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Benthic Macroinvertebrate Diversity in Relation to Environmental Parameters, and Ecological Potential of Reservoirs, Danube River Basin, North-West Bulgaria

***Teodora Trichkova*[1], *Violeta Tyufekchieva*[1], *Lyubomir Kenderov*[2], *Yanka Vidinova*[1], *Ivan Botev*[1], *Dimitar Kozuharov*[2], *Zdravko Hubenov*[3], *Yordan Uzunov*[1], *Stefan Stoichev*[1], *Svetoslav Cheshmedjiev*[4]**

[1] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Str., Sofia 1113, Bulgaria, Email: trichkova@zoology.bas.bg, vtyufekchieva@yahoo.com;
[2] Biological Faculty, Sofia University, 8 Dragan Tsankov Blvd., Sofia 1164, Bulgaria;
[3] National Museum of Natural History, Bulgarian Academy of Sciences, 1 Tsar Osvoboditel Blvd., Sofia 1000, Bulgaria;
[4] NGO EcoForum for the Nature.

Abstract: Twelve reservoirs in North-West Bulgaria were sampled in autumn 2009 to study the species diversity and distribution of benthic macroinvertebrates in relation to some environmental parameters, and to assess the ecological potential of the reservoirs based on macroinvertebrate metrics. A total of 75 taxa belonging mostly to Oligochaeta, Ephemeroptera, Chironomidae, and Mollusca were recorded. The most abundant were the invasive bivalve mollusks *Dreissena sp.*, larvae of *Ch. crystallinus* and oligochaetes. The highest taxa diversity was recorded in the reservoirs located in close proximity to the Danube River and in the reservoirs with the largest areas. The occurrence and abundance of invasive *Dreissena* species, electrical conductivity, Ca^{2+} concentration and water transparency were identified as potential factors for the mactroinvertabrate distribution. Based on 7 macroinvertebrate metrics, the ecological potential of the reservoirs was assessed in the range from “Good” to “Bad”. Most of the reservoirs were classified as having a “Moderate” ecological potential. It is recommended that the invasive alien species are considered in the use and development of macroinvetebrate metrics and assessment tools for lakes, and in the river basin and reservoir management strategies. Immediate management actions are crucially needed to improve the ecological potential of reservoirs.

Key words: benthic macroinvertebrates, distribution, water physico-chemical parameters, invasive alien species, ecological potential, reservoirs, Danube River Basin

Introduction

In lentic freshwaters, the benthic invertebrates play an essential role in key ecosystem processes, such as food chain dynamics, productivity, nutrient cycling and decomposition (Covich *et al.* 1999). Their distribution and abundance is directly related to different environmental factors such as food availability and quantity, sediment type, substrate, and water quality (Wilhm, McClintock 1978, Bechara, 1996, Jónasson 1996, Real *et al.* 2000, Arslan *et al.* 2007, Odabasi *et al.* 2009). They also show considerable spatial variation with lake depth, across habitats, and across lakes (Petridis, Sinis 1993, 1995, Di Giovanni *et al.* 1996, Baudo *et al.* 2001, Pamplin, Rocha 2007, Smiljkov *et al.* 2008). In reservoirs, the benthic macroinvertebrate community may be particularly susceptible to water-level changes that alter sediment exposure, temperature regime, wave-induced sediment redistribution and basal productivity (McEwen, Butler 2010).

Since benthic invertebrates respond sensitively to pollution, as well as to a number of other human impacts (hydrological, climatological, morphological, navigational, recreational, and others), their potential use for a holistic indication system for lake ecosystem health has been considered to support EU WFD (2000/60/EEC) implementation (Solimini *et al*. 2006). In many countries including Bulgaria, reservoirs are of great economic importance, being used for water supply, power generation, water abstraction for agriculture, aquaculture, etc. According to the EU WFD, these heavily modified water bodies should be assessed similarly to lakes, using the best 'ecological potential' as a reference.

A comprehensive review of available information on the benthic fauna of non-lotic water basins in Bulgaria was published by Trichkova (2007). It showed that data on the qualitative and quantitative composition of benthic invertebrate communities in the standing water basins in Bulgaria by that time were scarce and fragmentary. Generally, studies concerned only single groups or communities of benthic invertebrates and did not consider the relations between benthic invertebrates and other ecological groups, as well as the influence of the environmental factors.

In the North-West Bulgarian reservoirs, Danube River basin, data on benthic macroinvertebrates are still lacking, with the exception of recent studies related to the invasion of mussels from genus *Dreissena* (Hubenov 2005, Trichkova *et al*. 2007, 2008, 2009). Three of the reservoirs in the region 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). *Dreissena* species had established abundant populations in the reservoirs Rabisha and Ogosta (Trichkova *et al*. 2008). Based on water chemistry, about 64% of the territory in the region was classified as having a high risk of zebra mussel infestation (Trichkova *et al*. 2007).

