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Comparative Analysis of Zooplankton Composition in Reservoirs of North-West Bulgaria: Relation to Water Physicochemical Parameters and *Dreissena* Infestation

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Abstract: Fifteen reservoirs in North-West Bulgaria, in the Danube River basin, were monitored to make a comparison of the zooplankton qualitative and quantitative composition and community structure in relation to water physicochemical parameters and *Dreissena* infestation. A total of 95 zooplankton taxa were recorded. They were represented mostly by Rotifera, followed by Cladocera and Copepoda, as well as Copepodites, Nauplii of Copepoda and *Dreissena* veliger larvae. Most of the recorded zooplankton taxa are typical for the mesotrophic and eutrophic water bodies in Bulgaria. The highest zooplankton abundance and biomass were recorded in the reservoirs Poletkovtsi, Christo Smirnenski, Kula, Ogosta and Drenovets. The infested reservoirs were characterized with high zooplankton taxa richness, unstable dominant complexes, and low quantitative parameters (Rabisha), or seasonal fluctuations in abundance and biomass due to the share of *Dreissena* veliger larvae (Ogosta). Regular zooplankton monitoring in infested and non-infested reservoirs is required in order to further study the potential negative effects of *Dreissena*.

Key words: Rotifera, Cladocera, Copepoda, *Dreissena* veliger larvae, abundance, biomass, eutrophication, reservoirs, Danube River basin

Introduction

The mussels from genus *Dreissena* – zebra mussel*, D. polymorpha* (Pallas, 1771) and quagga mussel, *D. bugensis* (Andrusov, 1897), are known as successful aquatic invaders with a great potential to adversely impact the infested ecosystems (Ludyanskiy *et al*. 2993, Therriault, Orlova 2010). *Dreissena* impact can have significant negative consequences for zooplankton communities (Kelly *et al*. 2010). First, mussel feeding can negatively affect zooplankton through direct predation on the small and weak-swimming species, including rotifers and copepod nauplii; and second, mussels may indirectly suppress zooplankton by depleting food resources (Grigorovich, Shevtsova 1995, Pace *et al*. 1998, Horgan, Mills 1999, Strayer *et al*. 1999, Johannsson *et al*. 2000, Thorp, Casper 2003, Wong *et al*. 2003). The presence of dreissenid veligers may also have a direct influence on the structure of the zooplankton community (Johannsson *et al*. 2000).

A rapid spread of *Dreissena* mussels into the inland waters of Bulgaria was reported in recent years (Hubenov 2005, Trichkova *et al*. 2009). In the North-West Bulgarian reservoirs, in the Danube River basin, three of the reservoirs were found to be infested heavily by *Dreissena* (Ogosta, Rabisha, Kovachitsa) and two reservoirs had traces of previous infestations (Asparuhov Val, Drenovets) (Trichkova *et al*. 2007, 2009). The species had established abundant populations in the reservoirs Rabisha (*D. polymorpha*) and Ogosta (*D. polymorpha* and *D. bugensis*) (Trichkova *et al*. 2008, 2009). A few live specimens and numerous shells of *D. polymorpha* were found in the Kovachitsa Reservoir, and only shells in the Drenovets Reservoir (*D. polymorpha*) and Asparuhov Val Reservoir (*D. polymorpha* and *D. bugensis*) (Trichkova *et al*. 2007, 2009). Based on water chemistry, about 64% of the territory in North-West Bulgaria was classified with a high risk of zebra mussel infestation (Trichkova *et al*. 2007).

In Bulgaria, studies on zooplankton community composition and dynamics as well as their relation to environmental factors in reservoirs (Batak, Dospat, Studen Kladenets, Zhrebchevo, Pchelina, Yasna Polyana) were carried out most intensively in the 1970-1990s (Naidenow 1964a,b,c, 1976, 1977a,b, 1981a, 1993, Naidenov, Baev 1987, Kozuharov 1995a,b, Kozuharov *et al.* 2007). Data on the zooplankton composition in the North-West Bulgarian reservoirs (Rabisha Reservoir) were found only in the work of Ivanov *et al.* (1964). Recently, the zooplankton composition, its seasonal dynamics and share in the diet of *P. fluviatilis* were studied in the reservoirs Drenovets and Poletkovtsi by Trichkova *et al.* (2005) and Evtimova *et al*. (unpubl. data). Data on the zooplankton composition in relation to *Dreissena* occurrence in the reservoirs Ogosta and Poletkovtsi were published by Kozuharov *et al.* 2009).

The objectives of the present study were: (1) to make a comparative study of the zooplankton qualitative and quantitative composition and community structure in reservoirs in North-West Bulgaria; (2) to study the water physicochemical characteristics of the reservoirs; (3) to analyze a potential relation of zooplankton composition and distribution to *Dreissena* occurrence; to study the occurrence and abundance of *Dreissena* larvae in the reservoirs.

Materials and Methods

Fifteen reservoirs in North-West Bulgaria, in the Danube River basin, were studied (Fig. 1). Sampling was carried out during two seasons: five of the reservoirs were first sampled in April 2006 (Kula, Poletkovtsi, Rabisha, Drenovets, Ogosta); then all fifteen reservoirs were sampled in the period 28 August – 07 September 2006. The reservoirs differed in their hydrological and morphometric characteristics (Table 1). The number of sampling sites in each reservoir ranged from one to five, and they were selected according to the reservoir surface area and depth.

