Diversity of Oligochaeta Fauna in the High-Mountain Lakes of Šar-Planina Mountain

Nebojša V. Živić[1], Branko M. Miljanović[2], Ana D. Atanacković[3] and Momir M. Paunović[3]

[1] University of Kosovska Mitrovica, Faculty of Sciences and Mathematics, Serbia

[2] University of Novi Sad, Faculty of Sciences and Mathematics, Serbia

[3] University of Belgrade, Institute for Biological Research "Sinisa Stankovic", Bulevar Despota Stefana 142, 11000 Belgrade, Serbia.
Corresponding author: Ana Atanacković, Phone: +38111 2078369, E-mail: adjordjevic@ibiss.bg.ac.rs

Abstract

Initial investigations of the high-mountain lakes of Mt. Šar-planina were performed from 1996 to 1997, with the aim of studying the distribution and diversity of Oligochaeta fauna. These studies included 9 glacial lakes at an altitude ranging from 1,560 m to 2,260 m. Fourteen taxa, belonging to 12 genera and 4 families were recorded. The greatest number of taxa of Oligochaeta fauna was recorded at the Gornje (10 taxa) and Donje Tupankamensko Lakes (7 taxa). The species *Nais communis, Limnodrilus hoffmeisteri* and *Lumbriculus variegatus* were detected in six out of the nine lakes examined. The greatest number of collected specimens belonged to the species *Stylodrilus lemani* in the peat of Šištevačko Lake. The other species were represented by only 2-5 individuals in the lakes where they were recorded. After processing the samples, we concluded that the high-mountain lakes of Mt. Šar-planina are characterized by low diversity and low abundance of Oligochaeta fauna.

Keywords: high-mountain lakes; Oligochaeta; Mt. Šar-planina

Introduction

The Oligochaeta (Annelida) fauna of high-mountain aquatic ecosystems has been studied by many limnologists (Dumnicka, 1994; Dumnicka and Boggero, 2007; Lafont and Florian, 2001; Lencioni and Maiolini, 2002; Yildiz *et al*., 2005; Krno *et al*., 2006; Kownacki *et al*., 2000). Examinations of the macrozoobenthos of the Đeravica Lakes at Mt. Prokletije by Živić *et al*. (1996) were the first zoological studies of the high-mountain lakes in Kosovo and Metohija. Ensuing studies that included the high-mountain natural lakes of Mt. Šar-planina were undertaken in order to determine the distribution and diversity of Oligochaeta fauna in these water bodies.

Mt. Šar-planina belongs to the mountain massifs of the Balkan Peninsula which are very rich in freshwater systems consisting of numerous springs, streams and rivers. One particularly interesting feature is the existence of many natural high-altitude lakes. There are 90 described natural lakes at Mt. Šar-planina, which includes 70 glacial and 20 nivational lakes (Ćukić, 1983). From a biological standpoint, these lakes belong to a very poorly studied group of landlocked aquatic ecosystems. Algological studies that were undertaken at the lakes of Sirinićka Župa (Urošević, 1994) were the first biological studies of any of Mt. Šar-planina's lakes. Subsequent research included other lakes and watercourses of this mountain (Urošević, 1997a, b, c; Protić and Živić, 2013). Ranđelović *et al*. (1997) have determined that the peat associations of the high-mountain lakes of Mt. Šar-planina include many endemic species with a relict character of vegetation.

Materials and methods

This hydrobiological study of high-mountain aquatic ecosystems was performed in one area of Mt. Šar-Planina as summer expeditions during 28 August - 5 September 1996, and 25-30 August 1997. The studies included nine glacial lakes at altitudes

ranging from 1,560 m to 2,260m (Fig.1). The following lakes were examined:

1. The lake on Šištevačka Mt. lying to the north-west (42°55'30'' N, 20°36'30'' E) of the Mt. Šar-planina massif. The lake is located at the south-eastern side of Šištevačka Mt., in its foothills, 1,720 m above sea level. The lake is 25 m long, 15 m wide and its maximal depth is about 30 cm. There are no feeding rivers or streams, and the lake receives its water from thawed snow. The bottom of the lake is covered in peat.

