ACTA ZOOLOGICA BULGARICA

Acta Zool. Bulg., Supplement 16, 2023: 49-60

Zoological Proceedings of the 9th International Conference "Modern Trends in Science", Blagoevgrad, Bulgaria, 15–19 September 2021

Research Article

http://www.acta-zoologica-bulgarica.eu/2022/Suppl_16_05

Macrozoobenthos in Mountain Standing Water Bodies in Bulgaria

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Abstract: A survey of macrozoobenthos in selected standing water bodies situated in mountain areas of Bulgaria was carried out. The study was conducted in the summer of 2020 (July-August) at one lake (Trevisto Lake – Rhodopes Mts.) and eight reservoirs (Ognyanovo – Sredna Gora Mts.; Bebresh, Hristo Smirnenski and Yovkovtsi (two sites) – Balkan Mts.; Belmeken – Rila Mts.; Batak, Golyam Beglik and Shiroka Polyana (two sites) – Rhodopes Mts.). These water bodies are classified as mountain type of water bodies according to the Bulgarian National Typology and are situated in two ecoregions, i.e. Ecoregion 7 (Eastern Balkans) and Ecoregion 12 (Pontic Province). Totally, 120 taxa have been identified. The macroinvertebrate communities were specific to lentic waters and were dominated by oligochaetes and chironomid larvae. Larvae of dragonflies, mayflies and caddisflies as well as aquatic beetles, freshwater gastropods and mussels were also present with great taxonomic diversity. The influence of the environmental factors on the formation of the macroinvertebrate communities in the studied lentic ecosystems was analysed.

Key words: macroinvertebrates, taxonomic composition, lake, reservoirs

Introduction

Benthic macroinvertebrates are important components of freshwater ecosystems; they are involved in ecological processes such as energy transfer between detritus and consumers and organic matter recycling (Zerlin & Henry 2014) and play an essential role in key ecosystem processes (food chain dynamics, productivity, nutrient cycling and decomposition) (Solimini et al. 2006). The zoobenthos is the major source of food to most lake-dwelling fish and can control the amount and composition of phytoplankton, zooplankton, attached algae and aquatic plants in lakes (Strayer 2009). Invertebrates inhabiting alpine water bodies are sensitive to environmental variability and lake faunal communities can be important indicators of long-range airborne pollution, climate change and other human impacts (Fjellheim et al. 2009).

In Bulgaria, there are no up-to-date systematic data on the aquatic invertebrates in mountain stagnant ecosystems. In an earlier study, Pavlova et al. (2012) considered macrozoobenthos as a component of representative aquatic communities in the

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Rhodopes Mountain landslide lakes (South Bulgaria) and their changes for the last 40 years. Vidinova et al. (2016) presented comprehensive faunistic composition of Bulgarian standing water bodies, including also species diversity and distribution of benthic macroinvertebrates in some mountain lakes and reservoirs based on a monitoring programme 2011–2012 (Varadinova et al. 2011, 2012). In recent years, studies have focused on developing an appropriate methodology and assessment of the status of different types of standing waters (including mountain water bodies) based on macrozoobenthos (Chesmedjiev et al. 2013, Trichkova et al. 2013, Obolewski et al. 2014, Smilyanov et al. 2018, Subeva et al. 2019, Varadinova et al. 2019, Varadinova & Smilyanov 2020).

The aim of this study is to present the current composition of macroinvertebrate communities in representative mountainous standing water bodies in relation to the conditions in the aquatic environment.

Materials and Methods

Study area

The survey was conducted in the summer (July and August) of 2020 in nine standing water bodies (11 sites) situated in Bulgaria. These included one lake and eight reservoirs (Fig. 1). The studied lentic ecosystems, located at different altitudes, belonged to different ecoregions and water body types (Table 1).

Sampling methods

The multi-habitat approach for macrozoobenthos samplings was applied following Cheshmedjiev et al. (2011) and in accordance with BDS EN ISO 10870:2012 standard. The benthic samples were transferred into plastic jars and fixed in 70% ethanol until transportation to the laboratory. Laboratory treatment of the collected sample included washing, cleaning and sorting according to the taxonomic affiliation of the found macroinvertebrates.

The particle size distribution of the bottom substrate was analysed on site and the physicochemical parameters such as water temperature (Temp, ^{o}C), oxygen concentration (O_2, $mg.dm^{-3}$), conductivity (Cond, $\mu S.cm^{-1}$) and pH were measured *in situ* using portable Windaus Labortechnik Package and HANNA multi-parameter package. Nutrients, i.e. total phosphorus (TP, $mg.dm^{-3}$) and total nitrogen (TN, $mg.dm^{-3}$) were measured in an authorised laboratory. Standard ISO 5667-3:2018 was applied for water samples processing.

Methods of analyses

The Excel 2010 program was used to visualize the number of taxa and abundance by taxonomic groups and studied sites. Pearson correlations and their level of significance among water parameters were identified using R 4.0.3. (R Core Team 2021). Statistical package Canoco 5, PCA analyses and unconstrained method was used to present the ordination distribution of the environmental factors and studied points. Primer v. 6 statistical package and its functions RELATE, BEST and non-parametric distance-based linear model regression were applied to analyse the relationship between the biological and environmental data matrices. Biological data were transformed with a square-root. Environmental data were logarithmic transformed and normalised.