Standard water physicochemical parameters were measured. Transparency was measured with a Secchi disk. The water samples were collected with a water sampler of Hydrobios PVS 436 302. Water temperature, dissolved oxygen, pH and electrical conductivity were measured using portable Oxygen, pH and Conductivity meters Schott GMBH. One liter water samples were taken in plastic bottles and transported to the laboratory in a cooler with ice for determining Ca^{2+} and bicarbonate concentrations. At the laboratory, Ca^{2+} concentration was determined using the volumetric method with Na_2EDTA solution with murexide indicator. Bicarbonate concentration was determined by titration with HCl solution and methylorange as an end point indicator (Golterman, Clymo 1970, Höll *et al*. 1970). For each reservoir average values from surface water samples were used in the analyses.

A total of 62 zooplankton samples were collected in the studied reservoirs, using an Apstein qualitative net (mouth diameter 16 cm, mesh size 38 μm), and Juday quantitative net (mouth diameter 16 cm, mesh size 55 μm) hauled from the bottom to the surface at different lengths depending on the site depth.

Quantitative samples were counted according to the method of Hensen modified by Dimoff (1955).

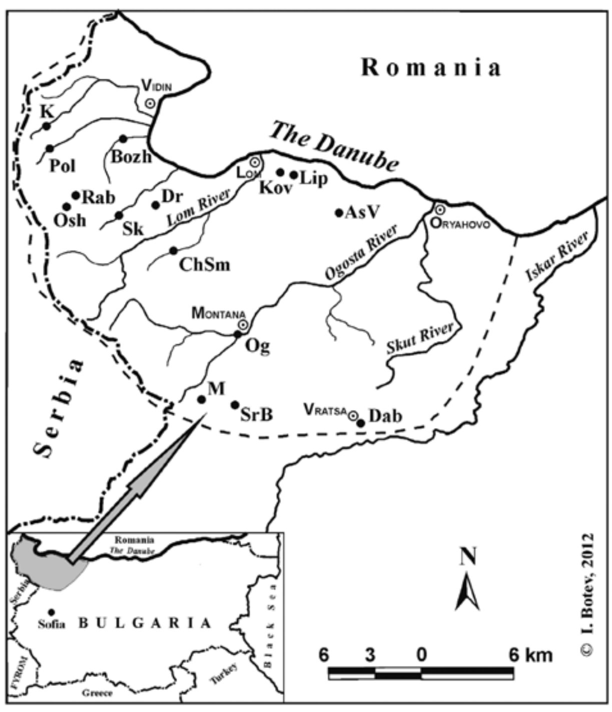

Fig. 1. Study region and survey reservoirs. For reservoir codes see Table 1

Table 1. Studied reservoirs in North-West Bulgaria – altitude and morphometric characteristics

	Name	Reservoir Code	Altitude m a. s. l	Surface area km^2	Maximum volume m^{3}x10^3	Maximum depth m
1	Ogosta	Og	203	23.60	506000	56
2	Rabisha	Rab	302	3.25	43200	22
3	Poletkovtsi	Pol	196	1.65	17500	36
4	Dabnik	Dab	354	0.80	-	20-36
5	Kula	K	210	1.57	20250	31
6	Drenovets	Dr	188	1.07	12000	28
7	Asparuhov Val	AsV	108	0.99	8000	<15
8	Christo Smirnenski	ChSm	165	0.98	17000	25
9	Skomlya	Sk	273	0.11	-	<15
10	Srechenska Bara	SrB	445	0.75	-	52
11	Lipnitsa	Lip	66	0.47	955	8
12	Oshane	Osh	347	0.08	609	20
13	Kovachitsa	Kov	118	1.12	8020	25
14	Bozhuritsa	Bozh	87	0.24	1430	13
15	Mishkovets	M	446	0.04	-	<15

Biocoenological analyses were made on the basis of the following indices: frequency of occurrence (pF), frequency of dominance (DF) and order of dominance (DT). In order to assess the community structure, the indices of taxa diversity ($\overline{H}$), dominance (C) and evenness (E) according to Pielou (1975) were used.

The ordination technique Detrended Correspondence Analysis (DCA) (Hill, Gauch 1980 ter Braak, Prentice 1988) was used to distinguish the pattern in zooplankton distribution in the reservoirs. DCA (detrended by segment with downweighting of rare species) was performed on a matrix of 40 species – only from quantitative samples collected during the summer sampling period, and from those found in more than one sample. Ordination was implemented by the CANOCO statistical package, version 4.5 (ter Braak, Šmilauer 2002).

Results and Discussion

Water physicochemical parameters

All studied reservoirs were dimictic or poly-holomictic water bodies. The first sampling was carried out after the spring turnover, and the second was before the autumn turnover. The results from the measurements of the water physicochemical parameters (average values) in both seasons are given in Table 2.

During the spring sampling the average surface water temperature ranged from 8.5^{o}C (Kula) to 11.5^{o}C (Drenovets), while in summer it ranged from 19.7^{o}C (Rabisha) to 25.1^{o}C (Srechenska Bara). During the two sampling periods, the highest values of Secchi disk transparency were registered in the reservoirs Rabisha and Ogosta (Table 2). The two reservoirs supported sustainable *Dreissena* populations (Trichkova *et al*. 2007, 2009), and it is known that as efficient filter feeders the *Dreissena* mussels are capable of increasing the water clarity (Kelly *et al*. 2010). The Srechenska Bara Reservoir also had high values of transparency. This reservoir is used for drinking water supply and it has mountain stream and spring water input. The transparency was low in the reservoirs Skomlya, Lipnitsa, Asparuhov Val, Bozhuritsa and Poletkovtsi (Table 2). These reservoirs were characterized also with high average values of dissolved oxygen, most probably as a result of phytoplankton development and blooms.