Currently, macroinvertebrate metrics and assessment systems for lakes in compliance with the EU WFD (2000/60/EEC) requirements are under development in Bulgaria (Cheshmedjiev *et al*. 2010a). The following metrics were suggested for the assessment of the ecological potential of lakes and reservoirs: total number of taxa, total abundance, and percent of Oligochaete taxa (Cheshmedjiev *et al*. 2010b).

The goals of the present study were: 1) to study the species diversity and distribution of benthic macroinvertebrates in reservoirs in North-West Bulgaria; 2) to study the water physico-chemical parameters in the reservoirs; 3) to identify the main factors for the macrozoobenthos diversity and distribution; 4) to assess the ecological potential of the reservoirs based on benthic macroinvertebrate metrics.

Study Area

Twelve reservoirs were sampled. They are located in the Danube River basin, North-West Bulgaria (Fig. 1). Information on altitude, size and use of the reservoirs is presented in Table 1.

Material and Methods

The sampling was made during the period September – October 2009.

Qualitative and quantitative samples of benthic macroinvertebrates were collected according to standard methods ISO 9391:1993/ EN 9391:1995 and ISO 7828:1985/ EN 27828:1994. The quantitative benthic samples were collected with a Petersen's grab of medium size (17.0x16.5 cm) at six sites in each reservoir, at different depths (in the range from 0.5 to 30 m) and different substrate types. The qualitative samples were collected by a hand-net and a Surber's net (35x30cm) at different substrate types in the littoral area (at depths <0.5 m). All samples were sieved using a collecting net with a mesh size

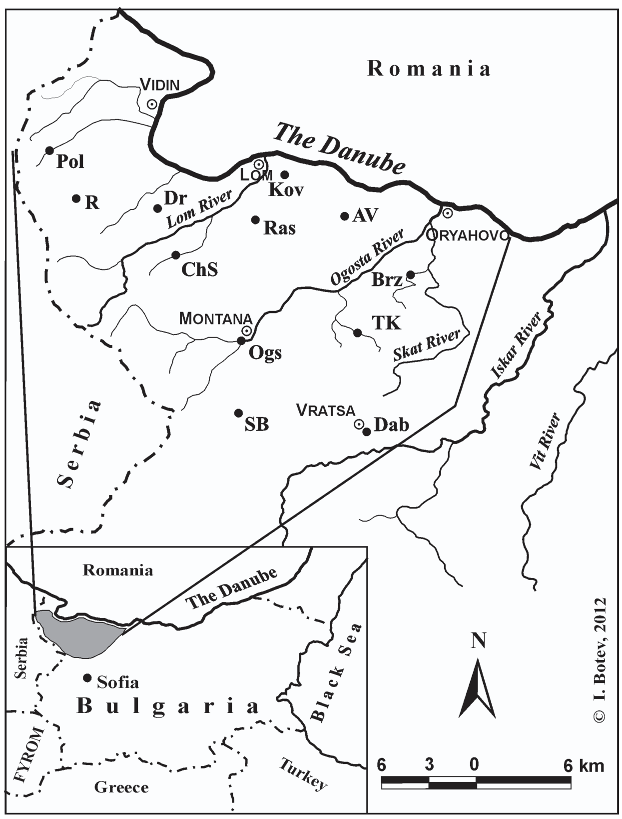

Fig. 1. Location of studied reservoirs. For reservoir code see Table 1

Table 1. Characteristics of the studied reservoirs in North-West Bulgaria

Reservoir	Reservoir code	Altitude, m a.s.l.	Max surface area, ha	Max depth, m	Use
Poletkovtsi	Pol	210	164,8	36	Irrigation, power generation, commercial and recreational fishing
Rabisha	R	302	324,6	22	Irrigation, power generation, recreational fishing
Drenovets	Dr	188	107	28	Irrigation, aquaculture, commercial and recreational fishing
Christo Smirnenski	ChS	163	97,5	25	Irrigation, power generation, aquaculture, commercial and recreational fishing
Rasovo	Ras	130	50	<15	Aquaculture, commercial fishing
Kovachitsa	Kov	117,5	112	25	Irrigation, recreational fishing
Ogosta	Ogs	202,5	2360	56	Irrigation, power generation, recreation, recreational fishing
Tri Kladentsi	TK	159		<15	Aquaculture, commercial fishing
Barzina	Brz			<15	Recreational fishing
Srechenska Bara	SB	445	75	52	Drinking water supply
Dabnik	Dab	354	80	20-36	Industrial water supply, recreational fishing
Asparuhov Val	AV	108	98,6	<15	Irrigation, recreational fishing

of 500 µm and fixed in situ in 4% formaldehyde.

The samples were sorted at the laboratory. The invertebrate groups were identified at the species or nearest possible taxa level and the counts were converted to number of individuals per square meter (ind./m^2). In order to characterize the macroinvertebrate communities in the reservoirs the following variables were used: total number of taxa, percentage of total abundance of all taxa (%), frequency of occurrence (pF), frequency of dominance (DF) and range of dominance (DT) – by De Vries (1937) and Kozhova (1970). The pF coefficient was calculated based on both qualitative and quantitative data.