Results

Macrozoobethos species composition

Totally, 120 macroinvertebrate taxa were recorded, most of them to the species level (Table 2). The dominant group (in terms of both abundance and species richness) was the Oligochaeta (20 taxa, 1283 individuals) (Fig. 2). The most common among them were *Limnodrilus* sp., *Nais communis* and *Stylaria lacustris.* Heteropterans were registered as the second group based on their density, which is mainly due to the *Micronecta* sp. (500 individuals were found at Ogn_R). Chironomidae (Diptera) was the richest family of aquatic insects and was represented with 19 taxa, followed by other Diptera (excluding Chironomidae) recorded with 16 taxa. Within midge larvae, *Ablabesmyia* sp. and *Tanytarsus* sp. were the most frequent. Both genera were found in seven of the total 11 studied sites.

Given the specific characteristics of the stagnant ecosystems, taxa typical for lentic environments were found in the composition of benthic communities. Among the snails, *Acroloxus lacustris, Gyraulus albus, Haitia acuta, Radix auricularia* and *Peregriana labiata*, all inhabiting stagnant and slow-flowing clear waters, were found. *Anodonta anatina* prefers a finer sandy bottom, representative for Yov_R. *Musculium lacustre* is dwelling in small, swampy and not very deep waters, which have been observed on Tre_L. Among the caddisflies, *Agraylea sexmaculata, Ecnomus tenellus*, *Oecetis ochracea* and the representatives of genus *Mystacides* are typical for stagnant and slowly flowing waters. All the mayflies found in this study are commonly seen in standing waters; *Caenis robusta* and *C. horaria* are typical inhabitants of the coastal zone of lakes

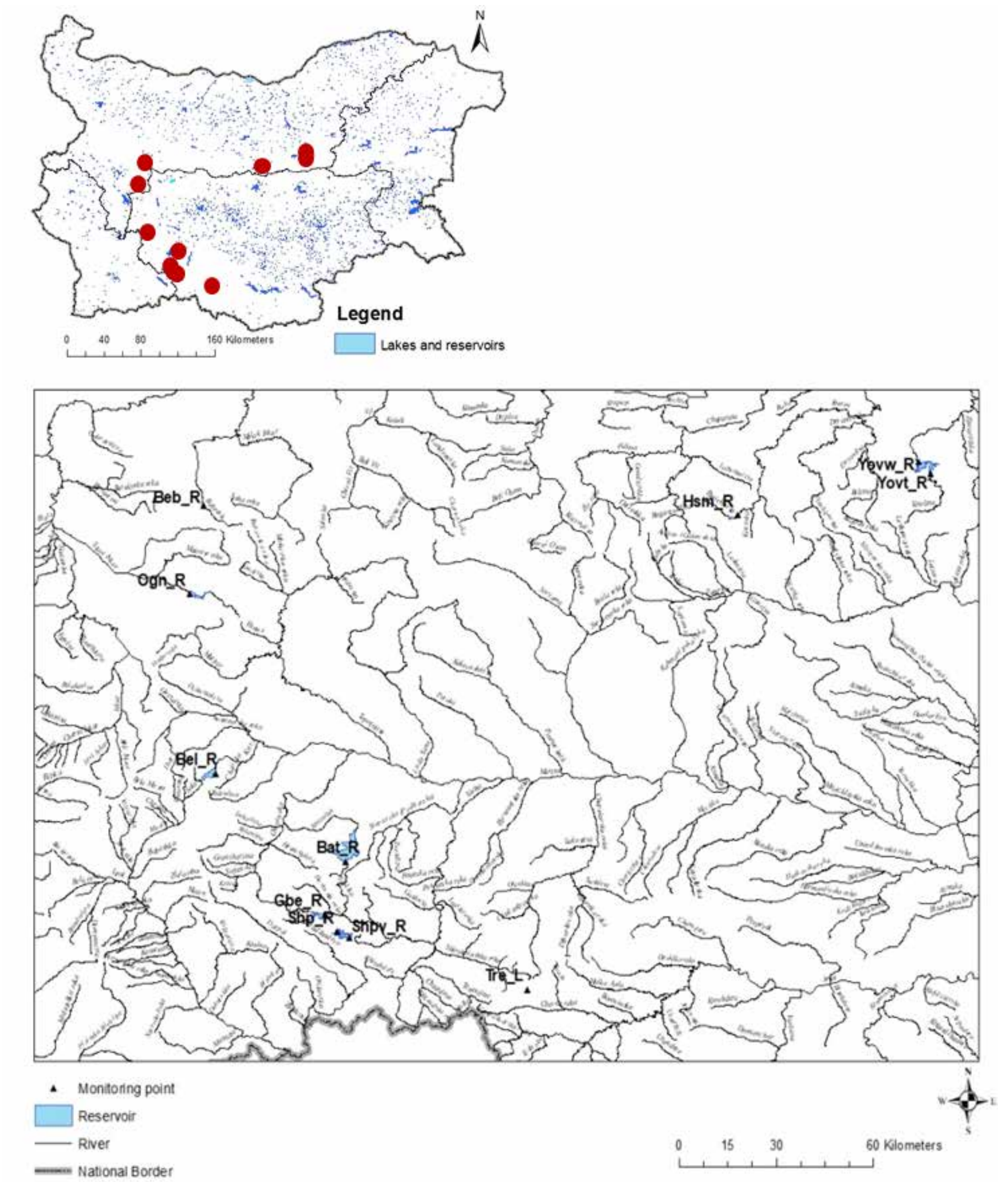

Fig. 1. Map of the studied sites. For site codes, see Table 1.