The average values of pH ranged from 7.50 (Ogosta, spring) to 8.72 (Asparuhov Val, summer), being above 8.00 in most of the reservoirs (Table 2). This indicated alkaline water and could also be a result of phytoplankton blooms and processes of eutrophication in some of the reservoirs. This pH interval was considered optimal for the development of the zooplankton (Naidenov 1981b), as well as for the larvae and early growth stages of *Dreissena* (Sprung 1987, Cohen, Weinstein 1998).

The values of electrical conductivity measured were in the range from 64 μS/cm (Srechenska Bara) to 916 μS/cm (Lipnitsa) (Table 2). The reservoirs

Table 2. Water physicochemical parameters (average values) in the studied reservoirs

Reservoir	Water temp., ^{o}C	Secchi Disk depth	Dissolved oxygen, mg/l	pH	Electric conductivity, µS/cm	HCO^{3-}, mg/l	Ca^{2+}, mg/l
April 2006							
Ogosta	9.3	114	9.52	7.50	-	103.7	32.06
Rabisha	10.4	370	9.60	8.50	-	82.4	23.05
Poletkovtsi	9.3	40	7.80	7.80	-	169.3	45.09
Kula	8.5	60	12.00	8.00	-	173.9	42.08
Drenovets	11.5	75	10.00	8.30	-	180.0	46.09
August – September 2006							
Ogosta	22.2	205	6.70	8.20	168	97.6	22.04
Rabisha	19.7	250	7.20	8.02	178	85.4	20.04
Poletkovtsi	23.5	55	10.01	8.65	328	207.4	50.10
Dabnik	22.7	70	7.77	8.20	397	134.2	37.08
Kula	24.0	150	9.07	8.35	374	143.3	26.05
Drenovets	21.4	70	6.53	7.97	276	143.3	26.05
Asparuhov Val	24.6	35	10.50	8.72	886	512.4	148.30
Christo Smirnenski	20.5	50	8.12	8.25	275	183.0	36.07
Skomlya	25.0	25	17.00	8.40	577	256.2	20.04
Srechenska Bara	25.1	190	8.40	7.90	64	42.7	8.02
Lipnitsa	22.0	25	10.40	8.50	916	594.8	136.27
Oshane	20.4	80	10.10	8.40	262	183.0	40.08
Kovachitsa	22.3	95	9.16	8.55	672	475.8	82.16
Bozhuritsa	21.4	52	14.40	8.37	460	216.6	42.08
Mishkovets	23.2	70	6.78	8.20	180	97.6	22.04

Asparuhov Val and Kovachitsa were also characterized with high values of electrical conductivity. The concentrations of bicarbonates and Ca^{2+} ions were the highest in the same reservoirs: Lipnitsa, Asparuhov Val and Kovachitsa. Lipnitsa Reservoir was a small one intensively used for aquaculture. In the reservoirs Asparuhov Val and Kovachitsa, the high concentrations of dissolved substances may be a result of different factors, such as: local pollution, agricultural runoff, their disconnection from the Danube (Trichkova *et al*. 2007), high levels of groundwater input, etc.

Zooplankton qualitative composition

A total of 95 taxa at species and genus ranks were recorded in the studied reservoirs (Table 3). They were mostly from the groups of Rotifera – 50, Cladocera – 23, Copepoda – 9 taxa, and 8 taxa from the groups of Testacea and Cilaitea. Additionally, Copepodites, Nauplii of Copepoda and veliger larvae of *Dreissena spp*. were found in the samples.

Most of the recorded zooplankton taxa are typical for the mesotrophic and eutrophic water bodies in Bulgaria. Although they are common in the Bulgarian zooplankton communities, they have not been reported so far in North-West water basins, because of the very few previous studies in the region (e.g. Ivanov *et al*. 1964, Kozuharov *et al*. 2009). A typical inhabitant of meso- and eutrophic waters is the species *T. emarginila,* which was found in the reservoirs Ogosta and Poletkovtsi (Table 3). It was newly reported for the Rotifera fauna of Bulgaria (Kozuharov *et al*. 2009). The species prevailed in the shallow parts of the reservoirs – especially in the ecotone zones.

The species *T. crassus* was found in 11 out of the 15 sampled reservoirs. In the past this species was rare in the inland waters of Bulgaria. During the last 10 years it has been found frequently all over the country. The species has an African origin and it was reported as an indicator of changes of the thermal regime of water bodies (Wagner, Adrian 2011).

Table 3. Qualitative composition of the zooplankton in the reservoirs in North-West Bulgaria. For reservoir code see Table 1

