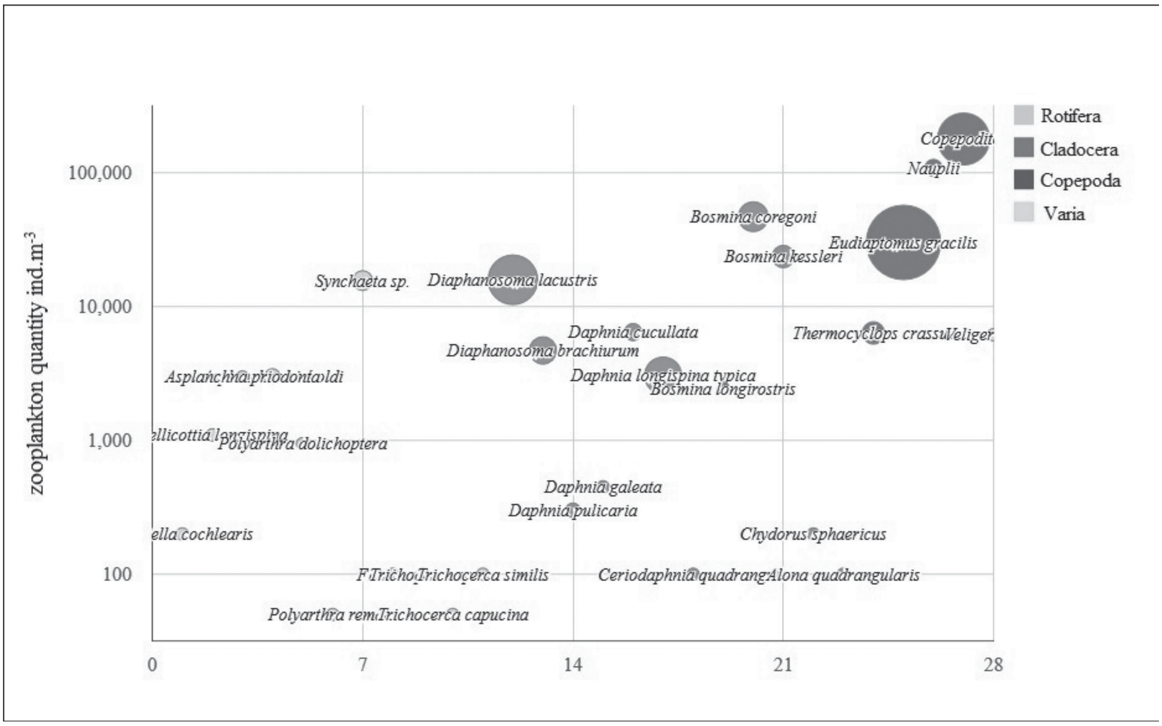

Fig. 5. Correlation between total number of species and their biomass within October 2010

During 1977-1980, the biomass varied between 427 and 1119 mg.m^{-3} while in the period 2009-2011 the average value ranged from 241 to 1254 mg.m^{-3}. The variability of the zooplankton biomass was higher than in the first years after filling the reservoir. According to NAIDENOW (1984), the maximum zooplankton density in Zhrebchevo Reservoir was found in summer however, in 2009-2011 we recorded the peak abundance and biomass earlier. This might be related to the presence of zebra mussel. Zooplankton quantities decreased in summer (Fig. 3) when the higher temperatures lead to an increase in the mussel's filtration activity. As active filter feeders mussels may suppress the zooplankton by reducing the