Standard water physico-chemical 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 calcium and bicarbonate concentrations. At the laboratory, Ca^{2+}concentration was determined using the volumetric method with Na_2EDTA solution with a 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). One to five sites were sampled in each reservoir, and the average values of measurements from surface water samples were used in the analyses.

Principal components analysis (PCA) – based on the correlation matrix by centering and standardization was used to summarize the major patterns of variation within the physico-chemical data. Detrended Correspondence analysis (DCA) (Hill, Gauch 1980) – detrending by segments was run with benthos data in order to distinguish major patterns in macrozoobethos distribution in the reservoirs. The analysis was implemented on a matrix of 45 taxa – only data from quantitative samples were included, with the exception of 3 taxa identified up to the family level and having a very low percentage (0,05%) (Lumbricidae, gen. sp. juv., Tubificidae, gen. sp. juv., Leptoceridae, gen. sp.). The taxa data were square roots transformed with downweighted rare taxa. Ordinations were performed by the CANOCO statistical package (Ter Braak, Šmilauer 2002). Two of the reservoirs (Barzina and Rasovo), which had only one taxon recorded during quantitative sampling, were excluded from the statistical analyses.

The ecological potential of the reservoirs was assessed based on the total number of benthic macroinvertebrate taxa recorded (TTN), total abundance (N, ind./m^2), modified Irish Biotic Index (BI) and total number of taxa based on BI – TTN (BI) (Flanagan, Toner 1972, Clabby, Bowman 1979, Yaneva, Cheshmedjiev 1999 Cheshmedjiev *et al.* 2010); share of oligochaete and dipteran species (% Oligochaeta; % ODT- Oligochaeta + Diptera Taxa: N ratio) (Kachalova, Parele 1987, Cheshmedjiev *et al*. 2010); as well as on the presence and abundance of invasive species (Arbačiauskas *et al*. 2008, Panov *et al*. 2009). Both qualitative and quantitative data were used in the analyses.

Results

A total of 75 macrozoobenthic taxa were recorded in the reservoirs (Table 2). They belonged mostly to Oligochaeta, Ephemeroptera, Chironomidae, and Mollusca. Among them there were five species considered invasive to the inland water bodies of Bulgaria: *B. sowerbyi, L. benedeni*, *Ph. acuta, D. polymorpha* and *D. bugensis* (based on the list of Panov *et al*. 2009). The most abundant of the macrozoobenthic invertebrates were Bivalvia (35%). They were followed by Oligochaeta (26%), Chaoboridae (22%), Chironomidae (8%), Gastropoda (4%), Ceratopogonidae (3%), Trichoptera (1%), Ephemeroptera, Odonata and Hydracarina (less than 1%). The species with the highest abundance were *D. polymorpha* and *Ch. crystallinus* (Table 2). Most frequently found (with frequency of occurrence more than 50%) were *L. hoffmeisteri*, *T. tubifex*, *Ch.* gr. *plumosus*, *Ch.* gr. *riparius* and *Bezzia* sp. The highest range of dominance was determined for *P. hammoniensis, E. vulgata*, *D. bugensis* and *D. polymorpha*. These species had low values of frequency of occurrence and dominance, as they were found dominating in specific reservoirs only.

The highest number of macrozoobenthic taxa (from both qualitative and quantitative samples) was recorded in the reservoirs Kovachitsa (31), Ogosta (25) and Asparuhov Val (21), and the lowest in Barzina (1). The highest abundance was recorded in the reservoirs Rabisha, Kovachitsa and Ogosta (Table 2 and 3).

The results of the PCA analysis of the water physico-chemical parameters in the reservoirs showed that the first two principal components (eigenvalues ($\lambda_1 = 0.591$; $\lambda_2 = 0.231$) cumulatively explained 82.2 % of total variance and effectively captured the main pattern of variation in the environmental data. The first axis was related to electrical conductivity, concentrations of bicarbonates and Ca^{2+}, and pH (with loadings 0.986, 0.969, 0.942 and 0.868 respectively) (Fig. 2). It separated the reservoirs Asparuhov Val and Kovachitsa with the highest values of these parameters compared to the rest of the reservoirs. Axis 2 reflected two gradients: the first gradient was related to transparency (with loading -0.661) and separated the reservoirs Ogosta, Rabisha and Srechenska Bara with the highest values of transparency; the second gradient was related to dissolved oxygen (with loading 0.904) and separated the reservoirs Tri Kladentsi and Dabnik with the highest concentrations of dissolved oxygen. The reservoirs Drenovets, Christo Smirnenski and Poletkovtsi had average or near average values of all parameters (Fig. 2).