№	Taxa	Reservoir
	Protozoa	
1	*Arcella catinis* Stepanek, 1942	Rab, Pol, ChSm, Bozh
2	Difflugia sp.	Rab, Dr, ChSm, Bozh
3	*Stentor roseli (*Ehrenberg, 1834*)*	Rab
4	Aspidisca sp.	Rab
5	*Carchesium polypinum* (L., 1782)	Rab, Pol
6	*Epistilis plicatilis* (Ehrenberg, 1834)	Og
7	*Opercularia coarctata* Claparede et Lachmann	Lip, Kov
8	Acineta sp.	Sk
	Rotifera	
9	Encentrum sp.	Sk
10	*Brachionus calyciflorus* Pallas, 1766	Og, Dr, ChSm, Sk, Lip, Osh, Kov, Bozh
11	*Brachionus urceolaris* (O.F.Müller, 1773)	Dr, ChSm, Sk, Lip, Osh, Kov
12	*Brachionus angularis* Gosse, 1851	Rab, Osh
13	*Brachionus diversicornis* Daday, 1883	Rab, Dab, Dr, AsV, ChSm, Sk, Osh, Kov, Bozh
14	*Brachionus quadridentatus* Hermann, 1783	Rab
15	*Brachionus forficula* Wierzejski,1891	ChSm, Bozh
16	*Brachionus bidentata* Anderson, 1889	Kov
17	*Brachionus falcatus* Zacharias, 1898	Sk
18	*Brachionus budapestiensis* Daday, 1885	Sk
19	*Keratella cochlearis* Gosse, 1851	Og, Rab, Pol, K, Dr, AsV, ChSm, SrB, Lip, Bozh
20	*Keratella quadrata* (O.F.Müller,1773)	Rab, AsV, Sk
21	*Keratella tecta* Gosse, 1851	Og, Rab, Pol, Dab, Dr, AsV, ChSm, Lip, Bozh
22	*Keratella frenzeli* Eckstein, 1895	Og, Rab
23	*Keratella valga* (Ehrenberg, 1834)	AsV
24	*Notholca* sp.	Osh
25	*Notholca squamula* (O.F.Müller, 1785)	Rab
26	*Euchlanis dilatata* (Ehrenberg, 1832)	AsV
27	*Kellicottia longispina* (Kellicott, 1879)	Og, Rab, Pol, AsV, Sk
28	*Anuraeopsis fissa* Gosse, 1851	Rab, K, ChSm, Sk, Bozh
29	*Asplanchna priodonta* Gosse, 1851	Og, Rab, Pol, Dab, Dr, AsV, ChSm, Sk, SrB, Osh, Kov, M
30	*Asplanchna sieboldi* Leydig, 1854	Og, Rab, Dab, Dr, AsV, ChSm, SrB, Lip, Osh, Kov, Bozh, M
31	*Polyarthra vulgaris* Carlin, 1943	Og, Rab, Pol, Dr, AsV, ChSm, Lip, Osh, Kov, Bozh
32	*Polyarthra dolichoptera* Idelson, 1925	Og, Rab, Pol, Dr, AsV, ChSm, Bozh
33	*Polyarthra remata* Skorikov, 1896	Lip, Osh, Kov
34	*Polyarthra minor* Voigt, 1904	Pol, AsV
35	*Synhaeta pectinata* (Ehrenberg, 1832)	Og, Dr, ChSm
36	*Synhaeta* sp.	Og, Dab, K, ChSm, SrB, Lip, Osh, Kov
37	*Pompholyx complanata* Gosse,1851	Og, Rab, Dr, ChSm
38	*Pompholix sulcata (*Hudson*,* 1885*)*	Og, Dr, ChSm
39	*Filinia terminalis* Plate, 1886	Og, Dab, Dr, AsV, ChSm
40	*Filinia longsetta* (Ehrenberg, 1834)	Og, ChSm, SrB
41	*Filinia* sp.	Osh
42	*Hexarthra mira* (Hudson, 1871)	Og
43	*Trichocerca rattus* (Müler, 1776)	Og, Dr, Lip, Kov

Table 3. Continued

№	Taxa	Reservoir
44	*Trichocerca similis* (Wierzejski, 1893)	Dr, ChSm
45	*Trichocerca longiseta* (Schrank, 1802)	Dr, ChSm
46	*Trichocerca pusilla* (Jennings, 1903)	ChSm, Lip, Kov, Bozh
47	Trichocerca cf. cylindrica	Og
48	*Trichocerca cylindrica* (Imhof, 1891)	Rab, Dab, Dr, ChSm, Lip, Kov
49	*Trichocerca* sp.	K, AsV, Osh
50	*Conochilus hippocrepsis* (Schrank, 1803)	Og, Dr, ChSm, Osh
51	*Conochilus unicornis* (Rousselet, 1892)	SrB, M
52	*Testudinella caeca* (Parson, 1892)	Rab, Dr, ChSm
53	*Testudinella truncata* (Gosse, 1886)	Og, Rab
54	*Testudinella incisa* (Ternetz, 1892)	Dr, ChSm
55	*Testudinella emarginula* (Stenroos, 1891)	Og, Pol
56	Testudinella sp.	Og
57	*Trochospaera solstitalis* Thrope, 1872	Og, Osh
58	Lepadella sp.	Bozh
	Cladocera	
59	*Diaphanosoma brachyurum* (Lievin, 1848)	K, Kov
60	*Diaphanosoma lacustris* Korjinek, 1981	Og, Rab, Pol, K, Dr, AsV, ChSm, SrB, Kov, M
61	*Diaphanosoma* sp.	K
62	*Daphnia galeata* Sars, 1864	Og, Rab, K, Dr, AsV, ChSm, Sk, SrB
63	*Daphnia cucullata* Sars, 1864	Og, Rab, Pol, K, Dr, AsV, ChSm, Sk, Kov, Bozh, M
64	*Daphnia longispina typica* Müller,1785	Pol
65	*Daphnia pulex* (Leydig, 1860)	Dr, ChSm
66	Daphnia gr.pulex	K
67	Daphnia sp. juv	AsV, Osh
68	*Ceriodaphnia quadrangula* (Müller, 1785)	Og, Pol, Dr, AsV, ChSm, SrB, M
69	Moina sp.	Og
70	*Moina dubia* Guerne et Richard, 1892	Rab, Dab, K, Dr, AsV, ChSm, SrB, Osh
71	*Bosmina longirostris* (Müller, 1785)	Og, Rab, Dab, K, Dr, AsV, ChSm, Sk, SrB, Kov, Bozh, M
72	Bosmina cf. kesleri	Og, ChSm
73	*Bosmina kessleri* Ujanin, 1872	Og, Pol, Dr, AsV, ChSm, Lip
74	*Bosmina coregoni* Baird, 1857	Og, Pol, Dab, Dr, AsV, ChSm, Bozh
75	*Chydorus sphaericus* (Müller,1785)	Og, Pol, AsV, Osh, M
76	*Ilyocriptus sordidus* (Lievin, 1848)	Og, Dr, ChSm
77	*Alona protzi* Hartwig, 1900	Pol
78	*Alona costata* Sars, 1862	Pol
79	*Alona rectangula* Sars, 1862	Og
80	*Alona guttata* Sars, 1862	Dab
81	*Leptodora kindti* (Focke, 1844)	ChSm, SrB, Bozh
	Copepoda	
82	*Acanthocyclops robustus* (Sars, 1863)	Og, Rab, Dab, K, Dr, ChSm, Sk
83	*Acanthocyclops* sp.	SrB
84	*Cyclops vicinus* Uljanin, 1875	Rab, Pol, Dr, AsV, ChSm
85	Thermocyclops sp.	Og
86	*Thermocyclops crassus* Ficher, 1853	Og, Rab, Pol, Dab, K, Dr, AsV, ChSm, Sk, SrB, Bozh
87	*Eucyclops serrulatus* (Fisher, 1851)	Dab, K, ChSm, Sk, Bozh