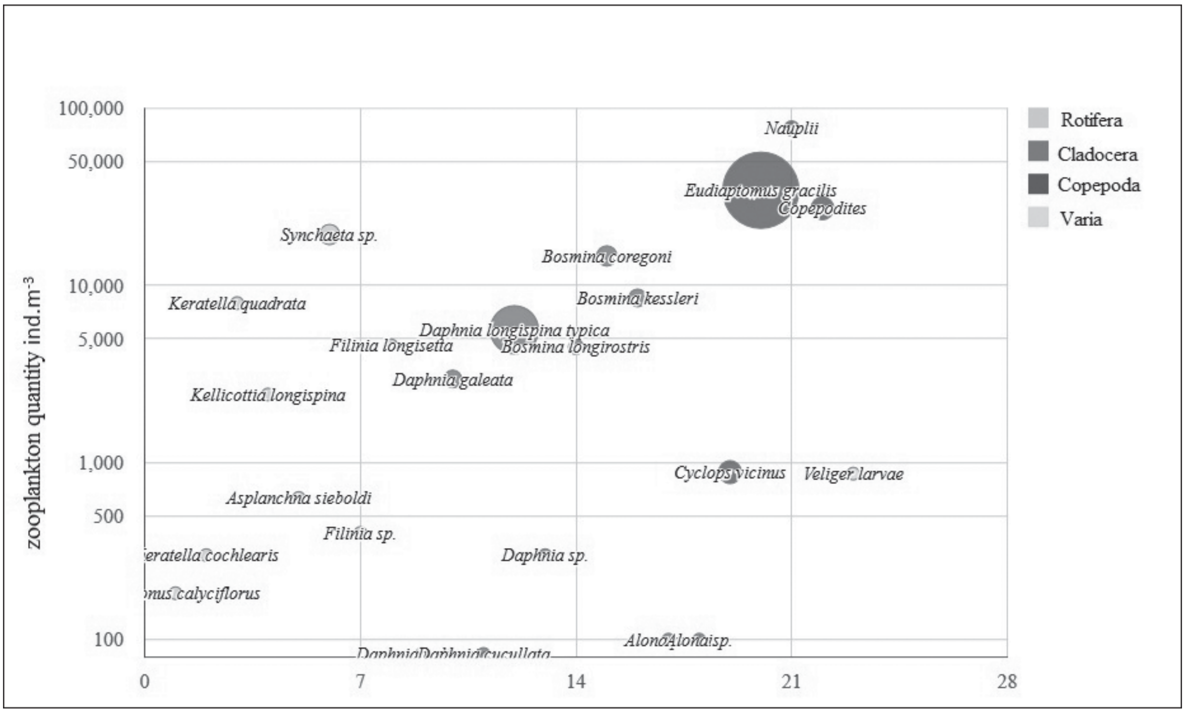

Fig. 6. Correlation between total number of species and their biomass within February 2011

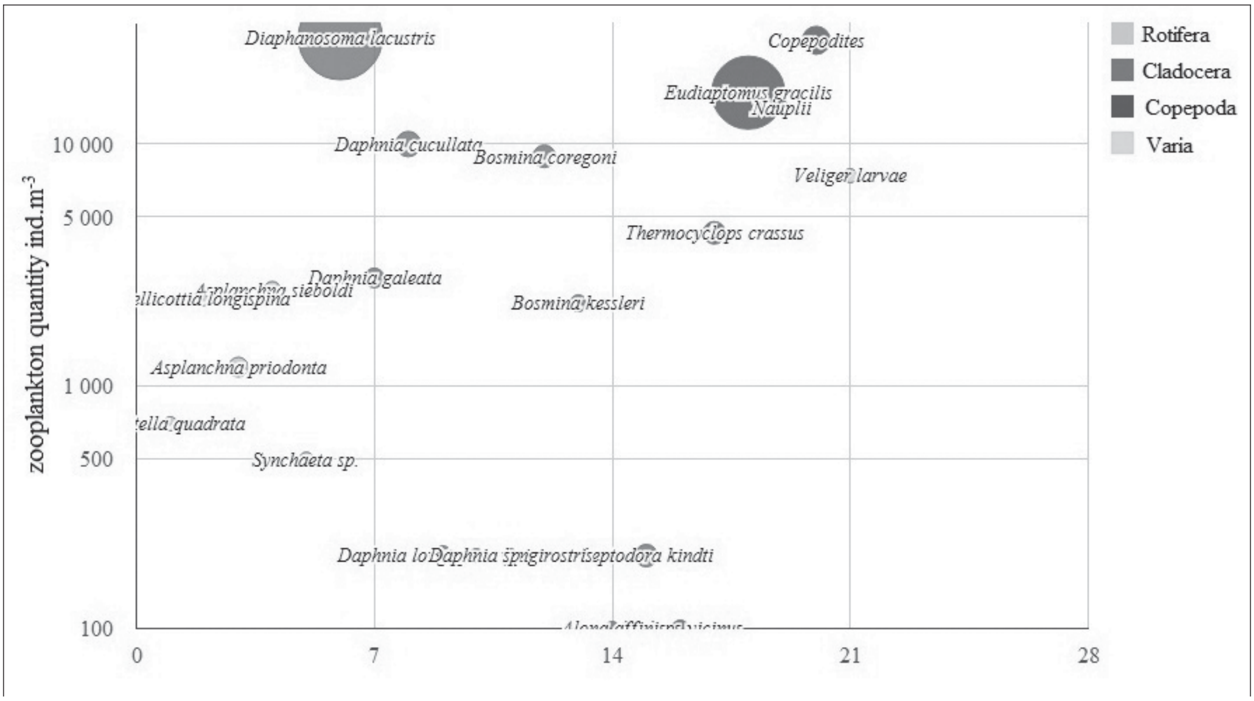

Fig. 7. Correlation between total number of species and their biomass within June 2011