The results of ordination based on DCA of the macrozoobenthos data are shown in Fig. 3. The eigenvalues ($\lambda_1 = 0.784$; $\lambda_2 = 0.378$; $\lambda_3 = 0.028$) of the first three axes and length of gradient expressed in standard deviation units of species turnover (4.3 SD) of the first axis denoted a good separation of the species along this axis (Ter Braak, Šmilauer, 2002). The variance explained by the first three axes was 18.6%, 8.9% and 0.6% respectively. The first axis separated two main groups of reservoirs (Fig. 3). The first group included the reservoirs Kovachitsa, Asparuhov Val and Tri Kladentsi, which were characterized by the dominance of the following species: the larvae of *Ch. crystallinus,* the mayflies *C. macrura*, *C. robusta*, the mollusks *B. tentaculata, R. auricularia, Ph. acuta, G. laevis, V. piscinalis, Pisidium* sp., the chironomid *T.* gr. *gregarius,* and the oligochaete *L. hoffmeisteri*. The second group included the reservoirs Ogosta and Rabisha which were characterized by the mollusk species *D. polymorpha*, *D. bugensis, Viviparus* sp. and the oligochaete *D. obtusa*. Axis 2 separated the specific Srechenska Bara Reservoir, with its characteristic species the mayflies *E. vulgata* and *P. pennulatum*, from all other reservoirs (Fig. 3).

The ecological potential of the reservoirs was assessed in the range from "Good" to "Bad". Most of the reservoirs were classified as having "Moderate" ecological potential (Table 3).

Discussion

A total of 75 invertebrate taxa were recorded in the twelve studied reservoirs in North-West Bulgaria (Table 2). They were dominated by four groups of invertebrates – Bivalvia, Oligochaeta, Chaoboridae and Chironomidae, which is typical of many freshwater systems. The insects, although at low densities, formed the most diverse group, particularly well represented by Chironomidae. Four of the recorded species are of conservation concern in Bulgaria. The mayfly species *E. vulgata* and the leeches *H. medicinalis* are listed as Vulnerable in the Red Data Book of Bulgaria (Golemansky 2011); *H. medicinalis* and the crayfish

Table 2. List of benthic macroinvertebrates found in the studied reservoirs with percentage of total abundance of all taxa, frequency of occurrence (pF), frequency of dominance (DF), and range of dominance (DT). (*) – Taxa found only in the littoral area during qualitative sampling. (CC) – Species of Conservation Concern in Bulgaria

No.	Taxa	Reservoir	Percentage, %	pF, %	DF, %	DT, %
	Oligochaeta					
1	*Branchiura sowerbyi* Beddard, 1892	R, ChS, AV	0.29	25.00		
2	**Dero digitata* (Müller, 1773)	R		8.33		
3	*Dero obtusa* d'Udekem, 1855	R	0.05	8.33		
4	*Ilyodrilus templetoni* (Southern, 1909)	Ogs	0.12	8.33		
5	*Limnodrilus claparedeanus* Ratzel, 1868	Pol, Ogs, AV	1.44	25.00	8.33	33.33
6	*Limnodrilus hoffmeisteri* Claparede, 1862	R, ChS, Kov, Ogs, SB, Dab, AV	6.24	58.33	16.67	28.57
7	*Limnodrilus profundicola* (Verrill, 1871)	AV	0.29	8.33		
8	*Limnodrilus udekemianus* Claparede, 1862	Dab	0.38	8.33		
9	*Limnodrilus sp. juv.*	Ras, Ogs	0.25	16.67	8.33	50.00
10	Lumbricidae gen. sp. juv.	SB	0.05	8.33		
11	**Nais variabilis* Piguet, 1906	R, Kov		16.67		
12	*Potamothrix hammoniensis* (Michaelsen, 1901)	Pol	1.50	8.33	8.33	100
13	*Tubifex tubifex* (Müller, 1774)	Pol, R, ChS, Kov, Ogs, SB, Dab	15.16	58.33	8.33	14.29
14	Tubificidae gen. sp. juv.	TK	0.05	8.33		
	Hirudinea					
15	**Erpobdella octoculata* (Linnaeus, 1758)	Kov, Ogs		16.67		
16	**Helobdella stagnalis* (Linnaeus, 1758)	ChS		8.33		
17	**Hirudo verbana* (Carena, 1820)	AV		8.33		
	Arachnida: Hydracarina					
18	Hygrobates sp.	Kov	0.10	8.33		
	Mysidacea					
19	**Limnomysis benedeni* (Czerniavski, 1882)	AV		8.33		
	Decapoda					
20	**Astacus astacus* (Linnaeus, 1758) (CC)	ChS		8.33		
21	**Astacus leptodactilus* Eschscholtz, 1823 (CC)	R, Dr, Kov, TK, Dab, AV		25.00		
	Ephemeroptera					
22	*Caenis macrura* Stephens, 1835	Kov	0.05	8.33		
23	*Caenis robusta* Eaton, 1884	Kov	0.05	8.33		
24	*Caenis* sp.	Pol, SB	0.05	16.67		
25	**Cloeon dipterum* (Linnaeus, 1761)	ChS, Kov, AV		25.00		
26	*Ephemera vulgata* Linnaeus, 1758 (CC)	SB	0.60	8.33	8.33	100
27	**Ephemera danica* Müller 1764	Ras		8.33		
28	*Procloeon pennulatum* (Eaton, 1870)	SB	0.05	8.33		
	Odonata					
29	Coenagrionidae gen. sp.	Ras, Ogs, SB	0.11	25.00		
30	**Erythromma viridulum* Charpentier, 1840	Kov		8.33		
31	*Gomphus* sp.	Ras, Kov, SB	0.14	25.00		
32	**Sympetrum* sp.	Pol		8.33		
	Heteroptera					
33	**Cymatia rogenhoferi* (Fieber, 1864)	Kov		8.33		
34	**Micronecta* sp.	Kov		8.33		
35	**Nepa cinerea*	Ogs		8.33		
36	**Sigara* (*Vermicorixa*) *lateralis* (Leach, 1817)	Kov		8.33		
	Coleoptera					
37	**Limnoxenus* sp.	Kov		8.33		
	Trichoptera					
38	**Ecnomus tenellus* (Rambus, 1842)	Pol, Ogs		16.67		