Table 3. Continued

№	Taxa	Reservoir
88	*Eudiaptomus gracilis* (Sars,1863)	Og, Pol, AsV, SrB, M
89	Eudiaptomus sp.	Og, AsV
90	Nauplii	Og, Rab, Pol, Dab, K, Dr, AsV, ChSm, Sk, SrB, Lip, Osh, Kov, Bozh, M
91	Copepodites	Og, Rab, Pol, Dab, K, Dr, AsV, ChSm, Sk, SrB, Lip, Osh, Kov, Bozh, M
92	Calanoida g. sp. juv.	K
	Varia	
93	Harpacticoida g. sp.	K
94	*Chaoborus crystallinus* larvae	Rab, Pol
95	Veliger larvae	Og, Rab, Pol, Dab

The highest number of taxa was recorded in the reservoirs Ogosta (41), Christo Smirnenski (41), Drenovets (34) and Rabisha (31); and the lowest number in the Mishkovets Reservoir (9) (Table 3). The highest number of Rotifera taxa was found in the same reservoirs: Ogosta (23), Christo Smirnenski (24), Drenovets (20) and Rabisha (18). In Drenovets Reservoir, 17 species of Rotifera were recorded in the ecotone zone between the reservoir and the inflow river at depth of 1.5 m. Rotifera taxa dominated in the smaller reservoirs Lipnitsa and Oshane, where typical pelagic components such as larger Cladocera and Copepoda species were almost lacking. The Rotifera taxa richness was higher than Cladocera and Copepoda in some of the larger reservoirs, such as: Ogosta, Rabisha, Christo Smirnenski, Drenovets, Kovachitsa (Table 3).

Dreissena veliger larvae were found in the plankton of four of the investigated reservoirs – Ogosta, Rabisha, Poletkovtsi and Dabnik. Live adult specimens of *D. polymorpha* were recorded in the reservoirs Rabisha (3712 ind./ m^2) and Ogosta (885 ind./ m^2) (Trichkova *et al*. 2008). In the reservoirs Poletkovtsi and Dabnik, no adult mussels were found. It is possible that the larvae were transported into the reservoirs with water or fishing equipment from other infested water basins or from the Danube River (Trickova *et al*. 2007). The prevailing bottom substrate in the Dabnik Reservoir was thick anerobic mud which was not suitable for the development of *Dreissena*.

The benthic-plankton component *Chaoborus crystallinus* larvae were recorded in the reservoirs Rabisha and Poletkovtsi (Table 3). This species was reported as an important indicator for the stages of lake evolution (Kovachev, Stoichev 1996). It was reported in fishless lakes, being more abundant at highly eutrophic conditions (von Ende 1979, Wissel *et al.* 2003).

Zooplankton quantitative composition

The quantitative parameters of the zooplankton in the reservoirs varied widely (Fig. 2). In spring, the minimum values of abundance and biomass were detected in Ogosta Reservoir – 18 994 ind./m^3 and 387.8 mg/m^3. The maximum value of abundance was registered in the highly eutrophic water body – Kula Reservoir – 615 865 ind./m^3. In summer, the minimum value of abundance was registered in Skomlya Reservoir – 89 200 ind./m^3. The highest total abundance was recorded in Poletkovtsi Reservoir – 1641 528 ind./m^3. In the reservoirs Poletkovtsi and Kula, the number of taxa of Cladocera and Copepoda recorded was much higher than the Rotifera taxa which are smaller in size (Table 3). Being grazers, they may influence the phytoplankton dynamics and consequently the relationship between chlorophyll a and nutrients (Lampert, Sommer 1997). They can also regulate bacterioplankton abundance and protozoan populations.