food resources. Evidence for that change can be seen in the low zooplankton quantities after the invasion by the zebra mussel (Stanachkova *et al*. 2010). A correlation analysis showed a high negative correlation between the numbers and biomass of *D. polymorpha* and the zooplankton (Fig. 8). In May 2010, the correlation coefficient (r^2) reflecting the relationship between the biomass of the invasive mussels and zooplankton was -0.93 between the numbers of *D. polymorpha* and zooplankters, and r^2 = -0.84. In October 2010, the correlation was lower but still significant, with values -0.83 and -0.50, respectively. The invasive mussel seemed to be the most important element within this food web. Predation pressure by planktivorous fish had a significant negative impact on zooplankton community too. According to Kenderov *et al.* (2014), dominant fish species in Zhrebchevo Reservoir were the juvenile planktivorous *Rutilus rutilus* (Linnaeus, 1758) and *Vimba melanops* (Heckel, 1837).

In October 2010, zooplankton quantities dropped to 41 561 ind.m^{-3} and 325 mg.m^{-3}. The biomass of *E. gracilis* contributed mostly to the zooplankton biomass (Fig. 5). The pronounced decrease in mean abundance (13 222 ind.m^{-3}) and biomass (242 mg.m^{-3}) in February 2011 was due to the low temperature (3.4˚C to 4.8˚ C).