Table 1. Names and specific characteristics of the studied water bodies

Mountain	Water bodies	Code	Ecoregion	Type	Geographic coordinates		Altitude (m)
					Y	X	
Rhodopes Mts.	Trevisto Lake	Tre_L	7	L3	41.6209	24.67791	1533
Sredna Gora Mts.	Ognyanovo Reservoir	Ogn_R	12	L2	42.368061	23.44542	619
Balkan Mts.	Bebresh Reservoir	Beb_R	12	L2	42.49918	23.47103	468
	Hristo Smirnenski Reservoir	Hsm_R	12	L2	42.48892	25.16025	520
	Yovkovtsi Reservoir – tail	Yovt_R	12	L2	42.55159	25.47545	369
	Yovkovtsi Reservoir – wall	Yovw_R	12	L2	42.56762	25.45844	339
Rila Mts.	Belmeken Reservoir	Bel_R	7	L3	42.1640	23.81488	1930
Rhodopes Mts.	Batak Reservoir	Bat_R	12	L3	41.94312	24.17508	1109
	Golyam Beglik Reservoir	Gbe_R	7	L3	41.81063	24.11977	1532
	Shiroka Polyana Reservoir	Shp_R	7	L3	41.76722	24.1531	1534
	Shiroka Polyana Reservoir – village zone	Shpv_R	7	L3	41.7522	24.18672	1531

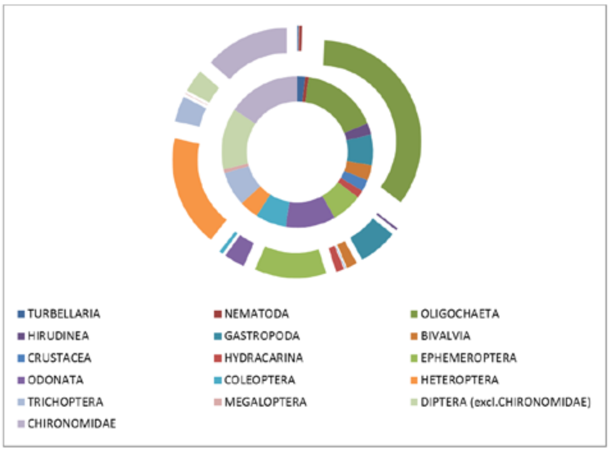

Fig. 2. Number of taxa (inner circle) and absolute abundance (outer circle) of the taxonomic groups.

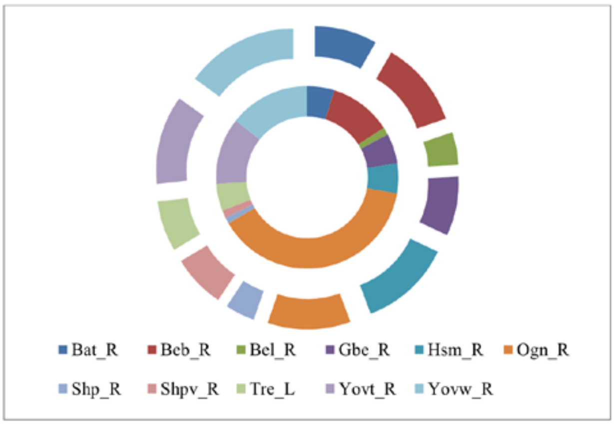

Fig. 3. Number of taxa (outer circle) and absolute abundance (inner circle) of the studied sites. For site codes, see Table 1.

and reservoirs. The larvae of the dragonflies *Coenagrion puella, Enallagma cyathigerum, Ischnura elegans, Aeshna* sp. and *Anax imperator,* which are defined as limnophilous epiphytic species, live only on submerged vegetation in stagnant waters, such as our studied points. Limnophilous benthic representatives of the families Corduliidae and Libellulidae also prefer standing waters (Table 1). The species of chironomid genera *Procladius, Anatopynia* and *Dicrotendipes*, found in our study, inhabit littoral sediments and muddy substrata of standing waters and may be common in lentic habitats. *Kiefferulus tendipediformis* is registered regularly in dystrophic small water bodies. *Paratanytarsus* sp. inhabits diverse habitats in standing waters (lakes, reservoirs and marshes) as well as rivers and streams. The species of the other chironomid genera are widespread in various lotic and lentic water bodies. All recorded species of snails and mussels are often found in standing waters but, among them, the most typical inhabitants of such environments are *Haitia acuta, Radix auricularia* and *Viviparus acerosus. Pontastacus leptodactylus* found in Yovw_R was more often met in lentic ecosystems.