At the main spring-fed stream of the Restelica River there are two lakes on a slight slope, separated by a 60 m wide strip of land (41°54'50'' N, 20°45'00'' E).

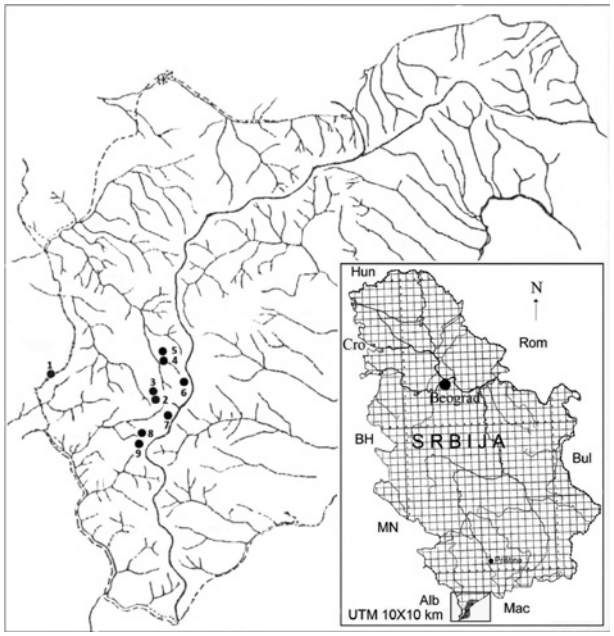

Figure 1: The position of Mountain Šar-planina and the studied lakes (UTM 10 x 10 km).

2. Donje Tupankamensko Lake which is 30 m below the lake at Šištevačka Mt. positioned at an altitude of 1,560 m above sea level (41°54'33'' N, 20°43'27'' E). The lake is 20.5 m long, 20.7 m wide and 1 m deep; its circumference is about 29 m.

3. Gornje Tupankamensko Lake which is situated at an altitude of 1,590 m above sea level (41°54'34'' N, 20°43'74'' E). The lake is 15 m long, 7 m wide, and its maximal depth is about 50 cm. It obtains its water from thawed snow and small springs.

At the upland plane of Šutman, which lies to the west from the mountain massif Rudoke, four glacial lakes with macrophyte vegetation, notably mosses that cover the muddy bottom with a layer of peat, were studied. These are:

4. Malo Šutmansko Lake which is situated at an altitude of 2 030 m (41°55'05'' N, 20°43'52'' E). The lake is 50 m long, 20 m wide, with a depth of about 50 cm;

5. Veliko Šutmansko Lake is situated 2,080 m above sea level (41°55'15'' N, 20°42'20'' E). The lake is 200 m long and 90 m wide; the length of the coastline is 529 m; the coastline quotient is 1.3 and its surface area is 11,940 m^2; the lake is about 1 m deep and the maximum temperature is 18°C.

6. Ginivodno Lake is found at an altitude of 2,260 m (41°54'30'' N, 20°43'45'' E). It is comprised of three interconnected small lakes which obtain their waters from thawed snow and many small springs (including two sublacustrine ones). Water leaves the lakes through two underground channels.

7. Veljinbeško Lake is situated at the Veljin Beg plateau at an altitude of 2,085 m (41°53'50'' N, 20°43'55'' E). This lake is not fed by any rivers but gets its water from thawing snow. At certain places, the lake demonstrates an acid water reaction of pH 3.5 due to peat deposits (Urošević, 1997a).

Two lakes at the Gornji Def plateau in the Donja Vraca valley were studied. These are:

8. Srednje Defsko Lake which lies at an altitude of 2,100 m. (41°53'15'' N, 20°43'10'' E). It is roughly circular in shape, 100 m long, 80 m wide and about 50 cm deep, and

9. Gornje Defsko Lake which lies at an altitude of 2,117 m (41°52'51'' N, 20°43'03'' E). This lake is 120 m long, 60 m wide and about 50 cm deep.