In June 2011 the biomass of zooplankton was higher than its abundance. *Diaphanosoma lacustris* was responsible to the peak of biomass at the season, with the total number reaching 59 800 ind.m^{-3} (Fig. 7).

```
> cor(Mdata July09)
               zp.ind.m.3  zp.mg.m.3
D.spp..ind.m.2 -0.18924132 -0.2458055
D.spp..gr.m.2  -0.08770814 -0.1452663

> cor(Mdata May10)
               zp.ind.m.3  zp.mg.m.3
D.spp..ind.m.2 -0.9321159 -0.9997501
D.spp..gr.m.2  -0.6002787 -0.8371645

> cor(Mdata Oct10)
               zp.ind.m.3  zp.mg.m.3
D.spp..ind.m.2 -0.8298586 -0.4313598
D.spp..gr.m.2  -0.8341692 -0.4969438
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Fig. 8. Pearson's correlation coefficients (r2) between the number and biomass of *Dreissena mussels* and the zooplankton within July 2009, May 2010 and October 2010

Horizontal Distribution

The abundance of the major zooplankton groups showed some differences along the four sampling points. The relative contribution of the rotifers to the density and biomass was low, but they were presented in the ecotone zones. Within this region the percentage proportions of the main taxonomic groups, Cladocera and Copepoda, were highly variable, most likely the result of the water level fluctuations.

Vertical Distribution

Sampling point №1 was the deepest and most stratified compared to the other sampling sites. According to Kalchev *et al.* (2013) the thermal stratification was quite stable during both investigation periods. In the present study the zooplankton concentrated in the hypo limnetic zone. Our study confirmed an uneven distribution of the zooplankton already reported by Naidenow (1981a). It is well known that the shorter hydraulic residence time affects the plankton communities. An abrupt drop in zooplankton abundance at the deepest station was recorded between 10m and 5m, a result of the direct drift of plankton out of the system at the intake tower (Fig. 9).

The results of this study confirmed that for larger and deep reservoirs the determination of the trophic state based on zooplankton have to include data over the entire water column and not only from the surface layer. Comparative analyses found a correlation between zooplankton and dissolved oxygen values measured in deeper water (Kalchev *et al.* 2013). The decline of the zooplankton corre-

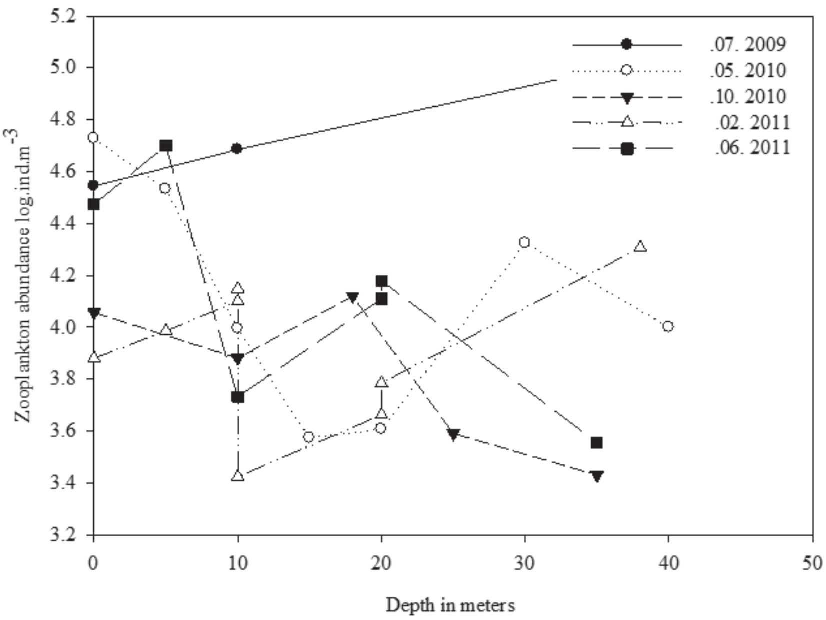

Fig. 9. Vertical distribution of zooplankton at sampling site 1

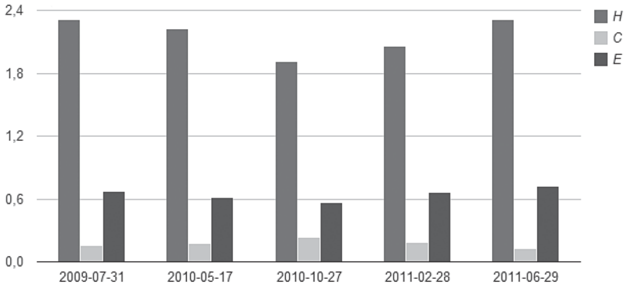

Fig. 10. Seasonal average values of species diversity index (H), dominance index (C) and evenness index (E) of the zooplankton community in Zhrebchevo reservoir for the 2009-2011 period

sponded to the oxygen reduction in the water column. The observed vertical variation in relation to oxygen was in accordance with the conclusions of Ravera (1996). Such a relationship was documented for other Bulgarian reservoirs too (Naidenow 1977, Kozuharov 1996, Kozuharov *et al.* 2007, Traykov *et al*. 2011).

*Species Diversity*The highest value of H was calculated for summer 2009 and 2011 (H=2.31; Fig. 10). Biotic interactions between *D. polymorpha* and zooplankton regulated community structure in May 2010 – Shannon, Weaver index (H) was 2.22. In October 2010, both low water level in the reservoir and strong competitive relations between species and predation pressure determined the lowest mean value of H – 1.91. In spite of the low water temperatures the value of species diversity index in the end of February 2011 increased to 2.06 (Fig. 10). This was probably the result of a weak fish predation in that period of the year. The zebra mussel invasion determined the structure of zooplankton community in the reservoir. Our result showed that there were significant variation of H values at the sites with higher mussel numbers. The same situation was observed at site 1 where both biotic and abiotic factors impacted on the zooplankton structure. Large variation of the Shannon-Weaver index was detected in the ecotone zone, river inflow and reservoir and at the sampling site near to the dam (Ward, Tockner 2001), while in the pelagic zone, typical for zooplankters, the H index was more or less similar.

Conclusions

During the recent investigation in 2009-2011, the annual, seasonal and spatial density and biomass of zooplankton were higher than in the period 1977-1980.

The dominant components were influenced by high water level fluctuations, which also determined the number of dominant species for different seasons. During the second period of investigation more significant changes in the temporal and spatial distribution and structure of the zooplankton became obvious. Zooplankton community structure has an important functional role within the trophic web of Zhrebchevo Reservoir. The results of the present study revealed changes in its size structure which may reflect the development of juvenile fish and the resulting predation pressure. The mainly hypolimnetic distribution of the zooplankton at the region close to the dam in the reservoir was due to intensive drift of the zooplankton through the water intake. The present data confirmed that the determination of the trophic state based on zooplankton needed to include data over the entire water column.

According to Kozuharov *et al.* (2007), increasing eutrophication in the ecotone zone of river-reservoir could be expected. However, in this case, the situation was influenced by the mussel invasion. It is known that for three to five years after mussel invasion, the eutrophication process might be delayed but after that eutrophication accelerates and the effect might be stronger than before the invasion Kozuharov *et al.* 2013. The species diversity of the zooplankton in Zhrebchevo Reservoir could be related to the strong competition between species and to fish predation pressure. The latter makes a future study on the relationship between the zooplankton and the fish populations important.

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