In this study, the non-indigenous tubificid worm *Branchiura sowerbyi* was registered only in Yovkovtsi Reservoir (Yov_R, Yovw_R). The snails and mussels found have low conservation status. The only exception is *Dreissena polymorpha* (found in 5 out of 9 studied sites), for which the IUCN criteria are assessed as „not applicable“. All other species are included in the IUCN Red List of Threatened Species in the category “least concern”. Of the two identified in Yovw_R species, which belong to order Decapoda, noble crayfish *Astacus astacus* has higher conservation status and is included in the IUCN Red List of Threatened Species as „vulnerable“. The narrow-clawed crayfish *Pontastacus leptodactylus* is characterised as „least concern“.

The two sites of the Yovkovtsi Reservoir (Yovt_R, with 30 taxa), and Yovw_R with 38 taxa) and the Hristo Smirneski Reservoir (Hsm_R – 31 taxa) had the most species-rich benthos. The highest community abundance was recorded at Ogn_R (1101). Shp_R was characterised with the poorest taxonomic composition (10) and the lowest abundance (30) (Fig. 3). The Trevisto Lake, which is the only natural water body in our study, was characterised by 17 taxa and 136 specimens.

Environmental variables

The reservoirs Ogn_R, Beb_R, Yovw_R, Yovt_R and Hsm_R_R were distinguished by a diverse bottom substrate, which included stones, sand, gravel, silt and dead organic matter. A greater presence of macrophytes was found in Ogn_R. Peaty predominated (90%) in the bottom substrate of Tre_L. Bel_R stood out with a dominant presence of stones and gravel (60%), Shp_R– natural organic and detritus (80%), Gbe_R and Shpv_R – sand (50% and 60%), Bat_R – silt (50%).

The values of Temp were typical for the sampling season and the altitude of the studied reservoirs. The highest temperatures were registered at Yov_R (26.8°C), Ogn_R (26.4°C), Yovw_R(25.5°C), Beb_R (23.5°C) and Hsm_R (23.4°C). The lowest values were recorded in the water bodies, which are located at the highest altitude - Bel_R and Tre_L (17.5 °C each).

High positive correlation was found between pH and O_2. Altitude (Alt) significantly and positively correlated with Cond and showed an indirect relationship with the concentration of nutrients, pH and oxygen content. The concentration of TN cor-

Table 2. List of taxa of macroinvertebrates of the studied mountain standing water bodies, with their abundance per site (ind./m²). For codes of the names of the water bodies, see Table 1.

Taxa	**Bat_R**	**Beb_R**	**Bel_R**	**Gbe_R**	**Hsm_R**	**Ogn_R**	**Shp_R**	**Shpv_R**	**Tre_L**	**Yovt_R**	**Yovw_R**
TURBELLARIA											
Schmidtea lugubris (Schmidt, 1861)										4	
Girardia tigrina (Girard, 1850)		2									
NEMATODA – Indet.	6					4	3	5			1
OLIGOCHAETA											
Branchiura sowerbyi Beddard, 1892		3								12	31
Chaetogaster diaphanus (Gruithuisen, 1828)					3						1
Dero digitata (Müller, 1774)								3		20	
Dero obtusa Udekem, 1855		6									9
Dero sp.		1				8					
Enchytraeidae gen. sp.				2			3		10		
Limnodrilus sp.	48	11	2		162	9				27	
Lumbriculus variegatus (Müller, 1774)		1									
Nais barbata Müller, 1774					66						
Nais bretscheri Michaelsen, 1899	2										
Nais communis Piguet, 1906		1			132	19		6		30	18
Nais elinguis Müller, 1774						27		2			9
Nais pseudobtusa Piguet, 1906	1				198			2		10	
Nais simplex Piguet, 1906	1				66						
Nais variabilis Piguet, 1906											4
Nais sp.					33						4
Pristina (*Pristina*) *aequiseta* Bourne, 1891							11				
Stylaria lacustris (Linnaeus, 1767)				2	163	24				57	8
Tubifex tubifex (Müller, 1774)									2		
Tubificidae gen. sp.						12				1	
HIRUDINEA											
Erpobdella octoculata (Linnaeus, 1758)									5		
Erpobdella sp.	1										
Hemiclepsis marginata (O. F. Müller, 1774)		9									
GASTROPODA											
Acroloxus lacustris (Linnaeus, 1758)						1					
Gyraulus albus (O. F. Müller, 1774)				1							
Gyraulus laevis (Alder, 1838)		43									
Physa fontinalis (Linnaeus, 1758)											4
Haitia acuta (Draparnaud, 1805)		6			3					1	
Radix auricularia (Linnaeus, 1758)		153		1	3					1	
Peregriana labiata (Rossmässler, 1835)	5										
Viviparus acerosus (Bourguignat, 1862)	4	5				2					
BIVALVIA											
Anodonta anatina (Linnaeus, 1758)										1	
Dreissena polymorpha (Pallas, 1771)		7			1	10				11	32
Musculium lacustre (O.F.Müller, 1774)									1		
Pisidium casertanum (Poli, 1791)					1						
CRUSTACEA											
ISOPODA											

Table 2. Continuation.