Table 2. Continued.

No.	Taxa	Reservoir	Percentage, %	pF, %	DF, %	DT, %
39	*Ecnomus* sp.	Kov, TK	1.10	16.67	8.33	50.00
40	Leptoceridae gen. sp.	SB	0.05	8.33		
	Diptera					
	Chaoboridae					
41	*Chaoborus crystallinus* (De Geer, 1776)	Kov, AV	22.00	16.67		
	Chironomidae					
42	*Cricotopus* gr. *algarum*	R, Ogs, AV	0.24	25.00		
43	**Cricotopus fuscus* (Kieffer, 1909)	Ogs		8.33		
44	*Cricotopus* (*Isocladius*) gr. *sylvestris*	Pol, R, Dab, AV	1.66	33.33	8.33	25.00
45	**Cricotopus* sp.	Ogs, AV		16.67		
46	*Chironomus* gr. *plumosus*	Pol, R, Dr, ChS, Kov, Ogs, Dab	2.28	58.33	8.33	14.29
47	*Chironomus* gr. *riparius*	Pol, R, Dr, ChS, Ogs, TK, AV	1.82	58.33	8.33	14.29
48	*Chironomus* sp.	ChS	0.05	8.33		
49	*Cladotanytarsus mancus* (Walker, 1856)	TK	0.05	8.33		
50	*Criptochironomus defectus* (Kieffer, 1913)	ChS, AV	0.47	16.67		
51	**Diamesa insignipes* Kieffer, 1908	Pol		8.33		
52	**Dicrotendipes nervosus* (Staeger, 1839)	Kov		8.33		
53	**Einfeldia longipes* (Staeger, 1839)	AV		8.33		
54	*Eukiefferiella clypeata* (Kieffer, 1923)	Ogs	0.04	8.33		
55	*Microtendipes chloris* (Meigen, 1804)	Kov	0.05	8.33		
56	*Polypedilum* gr. *nubeculosum*	Kov	0.42	8.33		
57	*Polypedilum* sp.	Dr	0.05	8.33		
58	*Tanytarsus* gr. *gregarius*	Dr, Kov, Ogs	1.23	25.00		
59	*Tanytarsus* sp.	TK, AV	0.10	16.67		
	Tvetenia sp.	Ogs	0.04	8.33		
60	Ceratopogonidae					
61	*Bezzia* sp.	R, ChS, Kov, Ogs, Brz, AV	2.53	50.00		
	Gastropoda					
62	*Bithynia tentaculata* (Linnaeus, 1758)	Kov	0.52	8.33		
63	*Gyraulus laevis* (Alder, 1838)	Kov	0.66	8.33		
64	*Physella acuta* (Draparnaud, 1805)	Kov, Ogs, TK, AV	0.90	33.33		
65	*Radix auricularia* (Linnaeus, 1758)	R, Kov, Ogs, AV	0.05	33.33		
66	*Radix balthica* (Linnaeus, 1758)	Ogs	0.05	8.33		
67	**Radix peregra* (O. F. Müller, 1774)	Ogs		8.33		
68	*Valvata piscinalis* (O. F. Müller, 1774)	Kov, AV	1.90	16.67	8.33	50.00
69	*Viviparus* sp.	R, ChS, TK	0.05	25.00		
	Bivalvia					
70	**Anodonta anatina* (Linnaeus, 1758)	Ogs		8.33		
71	*Dreissena bugensis* (Andrusov, 1897)	Ogs, AV	2.32	8.33	8.33	100
72	*Dreissena polymorpha* (Pallas, 1771)	R, Dr, Kov, Ogs, AV	32.47	16.67	8.33	100
73	*Pisidium* sp.	Kov	0.05	8.33		
74	**Unio pictorum* (Linnaeus, 1758)	Pol, R, Kov, AV		33.33		
75	**Unio tumidus* Philipsson, 1788	Kov		8.33		