Due to the nature of lacustrine substrates, the samples for quantitative analysis were collected by different methods, using Surber's net, by hand picking, bottom scraping, etc. All obtained samples were conserved in 4% formaldehyde. The Oligochaeta specimens were later transferred to 70% ethanol. Identification of specimens was performed using the following determination keys: Brinkhurst and Jamieson (1971), Hrabě (1981) and Timm (1999). The taxonomy applied herein adheres to Fauna Europea (2011) and Timm (2012).

The work discusses the main ecological features of the recorded communities with respect to their qualitative and quantitative composition. In order to evaluate differences between the investigated lakes, basic faunistic features of the oligochaete assemblages were analysed. The autecological data were taken from Aqem (2002) and Hörner *et al*. (2002), while the Asterics software 3.1.1. (Aqem, 2002) was used for calculating relationships between the functional groups within the community, including the characterisation of the species with regard to saprobic preference, zonation and substrate type, as well as, Diversity index H' (Shannon, 1948) and Evenness index E (Pielou, 1977).

Additionally, the faunistic similarity of the investigated lakes was determined according to Jaccard Index of Similarity (Jaccard, 1901).

Results

A total of 14 aquatic worm taxa, belonging to 12 genera and 4 families were recorded in the lakes of Mt. Šar-planina (Table 1). The family Tubificidae was represented by 5, Naididae by 3, and Lumbriculidae by 2 genera. Enchytraeidae was represented with only one taxa. Most of recorded taxa belong to the Tubificidae family (7), followed by the Naididae (4) and Lumbriculidae (2).

Table 1: The quantitative and qualitative composition of aquatic worm communities in the investigated lakes

Taxa \ Localities	1	2	3	4	5	6	7	8	9
Naididae									
Amphichaeta leydigii TAUBER,1879			2						
Nais communis PIGUET,1906		5	2	2			3	11	18
Nais sp.		3	2						5
Slavina appendiculata (UDEKEM,1855)		2	3				2		
Lumbriculidae									
Lumbriculus variegatus (MÜLLER,1774)		4	2		2	2	3	3	
Stylodrilus lemani (GRUBE,1879)	44							6	9
Tubificidae									
Embolocephalus velutinus (GRUBE, 1879)			1		1				
Isochaetides michaelseni (LASTOČKIN,1936)	1				1				
Limnodrilus hoffmeisteri CLAPARÈDE, 1862		3	2	3	3				
Limnodrilus sp.			1	2					
Psammoryctides albicola (MICHAELSEN,1901)	1				1				
Spirosperma ferox EISEN 1879		2	3		2				
Tubifex tubifex (MÜLLER,1774)		5	2			1		1	
Enchytraeidae	3								
Enchytraeus sp.	3								
No. of taxa	5	7	10	3	6	2	3	4	3

The greatest species richness of aquatic worms was recorded in the Gornje Tupankamensko Lake (10 species). In the Donje Tupankamensko Lake 7 species were identified. In the Malo Šutmansko Lake the smallest number, only 3 species were found. In the other lakes, Oligochaeta fauna was represented by 4-5 species. The species *Amphichaeta leydigii* Tauber were recorded only in the Gornje Tpankamensko Lake. The species *Nais communis* Piguet and *Lumbriculus variegatus* (Müller, 1774) were recorded in six lakes. The distribution of *Embolocephalus velutinus* (Grube, 1879), *Spirosperma ferox* Eisen, *Psammoryctides albicola* (Michaelsen, 1901) and *Isochaetides michaelseni* (Lastočkin, 1936) was limited to just two lakes.