Taxa	**Bat_R**	**Beb_R**	**Bel_R**	**Gbe_R**	**Hsm_R**	**Ogn_R**	**Shp_R**	**Shpv_R**	**Tre_L**	**Yovt_R**	**Yovw_R**
Asellus aquaticus (Linnaeus, 1758)		1									
DECAPODA											
Astacus astacus (Linnaeus, 1758)											1
Pontastacus leptodactylus (Eschscholtz, 1823)											1
HYDRACARINA gen. sp.						20					
Hydrachnidae gen. sp.				3	7		3	2		14	
EPHEMEROPTERA											
Caenis horaria (Linnaeus, 1758)	1				1			1		1	113
Caenis macrura Stephenes, 1835		2				5				1	
Caenis robusta Eaton, 1884		1				128					
Caenis sp.				3							
Procloeon pulchrum (Eaton, 1885)		1									
Cloeon dipterum (Linnaeus, 1761)	26	1				123					2
Cloeon simile (Eaton, 1870)					3	3					
Cloeon sp.									9		
ODONATA											
Aeshna sp.									1		
Anax imperator Leach, 1815											3
Calopteryx splendens (Harris, 1782)										2	
Coenagrion puella (Linnaeus, 1758)				3							
Coenagrionidae gen. sp.	1									3	29
Corduliidae gen. sp.										10	
Enallagma cyathigerum (Charpentier, 1840)				28							
Gomphus sp.								1			
Ischnura elegans (van der Linden, 1820)		1				7					
Libellulidae gen. sp.					15						
Onychogomphus forcipatus (Linnaeus, 1758)		4									
Orthetrum cancelatum (Linnaeus, 1758)					5	2					7
Platycnemis pennipes (Pallas, 1771)		2									
COLEOPTERA											
Dytiscidae gen. sp.							1		1		
Elmis sp.			1								
Elmidae gen. sp.	1						2				
Hydrophilidae gen. sp.								2			
Laccophilus sp.						1					
Platambus maculatus (Linnaeus, 1758)				12							
Platambus sp.			1								
Stenelmis sp.								1			
HETEROPTERA											
Corixidae gen.sp.				1						26	
Ilyocoris cimicoides (Linnaeus, 1758)	1										
Micronecta sp.		8			5	500					7
Gerridae gen. sp.				2							
Plea sp.					85				1	25	
TRICHOPTERA gen. sp.									2		

Table 2. Continuation.

Taxa	**Bat_R**	**Beb_R**	**Bel_R**	**Gbe_R**	**Hsm_R**	**Ogn_R**	**Shp_R**	**Shpv_R**	**Tre_L**	**Yovt_R**	**Yovw_R**
Agraylea sexmaculata Curtis, 1834					2						
Chaetopterygini gen. sp.			1								
Ecnomus tenellus (Rambur, 1842)					4	8				1	11
Mystacides longicornis (Linnaeus, 1758)				56				1			
Mystacides sp. (cf. *nigra*)				2							
Mystacides sp.	1	1		24				1			
Oecetis ochracea (Curtis, 1825)		6									
Orthotrichia sp.						10					14
Potamophylax sp. (cf. *latipennis*)	7										
MEGALOPTERA											
Sialis lutaria (Linnaeus, 1758)					2					1	
DIPTERA gen. sp.		1		2				5	3		
Ceratopogonidae gen. sp.				1						1	1
Bezzia sp.					6					1	3
Culicoides sp.						1					
Culicidae gen. sp.			22		8		1		33		
Anopheles sp.					1						
Culex sp.									12		14
Chironomidae gen. sp.											
Ablabesmyia sp.	3	15			2	8			4	1	4
Anatopynia sp.									1	6	
Chironomini gen. sp.			1								
Chironomus sp.		3	1	5	1						
Corynoneura sp.	2						2	4	19		
Cricotopus sp.					2	23			21		
Cryptochironomus sp.	5	3				5				2	
Dicrotendipes sp.						7					
Kiefferulus tendipediformis Goetghebuer, 1921											1
Metriocnemus sp.			3					1			
Orthocladiinae gen. sp.							3	1			
Paratanytarsus sp.			2								
Polypedilum nubeculosum (Meigen, 1804)		16			5	78				24	
Polypedilum bicrenatum Kieffer, 1921										19	
Polypedilum sp.							1	1		3	
Procladius sp.					6						12
Psectrocladius sp.	9		1								
Empididae gen. sp.				1							
Ephydridae gen. sp.											4
Simuliidae gen. sp.			3								
Sciomyzidae gen. sp.											1
Stratiomyidae gen. sp.											
Stratiomys sp.											1
Tanypodinae gen. sp.	6			1							
Tanytarsus sp.	6			1	18	56		1		20	58
Dixidae gen. sp.											
Dixa sp.									11		

responded to the concentration of TP (Fig. 4).

The PCA of the environmental variables revealed that the first two ordination axes explained 76.01 % of variance (the first axis c. 59 % and the second axis c. 17 % of variation) (Fig. 5). The first axis formed a gradient that separates sites (located to the right of the ordination diagram) with a lower pH (<8.5), lower Alt (below 620 m), higher Cond (above 299 µS/cm) and higher values of nutrients (TP and TN). The second axis correlated with the oxygen concentration and divided the studied sites into two groups. The first group included water bodies with O_2 up to 10 mg/l. The second group (positioned at the bottom of the ordination diagram) represented the sites with oxygen rich waters (above 10 mg/l). These were Hsm_R, Ogn_R, Shp_R, Shp_R, Yovt_R and Yovw_R.