A. astacus and *A. lelptodactilus* are protected by the Biological Diversity Act (2002).

The reservoirs Kovachitsa, Ogosta, Asparuhov Val and Rabisha were characterized with the highest diversity of macrozoobenthic taxa, and with the highest abundance of the invasive mussels *D. polymorpha* and *D. bugensis*, the larvae of Chironomidae, *Ch. crystallinus* and the Oligochaetes (Table 3). This may be a result of the complementary influence of several factors. The reservoirs Ogosta and Rabisha

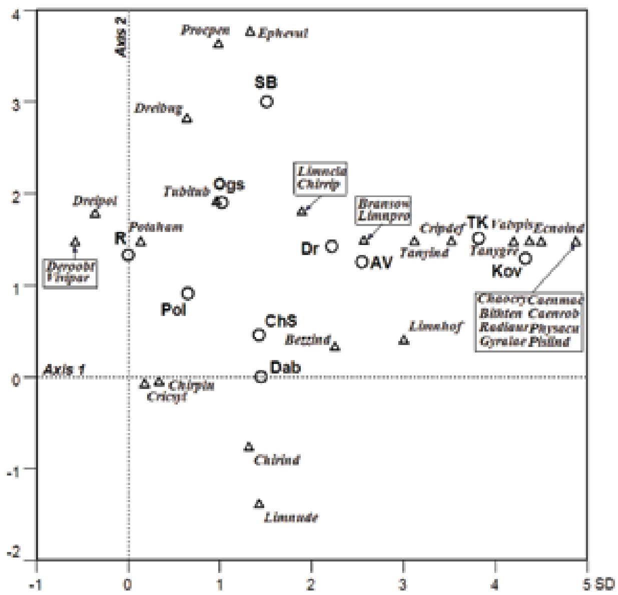

Fig. 3. Detrended Correspondence Analysis (DCA) ordination biplot ($\lambda_1 = 0.784$; $\lambda_2 = 0.378$) of macrozoobenthos data in ten of the studied reservoirs. Only species with weights > 2% are plotted on the diagram. The benthic invertebrate species shown are: *Bezzind=Bezzia* sp.; *Bithten=B. tentaculata; Bransow=B. sowerbyi; Caenmac=C. macrura*; *Caenrob=C. robusta; Chaocry=Ch. crystallinus*; *Chirind=Chironomus* sp.; *Chirplu=Ch.* gr. *plumosus; Chirrip=Ch.* gr. *riparius; Cricsyl=Cr.* gr. *sylvestris*; *Cripdef=C. defectus; Deroobt= D. obtusa; Dreibug= D. bugensis; Dreipol=D. polymorpha; Ecnoind=Ecnomus* sp.; *Ephevul = E. vulgata; Gyralae=G. laevis; Limncla= L. claparedeanus; Limnhof=L. hoffmeisteri; Limnpro=L. profundicola; Limnude=L. udekemianus; Physacu=Ph. acuta; Pisiind=Pisidium* sp.; *Potaham=P. hammoniensis*; *Procpen=P. pennulatum*; *Radiaur=R. auricularia*; *Tanyind=Tanytarsus* sp.; *Tanygre=T.* gr. *gregarious*; *Tubitub=T. tubifex; Valvpis=V. piscinalis; Viviviv=Viviparus* sp.

pollution, agricultural runoff, their disconnection from the Danube, high levels of groundwater input, etc.

Some authors reported a positive effect of enhanced Ca^{2+} concentrations and nutrient content on the presence of mollusks and other macroinvertebrate groups. The invertebrate fauna in clear-water localities varied considerably as a function of Ca^{2+} concentration at pH > 5,5, because at higher Ca^{2+} concentrations a greater number of species of snails, mussels and mayflies were present (Økland, Økland 1986; Lien *et al.* 1996). In the Rila high-mountain lakes, a higher number of gastropods and mussels were found in the lakes with high Ca^{2+} concentrations (Ognjanova-Rumenova *et al*. 2006). Our results also showed the largest number of recorded taxa of gastropods and mussels in the reservoirs Kovachitsa and Asparuhov Val (Fig. 3). The presence of high nutrient loading in these reservoirs also increased the abundance of detritivores species such as the oligochaete *L. hoffmeisteri* (Real *et al*. 2000, Slavevska-Stamenković *et al*. 2010). This species was recorded with the highest abundance (559 ind./m^2) in the Kovachitsa Reservoir. Another species found only in these two reservoirs and of extremely high abundance in the Kovachitsa Reservoir (2567 ind./m^2) was *Ch. crystallinus* (Fig. 3). The larvae of this species were reported in fishless lakes, being more abundant at highly eutrophic conditions (Pope *et al*. 1973, von Ende 1979, Wissel *et al*. 2003, Sweetman, Smol 2006). However, the enhanced nutrient loads in the reservoirs Asparuhov Val and Kovachitsa may have a negative effect on *Dreissena* populations (Trichkova *et al*. 2007). As already mentioned, despite the large deposits of shells of *D. polymorpha* and *D. bugensis*, no live specimens were found in these reservoirs during our study.