Between investigated sites, there are differences in oligochaetes diversity and their abundances (Figure 2). The most diversified locality was Gornje Tupankamensko Lake (H'=2.250), while the lowest value of diversity index was at the lake on Šištevačka Mt. (H'=0.427). From the quantitative standpoint, the Oligochaeta community was the most abundant in the lake at Šištevačke Mountains, where *Stylodrilus lemani* (Grube, 1879) predominated.

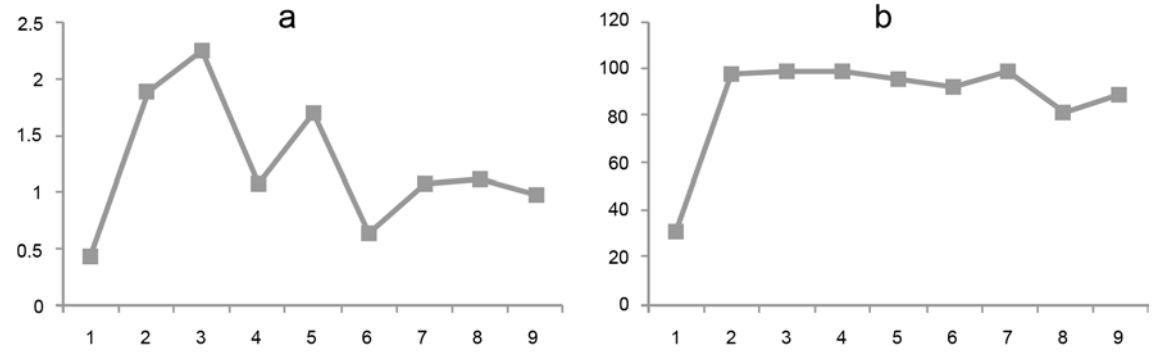

Figure 2: Diversity (a) and evenness (b) indices for investigated lakes

Evenness index presents the similarity of species abundances in each assemblage (how much the abundances of species are uniform in every assemblage) and results (Figure 2) are showing that the most uniform is community at Veljinbeško Lake (E=98.50%) which is almost the complete uniform community in number of individuals of all recorded species. In all assemblages the high values of evenness index were recorded, except in Gornje Tupankamensko Lake (E=30.80%).

Concerning the Jaccard index of similarity, we established very high similarity among investigated lakes (66.67-100%). The lowest values of this index were recorded between the lake on Šištevačka Mt. and other investigated lakes. Thus, with Veliko Šutmansko Lake similarity was 66.67%, with Srednje and Gornje Defsko Lake 50%, and with other lakes there was no similarity considering species composition.

Surprisingly for this type of ecosystem, the majority of recorded species within the investigated area could be considered as tolerant to a high organic load. Thus, according to the ecological classification of the taxa, with regard to saprobic conditions (saprobic valence) of Hörner *et al*. (2002), 37.34% of the identified species belong to the alpha-mesosaprobic group, while 27.09% of the taxa could be characterized as beta-mesosaprobic. Species adapted to high organic load (polysaprobic) were represented by 16.10% of the total number of taxa. Only 9.15% of the identified taxa are classified as sensitive to organic pollution (oligosaprobic taxa), while xenosaprobic species were not recorded. For the rest of the species (10.31%), there is no data to classify them in regard to saprobic tolerance.

Furthermore, according to Hörner *et al*. (2002) and the Aqem (2002) classification with regard to a preferred zone, the greatest part (30.15%) of the recorded species characterised as potamal. A lower proportion of the taxa belong to those of the littoral (12.35%) and profundal type (11.24%).

The majority of the identified species (38.63%) are adapted to the substrate types typical for lakes, fine-to-medium-sized gravel (pelal, psammal and argillal). Phytophilous taxa are represented with 28.90%, while those that prefer particulate organic matter and lithophilous ones had less than 10% of the total number of recorded Oligochaeta taxa. For the rest of identified species there is not enough information about microhabitat preference (Aqem, 2002).