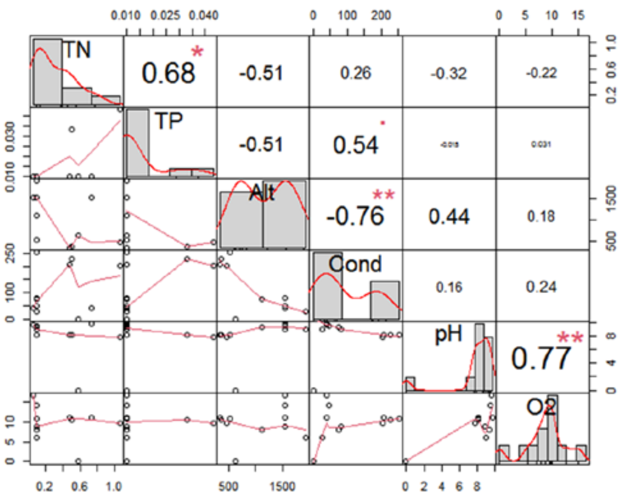

Fig. 4. Correlation analysis of selected environmental parameters with indication of the Pearson Correlation Coefficient. The significant correlations are indicated by stars.

RELATE analysis showed a significance level of statistics lower than 0.05 (p=0.02) only between matrices of biological data and the variables Alt, Cond, pH, O_2 and Temp and a higher one with nutrients and substrate. BEST analysis demonstrated that the highest correlation (0.730) had Alt, Cond, O_2 and Temp. According to the non-parametric distance-based linear model regression, only Cond, Alt and Temp had statistical significance (0.001, 0.002 and 0.001, respectively). The water bodies grouped on the ordination plot by type (L2 and L3) as those of type L3 were characterised with the higher Alt; those of L2 were with higher values of Cond (Fig. 6). The location of the sites according to Temp revealed a

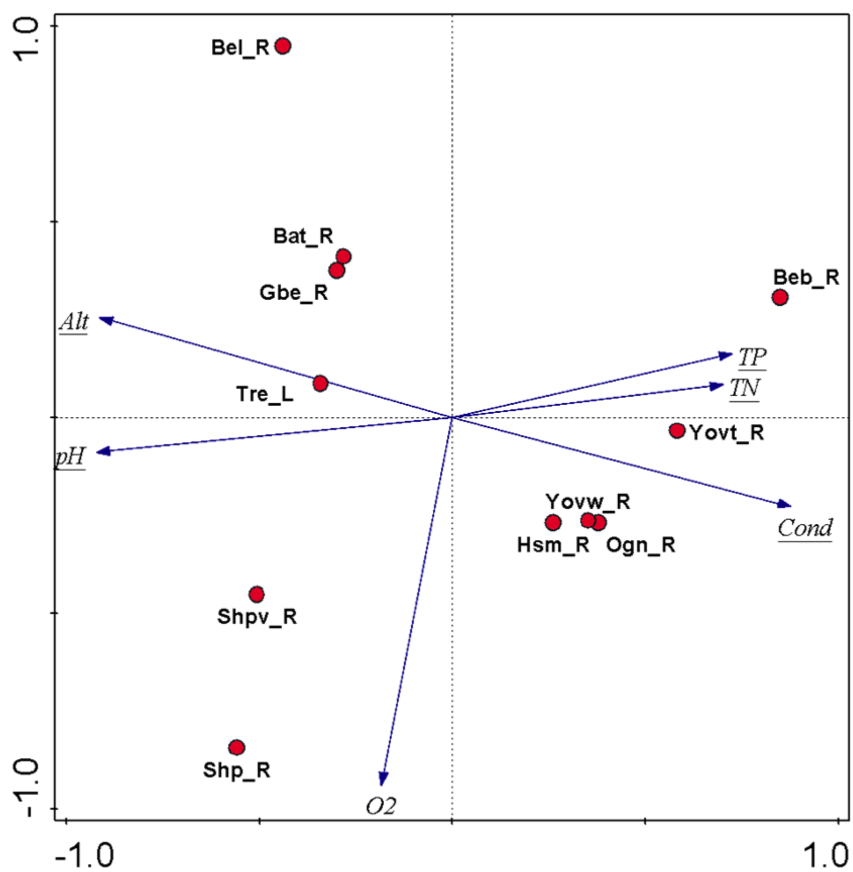

Fig. 5. Correlation biplot based on PCA of altitude and physicochemical parameters of 11 sites of the studied standing water bodies. For site codes, see Table 1.