The values of transparency in the reservoirs ranged from 30 cm (Rasovo) to 450 cm (Srechenska Bara). The highest values were measured in the reservoirs Srechenska Bara, Ogosta (400 cm) and Rabisha (320 cm) (Figs. 2 and 3). As efficient filter feeders, the mussels *D. polymorpha* and *D. bugensis* were most likely responsible for the considerable increase in transparency in the reservoirs Rabisha and Ogosta (Trichkova *et al.* 2007). In the Srechenska Bara Reservoir, we found the hydrozoan *Craspedacusta sowerbii* at high abundance, which probably contributed to the increased transparency. This reservoir is used for drinking water supply (Table 1); it was characterized by clear water, very low nutrient loading and a sandy substrate. Comparatively high densities of the mayfly species *E. vulgata* and *P. pennulatum* which prefer a sandy substrate were found only in this reservoir (Fig. 3).

The most frequently found species in the studied reservoirs were the euryzonic and ubiquitous species, such as: *L. claparedeanus*, *L. hoffmeisteri*, *T. tubifex*, *Ch.* gr. *plumosus*, *Ch.* gr. *riparius, C.* gr. *sylvestris, T.* gr. *gregarius* and *Bezzia* sp. (Table 2, Fig. 3).

Seven metrics were used for the assessment of the ecological potential of the reservoirs (Table 3). Some of them were originally developed and applied to rivers, e.g. the modified Irish Biotic Index (BI) (Flanagan, Toner 1972, Clabby, Bowman 1979, Yaneva, Cheshmedjiev 1999). The highest value of Total number of taxa index based on the Irish Biotic Index – TTN (BI), was estimated in the Kovachitsa Reservoir, and accordingly the BI in this reservoir had the highest value compared to others (Table 3). The total abundance of taxa in Kovachitsa ranked second after Rabisha, it was mainly due to the high abundance of larvae of *Ch. crystallinus*, and the oligochaete *L. hoffmeisteri*. Only one invasive species in this reservoir was included in the analysis – *Ph. acuta*. *Dreissena* species were not taken into account in this reservoir and in Asparuhov Val, because of the absence of live specimens. Based on different parameters, the ecological potential of Kovachitsa Reservoir was assessed in the range from "Good" to "Moderate" (Table 3). The values of TTN (BI) in most of the other reservoirs ranged from 14 to 7, and correspondingly, the BI values were estimated at 3-2.5 (Table 3). In five of these reservoirs (Poletkovtsi, Christo Smirnenski, Tri Kladentsi, Srechenska Bara and Asparuhov Val), the total abundance of taxa was comparatively low – in the range from 54 to 761 ind./m^2. The number of invasive species ranged from 0 to 3, but their abundance was very low. Therefore, the ecological potential of these reservoirs was assessed as "Moderate". The reservoirs Poletkovtsi, Christo Smirnenski and Tri Kladentsi were used intensively for aquaculture and commercial fishing, which may have contributed to the deteriorated environmental conditions; large quantities of quicklime, used for the control of phytoplankton blooms, were observed deposited on the shores of Christo Smirnenski and Tri Kladentsi. A higher ecological potential was expected in Srechenska Bara Reservoir. The low diversity of macroinvertebrate taxa was probably due to the low variety of substrates, as the prevailing substrate in this reservoir was sand.

The reservoirs Rabisha and Ogosta were characterized by the highest total abundance of taxa (Table 3). In the Rabisha Reservoir, this was attributed mainly to the invasive mussel *D. polymorpha* (3832 ind./m^2), while in the Ogosta Reservoir – to both species *D. polymorpha* (245 ind./m^2) and *D. bugensis* (291 ind./m^2), as well as to the extremely high abundance of the oligochaete *T. tubifex* (1844 ind./m^2). Additionally the invasive oligochaete *B. sowerbyi* was found in the Rabisha Reservoir and the gastropod *Ph. acuta* in Ogosta. As a result of the high values of the Integrated biocontamination index and Integrated biological pollution risk index (Arbačiauskas *et al.* 2008, Panov *et al*. 2009), the ecological potential of these reservoirs was assessed in the range from "Moderate" to "Poor" (Table 3). It is important to consider the biocontamination for the assessment of the ecological potential of reservoirs, as being artificial and heavily modified water bodies, they are highly susceptible to invasions. Although some invasive species such as *Dreissena* may have some positive effects on other invertebrates (by providing refuges, microhabitats or food sources) (Kelly *et al*. 2010, see other references cited above), it was reported that water bodies with higher biocontamination, as a result of benthic macroinvetebrate invasions, had lower estimates of ecological quality (Arbačiauskas *et al.* 2008, Panov *et al*. 2009). On the one hand, the water bodies and sites of lower ecological status with respect to water quality and hydromorphology were more susceptible to biological invasions; and on the other hand, the biocontamination directly affected the ecological quality by changing the environment and by suppressing native communities (Arbačiauskas *et al.* 2008, Kelly *et al*. 2010). The metrics currently used do not always reflect the potential impact of invasive alien species. Atalah *et al.* (2010) studied the performance of 3 ecological quality assessment tools based on macroinvertebrate assemblages in lakes in relation to *D. polymorpha* invasions, and found out that the three metrics performed consistently well in non-invaded systems, but they lost explanatory power for eutrophication pressure in invaded systems. The development of separate metrics for *Dreissena* invaded and non-invaded systems was suggested (Atalah *et al.* 2010).