The tendencies in the biomass did not follow those of the abundance because of the high biomass of subadult stages of Copepoda, compared to those of Rotifera. The values of abundance and biomass in April were lower due to the seasonal changes in zooplankton complexes in this period. The minimum value of biomass in summer was registered in Bozhuritsa Reservoir – 359.6 mg/m^3; while the highest total biomass was recorded in Ogosta Reservoir – 7134.1 mg/m^3. The highest values of biomass in spring were detected in Drenovets Reservoir – 5215.3

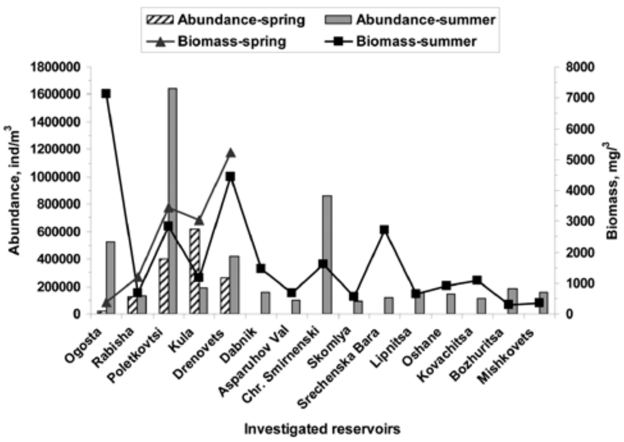

Fig. 2. Total abundance (ind./m^3) and biomass (mg/m^3) of zooplankton in the reservoirs in North-West Bulgaria sampled in spring and summer 2006.

mg/m^3. At different sites in the Ogosta Reservoir, the absolute abundance ranged from 1120 ind./m^3 in April to 297 200 ind./m^3 in the ecotone in August. The biomass in the same reservoir ranged from 14.45 mg/m^3 in April to 1936 mg/m^3 in August.

In summer, the abundance of *Dreissena* veliger larvae was the highest in the Ogosta Reservoir – over 10000 ind./m^3, followed by Rabisha Reservoir – 7893 ind./m^3 , Poletkovtsi Reservoir – 731 ind/m^3, and the lowest in Dabnik Reservoir – 200 ind./m^3 (Fig. 3). The mean values varied from 1100 ind./m^3 in Ogosta to 220 ind./m^3 in Dabnik. In spring the values of abundance of veliger larvae ranged from 1853 ind./m^3 in Rabisha to 331 ind./m^3 in Poletkovtsi. In Ogosta Reservoir veliger larvae were not found in the spring samples. Most likely the reason was the low water temperature – 9,3^{o}C. The values of biomass of veliger larvae followed those of abundance (Fig. 3). In the Poletkovtsi Reservoir a high number of Cladocera and Copepoda taxa and the highest zooplankton abundance and biomass were recorded (Table 3, Fig. 2). These taxa can be competitors for the food sources of the veliger larvae and suppress their development, which might be one of the reasons for the very low abundance of veliger larvae in the Poletkovtsi Reservoir and the lack of adult *Dreissena* species.

Despite the highest diversity of zooplankton taxa recorded in the *Dreissena* infested reservoirs Ogosta and Rabisha, compared to other reservoirs (Table 3), the zooplankton abundance and biomass were comparatively low (Fig. 2). For example, in spring, the zooplankton abundance and biomass in Ogosta and Rabisha were much lower than non-infested Kula and Poletkovtsi Reservoirs. In summer, the zooplankton abundance and biomass in Rabisha was again one of the lowest among all the reservoirs; while the abundance in Ogosta was much lower than these in Poletkovtsi and Christo Smirnenski (Fig. 2). The exception is the zooplankton biomass in Ogosta which has the highest value in summer, probably due to the contribution of veliger larvae and subadult stages of Copepoda to the total biomass. Therefore, the low quantitative parameters in infested reservoirs may be a result of the influence of *Dreissena* and high abundance of veliger larvae (Fig. 3). Declines in small-bodied zooplankton species due to direct ingestion by *Dreissena* mussels was reported by some authors (Pace *et al*. 1998, Strayer *et al*. 1999, Wong *et al*. 2003); while other authors attributed the reduction in zooplankton in *Dreissena* infested water bodies also to the depression of primary production and food limitation (Horgan, Mills 1999, Johannsson *et al*. 2000).

Dominant analysis of the zooplankton

The most frequent components of the zooplankton in all studied reservoirs were the Copepodites and Nauplii of Copepoda – pF=100 %. The frequency of occurrence (pF) of veliger larvae varied among reservoirs. The lowest values of pF were registered in the Poletkovtsi Reservoir – 10%. In other reservoirs the values of pF reached: 33% in Dabnik, 38% in Rabisha and 50% in Ogosta. In the infested reservoirs Rabisha and Ogosta the frequency of occurrence of Rotifera taxa did not exceed 70%, which might be again influenced by *Dreissena* occurrence.

Most dominant in all reservoirs were copepodites of Copepoda. Their DF ranged from 8% in Drenovets to 100% in Dabnik. Other subadults of Copepoda – Nauplii were also characterized with high values of DF. Some other zooplankton taxa also had high DF values: *Ceriodaphnia* spp. (DF=33%) in Srechenska Bara, *K. quadrata* (DF=40%) in Kula, and *T. crassus* (DF=43%) in Drenovets. All these dominant species are indicators for eutrophic conditions.

The lowest and the highest DT values were recorded again for Copepodites of Copepoda – from 8% in Drenovets to 100% in Dabnik.

The ecotone effects and the drastic changes from lotic to lentic conditions influenced significantly the values of the index of occurrence, frequency of dominance and order of dominance in the studied reservoirs. For example, the Rotifera taxa were found with very low frequency of occurrence in the

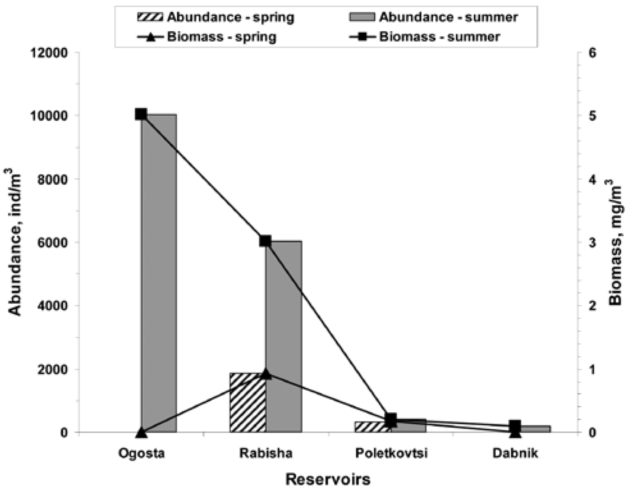

Fig. 3. Abundance (ind./m^3) and biomass (mg/m^3) of *Dreissena* veliger larvae in the studied reservoirs.

ecotone zone of the Ogosta Reservoir.