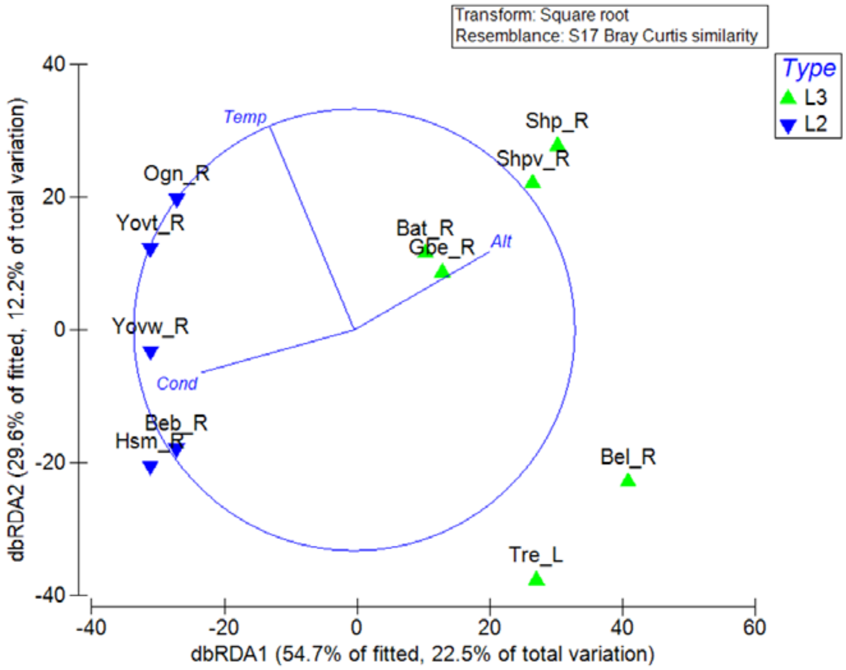

Fig. 6. Distance-based Redundancy Analysis (dbRDA) plot diagram of the biological matrix and environmental variables matrix (the first axis showed 22.5% and the second axis 12.2% of the macroinvertebrate taxa abundance in correspondence to the environmental variables of the studied standing water bodies. For site codes, see Table 1.

strong distinction between three groups. These were with lowest temperature (Tre_L, Bel_R – values of 17.5 °C), with higher temperature (Bat_R, Gbe_R, Shpv_R, Shp_R – values 21.7°C ÷22.3°C) and with highest temperature (Hsm_R, Beb_R, Yovw_R, Yovt_R, Ogn_R – values 23.4°C ÷26.8°C).

Discussion

The studied water bodies belong to the mountain type according to the national typology of surface waters in Bulgaria; they are lakes in the Ecoregion 7 (Eastern Balkans) and the Ecoregion 12 (Pontic Province) (Table 1). These lakes are considered oligotrophic, have a diverse substrate, relatively cold waters and polymictic character. In general, mountain ecosystems are much less influenced by human impact, including by pollutions from agriculture and wastewaters, as they are situated at higher elevations. The main pressure is resulting from hydromorphological changes (mainly water level fluctuation) and insignificant local influences, mainly activities such as fishing, recreation and tourism. Thus, these water bodies, which are relatively unaffected by anthropogenic activity, are characterised by rich species diversity. This has also been observed in our study. The relatively poor taxonomic composition found in Bel_R and Shp_R was probably a result of significant fluctuations in the water level, especially in the littoral zone due to the intense water use for drinking and industrial purposes. Pilotto et al. (2015) recommended littoral benthic fauna to be used for assessment of the impacts of morphological alterations; they determined indicator taxa of morphologically-altered shorelines and separated sites into three groups: unmodified sites, soft altered (mainly Oligochaeta) and hard altered (Chironomidae, *Ecnomus tenellus, Hydroptila* sp., Ceratopogonidae and others) sites. The development of approaches for assessing the relation between the degree of morphological changes in the littoral zone of standing water bodies and the indicative potential of species sensitive specifically to hydromorphological changes will be the subject of our future research.

The formation of the environmental conditions in the lake habitats is a result of a complex action of the environment variables. The major factors influencing the structure of the zoobenthos include the quantity and quality of organic matter inputs (e.g. primary production), biotic interactions such as fish predation and macrophyte cover, lake morphometry, water chemistry (including dissolved oxygen), temperature, sediment grain size and disturbance (Streyer 2009). Solimini et al. (2006) emphasised the importance of spatial and temporal factors on assemblage dynamics and relative bioindicator behaviour of invertebrates. As most of the aquatic parameters are closely related to each other, it is difficult to segregate the effect of each one on the distribution of macroinvertebrates (Kagaloua et al. 2006). In the mountain lakes, environmental factors are closely related to altitude, resulting in a complex series of relationships, in which the effects of particular variables are difficult to disentangle (Mendoza & Katalan 2010). The complementary interaction of the physical factors of the aquatic environment form the so-called altitudinal environmental gradient, i.e. altitude and altitude-related variables. Mendoza & Katalan (2010) revealed strong relevance of the altitudinal gradient by means of its environmental components and its potential influence on the number of macroinvertebrate groups per lake observed along altitude. According to Koperski (2011), different groups of benthic invertebrates may be strongly affected by simple, abiotic environmental parameters and diversity of different groups of macrobenthos is driven by specific factors. This probably explains the formation of specific non-unified benthic communities in the relatively anthropogenically-unaffected mountain ecosystems. The specific individual preferences of each species are also essential. Thus, in the reservoirs we studied, despite the predominant presence of aquatic worms and chironomid larvae, diversity with respect to other taxonomic groups was registered. Füreder et al. (2006) pointed out that benthic assemblages in the littoral zone of European high-mountain lakes appeared to resemble each other, no matter of the location of their examination. Parameters as the natural variability of substrate, water chemistry, organic matter availability and predator–prey interactions are known to affect macroinvertebrate communities. When one moves higher in elevation or latitude, biotic interactions are considered to lose impact, whereas abiotic conditions increasingly become more important. Our study revealed that the essential role for the formation of the aquatic environment and macrozoobethos in the studied mountain aquatic ecosystems in the studied sites had Alt, Cond, Temp and O_2 (Figs. 5 and 6).