The ecological potential of the reservoirs Rasovo, Drenovets and Dabnik was assessed as "Poor", and that of Barzina as "Bad" (Table 3). The values of TTN (BI) in these reservoirs ranged from 1 to 4, and the BI was estimated at 1-2. The taxonomic composition was dominated by oligochaetes and chironomid larvae, and the total abundance of taxa was low. The reservoirs Rasovo and Drenovets were used intensively for aquaculture and commercial fishing, including carp cage farming in Drenovets. Phytoplankton bloom and the use of quicklime for its control (it was deposited in large quantities on the reservoir shores) most likely had some adverse impact on the benthic macroinvertebrates. The Dabnik Reservoir was used for industrial water supply. Local spills of chemical pollutants near the dam of this reservoir most likely caused the mortality of some fish and crayfish observed on the shores, and probably that of other macroinvertebrates as well. Only one taxa – *Bezzia* sp. was found in the Barzina Reservoir. This was a small and shallow reservoir, with a prevailing muddy substrate and enhanced euthrophication.

Table 3. Ecological potential of the reservoirs in North-West Bulgaria. TTN - Total number of taxa recorded; the total number of taxa from quantitative samples are given in brackets (*); TTN (BI) - Total number of taxa based on the modified Irish Biotic Index (BI); N - Total abundance (ind./m^2); % Oligo - % Oligochaeta; % ODT- Oligochaeta & Diptera Taxa : N ratio; BI- modified Irish Biotic Index; IBCI - Integrated biocontamination index; IBPR - Integrated biological pollution risk index; (*) – only data from quantitative samples were used in the assessment.

Reservoir Code	TTN (*)	TTN (BI)	N* ind./m^2	% Oligo*	% ODT*	BI	IBCI	IBPR	Ecological Potential
Pol	11 (6)	7	529	42	100	2.5	0	0	Moderate
R	16 (9)	10	4058	0.6	5.6	2.5	4	4	Moderate-Poor
Dr	6 (4)	4	83	0	100	2	0	0	Poor
ChS	12 (4)	8	54	22	100	2.5	0	1	Moderate
Ras	4 (1)	4	12	100	100	2	0	0	Poor
Kov	32 (17)	24	3929	14	20.1	3.5	1	1	Good-Moderate
Ogs	25 (15)	12	2643	75	79.2	3	2	3/4	Moderate-Poor
TK	8 (5)	7	107	6	22.4	2.5	0	1	Moderate
Brz	1 (1)	1	18	0	100	1	0	0	Bad
SB	9 (9)	8	149	24	24.2	2.5	0	0	Moderate
Dab	6 (5)	4	220	70	100	2	0	0	Poor
AV	23 (10)	14	761	31	97.6	3	2	1	Moderate

Conclusions

The reservoirs in North-West Bulgaria, the Danube River basin, were characterized by a comparatively high diversity of macroinvertebrate taxa, dominated by cosmopolitan species. Most abundant were the invasive bivalve mollusks *D. polymorpha* and *D. bugensis*, the larvae of *Ch. crystallinus* and the oligochaetes. The highest taxa diversity was recorded in the reservoirs located in close proximity to the Danube River (Kovachitsa and Asparuhov Val) and in the reservoirs with the largest areas (Ogosta and Rabisha), which offered a variety of substrates. A potential factor for the distribution of mactroinvertabrate taxa appeared to be the occurrence and abundance of invasive *Dreissena* species – live specimens (in Ogosta and Rabisha) or shell deposits (in Kovachitsa and Asparuhov Val). Additionally, some water physico-chemical parameters, such as: transparency, Ca^{2+} concentration and electrical conductivity (used here as a proxy of nutrient load) may have a potential influence on the macroinvertabrate distribution in the reservoirs.

Based on macroinvertebrate metrics for the assessment of the ecological status of surface waters, such as: number of taxa, share of oligochaete and dipteran species, total abundance, modified Irish Biotic Index, as well as the presence and abundance of invasive species, the ecological potential of the reservoirs was assessed in the range from “Good” to “Bad”. Most of the reservoirs were assessed as having “Moderate” ecological potential. The results indicate the need for immediate actions for development and application of restoration measures aiming to improve the environmental conditions and achieve the “Good” ecological potential of the reservoirs as required by the EU WFD. Because of the growing threat of introduction of invasive alien species (IAS) to the inland waters in Bulgaria, the application and development of macroinvertebrate metrics and assessment tools for lakes, which consider the presence and impact of IAS, is recommended. The problem of IAS is also crucial for consideration in river basin and reservoir management strategies in order to prevent further spread and mitigate the impact of aquatic IAS.

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