Discussion

The aquatic ecosystems in high elevation areas are characterized by specific ecological conditions, historical and geological effects that influence its faunal composition, causing it to differ from other biotopes (Apfelbeck, 1896; Radovanović, 1957; Ivanović, 1970; Kownacki *et al*., 1997). Faunistic studies have shown that high-mountain aquatic ecosystems are characterized by a relatively small number of species, including many endemics (Glowacinski and Makomaska-Juchiewicz, 1992; Kownacki *et al*., 1997, 2000; Dumnicka and Galas, 2002). The substrate of the studied glacial lakes of Mt. Šar-planina was overgrown with thick macrophyte vegetation, which transformed areas of the lakes into peat bogs. However, these peat bogs differ from the peat bogs that are found in northern and central Europe and central Balkans. The presence of species belonging to the Arcto-Alpine range type points to the glacial origin of the lakes with peat domination (Ranđelović *et al*., 1997). Under these conditions, the fauna of Oligochaeta is represented by a small numbers of species, as is also a characteristic of high-mountain ecosystems in other regions (Uzunov and Varadinova, 2000a).

Despite the expectation that specific aquatic worm fauna would be recorded in the investigated high-mountain lakes, a wide distribution of species possessing a community structure that is not different from other aquatic ecosystems was observed. Oligochaeta fauna of the studied lakes of Mt. Šar-planina was represented by 14 widely distributed taxa; no species with a narrow distribution were recorded. According to Timm (1980), the majority of the species are widely distributed in different types of aquatic ecosystems.

The dominant taxa were representatives of the Tubificidae, Naididae and Lumbriculidae families. We expected to observe specific oligochaetes fauna due to the characteristic locations of the investigated lakes, such as the relatively high altitude, specific environmental conditions that prevail in high-mountain lakes, and the historical developments that the fauna has undergone. Central and southern parts of the Balkan Peninsula were an important refugium for numerous organisms during the glacial epochs (Stevanović and Vasić, 1995), and this particular region was one of the centres of biodiversity for different faunistic groups.

A similar composition to the one reported in this study was also recorded in other high-mountain lakes of the Balkans (Uzunov and Varadinova, 2000b; Yildiz, 2005). While in the glacial lakes and streams in the mountains of Central Europe the Enchytraeidae is the dominant family (Dumnicka, 1998; Dumnicka and Boggero, 2007), in the studied lakes of Mt. Šar-planina the greatest diversity was manifested by the five species belonging to the Tubificidae family. As this family is considered to have originated in the cold northern temperate zone (Timm, 1980), its dominance was expected. The three species of Oligochaeta fauna, *Isochaetides michaelseni, Amphichaeta leydigii* and *Stylodrilus*

lemani were the distinguishing feature of the studied glacial lakes of Mt. Šar-planina, compared to other high-mountain lakes in the Balkans and northern and central Europe (Uzunov and Varadinova, 2000a, b; Dumnicka, 1994; Dumnicka and Boggero, 2007; Yildiz *et al*., 2005). The Đeravica Lakes at the nearby Prokletije Mt. and the lakes described herein share (Živić *et al*., 1996) only two Oligochaeta species, probably because of differences in the lake bed substrate. The increased diversity of Oligochaeta fauna in lakes with a macrophyte vegetation was previously recorded in lakes in other regions (Yildiz *et al*., 2005).

According to the indicator species of algae, Urošević (1997a, b, c,) concluded that the studied lakes should be appropriated an oligo- to betamesosaprobic status. In certain ecosystems in northern Europe, *T. tubifex* species have been identified as indicators of an oligotrophic environment (Timm, 1987; Hrabe, 1981; Milbrink, 1980). This species, together with the oxyphile species of the genus *Spirosperma* (Timm, 1996), was recorded in the lakes of Mt. Šar-planina. However, the species from *Tubifex* and *Limodrilus* genera occupy deeper zones in the studied lakes, where the oxygen concentration is low as a result of decomposition of peat communities and sediment accumulation (Urošević, 1997a, b, c,).