Habitat complexity is a key factor for diversity of the macrozoobenthos and offers a variety of niches for the different benthic organisms (Anderson et al. 2017). Surface texture can contribute to differences in macroinvertebrate communities (Molokwu et al. 2014). According to Heino et al. (2000), the total species richness increased with habitat heterogeneity, which was apparently due to the positive effects of spatial heterogeneity on resource diversity. Our study showed that water bodies (Yovt_R, Yovw_R, Ogn_R, Beb_R and Hsm_R), which were characterised with the most diverse bottom substrates, have the greatest taxonomic richness.

Nitrogen and phosphorus are the major nutrients causing eutrophication of surface waters but they are also a source of the resource diversity in the lentic water bodies. These partially originate from natural sources but mainly from anthropogenic sources in areas affected by various human activities. The registered higher values of nutrients in certain water bodies (Beb_R, Ogn_R, Yovw_R) are mainly the result of fishing, recreation and tourism (RBMP 2016-2021). These reservoirs are located at lower altitude and are more affected by human impact. Elevated nutrient values were not recorded at the studied sites situated at higher altitudes (Table 1). Some of these reservoirs (Bel_R, Gbe_R and Hsm_R) have a restrictive access regime because they are designated as water protection zones according national legislation. Only in Tre_L, located at 1533 m a.s.l., a more significant load with TN was reported. In this lake, peaty formed about 90 % of the bottom substrate. Benthos was represented by only two oligochaete taxa and with a predominant presence of Diptera. The increase in the concentration of humic substances in lake waters leads to changes in the abiotic features of the environment, such as high water colour, decline in the thickness of the trophogenic zone, pH decrease, limitation of the bioavailability of biogenic compounds. Sediment enrichment has limited the benthic fauna to species tolerant to brief periods of bottom anoxia and increased levels of organic matter; this has resulted in the disappearance of many taxa and a decrease in the abundance of remaining invertebrates (Pavlova et al. 2013). In these conditions, some groups of benthic fauna are not found, e.g., Gastropoda (Joniak & Domek 2006). These findings were confirmed by our study (Table 2).

The substrate heterogeneity and the dynamics of the environmental conditions in the littoral zone formed a rich benthic community (Table 2). We found a variety of macroinvertebrate groups dominated by chironomids and oligochaetes. These observations comply with other studies on the biota of the littoral zone of natural lakes and reservoirs (Prat et al. 1992, Specziár & Bíró 1998, Krno et al. 2006). Prat et al. (1992) found that the prevalence of the oligochaetes, small crustaceans and the microcarnivore chironomids in natural lakes and reservoirs of Spain is due to meiofaunal loop/elements whose formation is resulting from allochthonous inputs of organic matter. Due to their ability to provide shelter, the macrophytes are responsible for greater diversity and abundance of invertebrates. Ogn_R, where we registered a significant presence of macrophytes, was one of the richest in benthic taxa water bodies (Table 2). The littoral zone of macrophyte-rich stagnant waters is characterised by a significant fraction of unique variance in some cases, such as Corixidae, Lymnaeidae and Aeshnidae (Mendoza & Katalan 2010). In our study, *Micronecta* sp. was found as an absolute dominant (500 specimens) not only for Ogn_R but also among all studied sites.

The registration of invasive species in the macrozoobenthos of the mountain standing waters could be interpreted in two aspects. It is important to consider the biocontamination for the assessment of the ecological potential of reservoirs; being artificial and heavily modified water bodies, they are highly susceptible to invasions. On the other hand, the possible positive effects should be also taken in view. Thus, the presence of mussel *Dreissena polymorpha* may be a prerequisite for providing new food sources, increasing transparency and offering a variety of refuges and microhabitats (Trichkova et al. 2013). We have found that *D. polymorpha* occurs in water bodies, which are characterised by the highest number of taxa (Yovw_R – 38 taxa, Hsm_R – 31, Yovt_R – 30, Beb_R – 29 and Ogn_R – 28). However, in order to track the impact of invasive species, additional targeted studies on different standing ecosystems should be carried out.

Conclusion

The studied standing water bodies are distinguished by specific and diverse macrozoobethic communities, which are formed in the absence of significant human impact. In such unaffected environmental conditions, the physicochemical factors are of paramount importance for aquatic habitats and for the formation and functioning of the composition of invertebrate communities. The data presented are the baseline for further systematic observations on macrozoobenthos in the mountain standing waters. They can be used as the basis for expanding the scope of studies on the biotic interactions and other significant environmental factors in these water bodies. This will contribute to increasing our knowledge of these unique ecosystems, vulnerable to both direct anthropogenic impact and global climate processes.

Acknowledgments. The field studies were funded by the World Bank, project # 71 957 35/17.4.2020, DICON-UBA; the analysis of the results has been carried out in the framework of the National Science Program “Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters”, approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № D01-230/06.12.2018).

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