The dominant complexes of the zooplankton in the studied reservoirs differed significantly from other reservoirs in Bulgaria, where 10-12 dominants commonly occurred throughout seasons and years (Naidenow 1976, Kozuharov 1995b). The registered comparatively low values of the index of occurrence, frequency of dominance and order of dominance in the infested reservoirs compared to others, may also be indications of negative effects of adult *Dreissena* and their larvae on the dominant complexes of the zooplankton.

Structure of the zooplankton communities

The diversity index ($\overline{H}$) after Shannon, Weaver (1963) in all studied reservoirs varied within a wide range (Fig. 4). The highest taxa diversity was recorded in the Skomlya Reservoir – 2.59. In this reservoir, the lowest value of index of dominance (C) after Simpson – 0.244 was recorded. During the sampling period, the water level in this reservoir was extremely low due to reconstruction of the dam, and there was phytoplankton bloom. The obtained results can be explained with the high abundance of Rotifera species, which can survive easily in such conditions. The high values of the index ($\overline{H}$) might be the result of the combination of a large number of species with small differences in the abundance of all found zooplankton species. Another reason might be the establishment of a high number of Rotifera taxa. Similar results were obtained for other eutrophic water bodies (Kozuharov 1999).

The species diversity index had the lowest value in Christo Smirnenski Reservoir – 0.49. This reservoir had a strong drifting process of the zooplankton because of the exchange of water quantities between the inflow and outflow river and the reservoir.

Comparatively high values of the Shannon-Weaver species diversity index were recorded in *Dreissena* infested reservoirs Ogosta and Rabisha (Fig. 4).

In the studied reservoirs, the values of index of diversity ($\overline{H}$) and index of evenness (E) were relatively lower compared to the index of dominance. The highest taxa diversity was established at the sites in the ecotone zones (between the reservoirs and the inflowing rivers), where the frequently changing environmental conditions and inflow of organic matter influenced the inhabiting communities.

Zooplankton distribution within the reservoirs

The results of DCA analysis are shown on Fig. 5.

The first two axes (λ_1=0.773, λ_2=0.374) cumulatively explained 22.5% of the variance of the zooplankton species data. Axis 1 separated the reservoirs with larger surface area, namely Ogosta, Rabisha, Asparuhov Val, Kovachitsa, Drenovets with their characteristic pelagic crustacean components – *D. galeata, D. cuculata, C. cuadrangula* and *E. gracilis* on the right side of the diagram. Some of the recorded Rotifera species in these reservoirs, such as: *F. terminalis, F. longiseta* and *K. longispina,* were also typical pelagic components. They are commonly found in water bodies which have large pelagic zones. The reservoirs in this group were infested or had traces of previous infestation by *Dreissena*.

The reservoirs Christo Smirnenski, Poletkovtsi, Oshane and Dabnika, plotted on the left of the ordination diagram (Fig. 5), are small in surface area and water volume. Most common zooplankton elements in these reservoirs were the rotifers *K. tecta, K. quadrata,* and *A. fissa,* which are typical for swamps and eutrophic water bodies. The reservoirs in this group were not infested by *Dreissena* during the studied period. Most likely, the substrate (predominantly muddy substrate) and environmental conditions were not suitable for the establishment of the mussels and their larvae.

The second axis separated the reservoirs Lipnitsa and Skomlya – plotted on the top of the ordination diagram (Fig. 5), with the following characteristic species: *B. calyciflorus, B. urceolaris, B. angularis, B. diversicornis, T. solstitalis, C. hippocrepsis, M. dubia, P. minor, T. crassus, C. sphaericus, A. robustus, E. serrulatus,* and *A. sieboldi.*

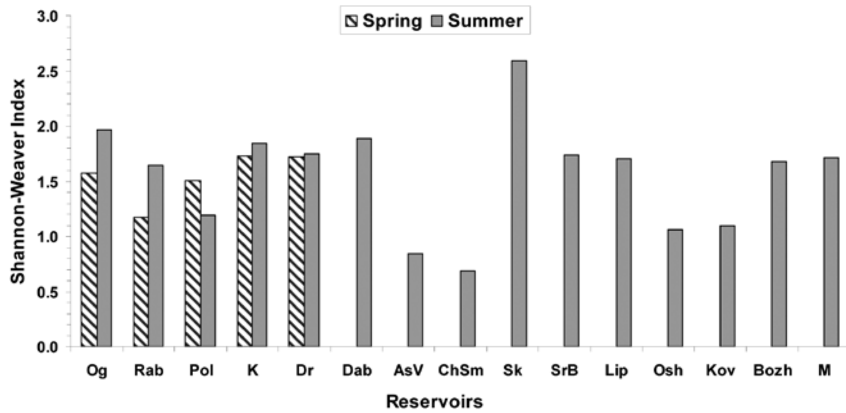

Fig. 4. Values of the Shannon-Weaver index ($\overline{H}$) of zooplankton in the reservoirs of North-West Bulgaria.