Acknowledgements

This work was supported by the Ministry of Education and Science of the Republic of Serbia, Projects No. TR 37009 and III 43002. We would like to express our gratitude to Dr. Dragan Ćukić†, Dr. Predrag Jakšić i Dragan Đorić. We also express our thanks to Dr. Goran Poznanović for his constructive comments during preparation of the manuscript.

References

Apfelbeck, V. (1896). Karakteristike faune invertebrata u Bosni i Hercegovini. Akademija nauka i umetnosti BiH, Sarajevo, 1-17.

AQEM (2002). Manual for the application of the AQEM system: a comprehensive method to assess European streams using benthic macroinvertebrates, developed for the purpose of the Water Framework Directive. Contract No: EVK1-CT1999-00027.

Brinkhurst, R. O. and B.G.M. Jamieson (1971). Aquatic Oligochaeta of the World. Oliver & Boyd, Edinburg, 1-860.

Ćukić, D. (1983). Turistička valorizacija prirodnih etnografskih i drugih kulturnih potencijala Šar-planine. Srpsko geografsko društvo, Beograd 55, 81-85.

Dumnicka, E. (1994). Communities of oligochaetes in mountain streams of Poland. Hydrobiologia 278, 107-110.

Dumnicka, E. (1998). A new species of Fridericia (Oligochaeta: Enchytraeidae) found in a spring in the Sudety mountains (Poland). Annls Limnol. 34, 155-158.

Dumnicka, E. and A. Boggero (2007). Fundamental and Applied Limnology. Arch. Hydrobiol. 168, 231-242.

Dumnicka, E. and J. Galas (2002). Factors affecting the distribution of Oligochaeta in small high mountain ponds (Tatra Mts, Poland). Arch. Hydrobiol. 156, 121-133.

Hörner, K., Moog, O. and F. Sporka (2002). Oligochaeta.– Part III. In: Fauna Aquatica Austriaca, Edition 2002 (Ed. Moog O.), 1-18. Wasserwirtschaftskataster, Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Wien.

Hrabě, S. (1981). Vodní maloštětinatci (Oligochaeta) Československa. Acta Univ. Carol. Biol. 1-167.

Ivanović, B. (1970). Hidrobiološka istraživanja nekih visoko planinskih jezera u Crnoj Gori. Poljoprivreda i šumarstvo, Titograd 24, 31-51.

Jaccard, P. (1901). Distribution de la flore alpine dans le bassin des Dranses et dans quelques régions voisines. Bull. Soc. Vaud. Sci. Natur 37, 241–272.

Kownacki, A., Dumnicka, E., Galas, J., Kawecka, B. and K. Wojtan (1997). Ecological characteristics of a high mountain lake-outlet stream (Tatra Mts, Poland). Arch. Hydrobiol. 139, 113-128.

Kownacki, A., Galas, J., Dumnicka, E. and S. Mielewczyk (2000). Invertebrate communities in permanent and temporary high mountain lakes (Tatra Mts). Annls. Limnol. 36, 181-188.

Krno, I., Šporka, F., Štefkova, E., Tirjakova, E., Bitišik, P., Bulankova, E., Lukaš, J., Illešova, D., Derka, T., Tomajka, J. and J. Èerny (2006). Ecological study of a high-mountain stream ecosystem (Hincov potok, High Tatra Mountains, Slovakia). Acta Soc. Zool. Bohem. 69, 299–316.

Lafont, M. and M. Florian (2001). Oligochaete communities in the hyporheic zone of a glacial river, the Roseg River, Switzerland. Hydrobiologia 463, 75-81.

Lencioni, V. and B. Maiolini (2002). L'ecologia di un ecosistema acquatico alpino (Val de la Mare, Parco Nazionale dello Stelvio). Natura alpine 54, 1-96.

Milbrink, G. (1980). Oligochaete communities in pollution biology: The European situation with special reference to lakes in Scandinavia. In: Aquatic Oligochaeta Biology (Eds. Brinkhurst, R.O. and D.G. Cook), 433-455. Plenum Press, New York.