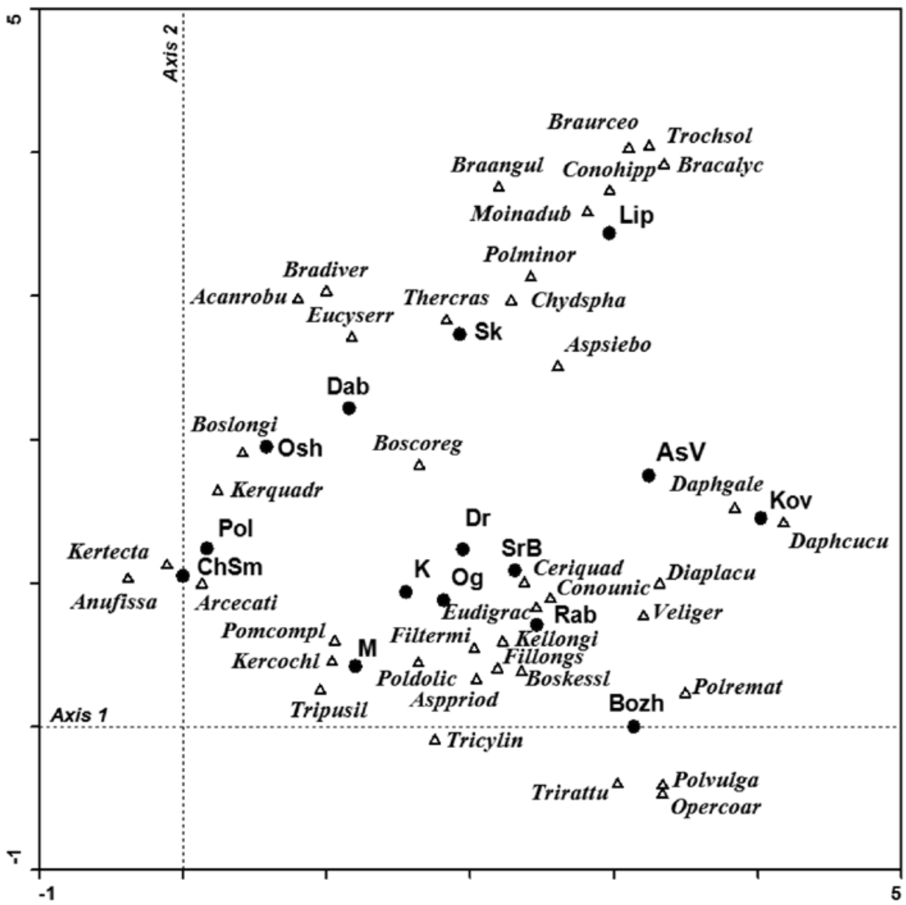

Fig. 5. Ordination diagram based on Detrended Corespondence Analysis (DCA) of zooplankton taxa in 15 reservoirs in North-West Bulgaria. For reservoir code see Table 1. Zooplankton taxa shown are: *Arcecati – A. catinis; Opercoar – O. coarctata; Bracalyc – B. calyciflorus; Braurceo – B. urceolaris; Braangul – B. angularis; Bradiver – B. diversicornis; Kercochl – K. cochlearis; Kerquadr- K. quadrata; Kertecta – K. tecta; Kellongi – K. longispina; Anufissa – A. fissa; Asppriod – A. priodonta; Aspsiebo – A. sieboldi; Polvulga – P. vulgaris; Poldolic – P. dolichoptera; Polremat – P. remata; Polminor – P. minor; Pomcompl – P. complanata ; Filtermi – F. terminalis; Fillongs – F. longsetta; Trirattu – T. rattus; Tripusil – T. pusilla; Tricylind – T. cylindrica; Conohipp – C. hippocrepsis; Conounic – C. unicornis; Trochsol – T. solstitalis; Diaplacu – D. lacustris; Daphgale – D. galeata; Daphcucu – D. cucullata; Ceriquad – C. quadrangula; Moinadub – M. dubia; Boslongi – B. longirostris; Boskessl – B. kessleri; Boscoreg – B. coregoni; Chydspha – C. sphaericus; Acanrobu – A. robustus; Thercras – T. crassus; Eucyserr – E. serrulatus; Eudigrac – E. gracilis; Veliger – Veliger larvae.*

Conclusions

Comparatively high diversity of zooplankton taxa is reported for the reservoirs in North-West Bulgaria. The group with the highest taxa richness was Rotifera, followed by Cladocera and Copepoda. The qualitative and quantitative composition of the zooplankton in the reservoirs is typical for mesotrophic and eutrophic water basins in Bulgaria.

Dreissena veliger larvae were recorded in high abundance in the infested reservoirs Ogosta and Rabisha, and in low densities in two other reservoirs, where adult mussels were not found. This shows the high vulnerability to *Dreissena* infestation of the reservoirs in the region. The infested reservoirs Ogosta and Rabisha were characterized with high taxa richness; Rabisha Reservoir had low values of zooplankton abundance and biomass in both seasons, while Ogosta Reservoir showed seasonal fluctuations in the zooplankton abundance and biomass, most likely due to the share of the veliger larvae. Unstable dominant complexes represented by small forms belonging mostly to Rotifera, Cladocera and the subadult of Copepoda were found in these reservoirs. These results may be a consequence of the presence and abundance of *Dreissena* veliger larvae and adult mussels.

The interactions and potential negative effects of *Dreissena* on the composition and structure of zooplankton communities in Bulgarian reservoirs require further investigation. Development of regular monitoring programs for zooplankton need to be considered for infested and vulnerable reservoirs in the river basin management plans.

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