Pielou, E.C. (1977). Mathematical ecology. John Wiley, New York, 1-385.

Protić, Lj. and N. Živić (2013). A contribution to the knowledge of aquatic Heteroptera in Šar planina Mts. and Pešter plateau (Serbia). Acta Entomol. Sloven. 21, 65-76.

Radovanović, M. (1957). Životinjski stanovnici planinskih jezera. Zaštita prirode, Beograd 11, 10-16.

Randjelović, V., Zlatković, B. and L. Amidžić (1997). Flora and Vegetation of High-mountain Peat-bogs of Mt. Šar-planina. The University Though, Priština 4, 23-27.

Shannon, C. E. (1948). A mathematical theory of communication. Bell Syst. Tech. J. 27, 379-423.

Stevanović, V. and V. Vasić (1995). Biodiverzitet Jugoslavije sa pregledom vrsta od međunarodnog značaja. Biološki fakultet i Ecolibri, Beograd, 1-562.

Timm, T. (1980). Distribution of Aquatic Oligochaetes. In: Aquatic Oligochaeta Biology (Eds. Brinkhurst, R.O. and D.G. Cook), 55-77. Plenum Press, New York.

Timm, T. (1987). Aquatic Oligochaeta of the Northwestern Part of the USSR. Tallin, Valgus, 1-299. [In Russian]

Timm, T. (1996). Tubifex tubifex (Müller, 1774) (Oligochaeta, Tubificidae) in the Profundal of Estonian Lakes. Int. Revue ges. Hydrobiologia 81, 589-596.

Timm, T. (1999). A Guide to the Estonian Annelida. Naturalist's Handbooks, Estonian Academy Publishers, Tartu- Tallinn, 1-208.

Timm, T. (2012). About the scientific names of paraphyletic taxa. Turk. J. Zool. 36, 139-140.

Timm, T. and N. Finogenova (1987). Checklist of aquatic Oligochaela of the USSR. Proc. 6th USSR Symp. on Aquatic Oligochaeta, Riga, 3-11. [In Russian]

Urošević, V. (1994). Alge visokoplaninskuh jezera sirinićke strane Šar-planine. Doktorska disertacija. Univerzitet u Prištini. Priština.

Urošević, V. (1997a). Obraštajne alge Gornjeg Veljinbeškog jezera na Šutmanu (Šar-planina). Zbornik radova, V simpozijum o flori jugoistočne Srbije, Zaječar, 8-18.

Urošević, V. (1997b). Obraštajne alge Gornjeg i Donjeg Tupankamenskog jezera na Šar-planini. Zbornik radova, Fizičko-geografski procesi na Kosovu i Metohiji –II. Univerzitet u Prištini, Priština, 49-58.

Urošević, V. (1997c). The Ginevodna Lakes alge on Šar-planina. Univ.Thought. Nat.Sci, Priština 4, 79-87.

Uzunov, Y. and E. Varadinova (2000b). Oligochaeta limicola from glacial lakes of the Rila Mountains National Park (Bulgaria). In: Biodiversity and evolution of glacial water ecosystems in the Rila Mountains (Eds. Golemansky, V. and W. Naidenow.), 45-48. Institute of Zoology, Sofia.

Uzunov, Y. and E. Varadinova (2000a). Aquatic oligochaeta from glacial lakes of the Pirin mountains national park (Bulgaria). Lauterbornia 39, 101-104.

Yildiz, S., Tasdemir, A., Ozbek, M., Balik, S. and M. R. Ustaoglu (2005). Macrobenthic Invertebrate Fauna of Lake Egrigol (Gundogmus-Antalya). Turk. J. Zool. 29, 275-282.

Živić, N., Miljanović, B., Labus, N. and T. Jakšić (1996). Composition of zooplankton and macrozoobenthos in Big and Small Djeravica Lake. Univ.Thought. Nat.Sci, Priština 3, 51-56.

http://www.faunaeur.org