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Original Scientific Paper

Macrophyte vegetation as a structuring factor of the macrozoobenthic communities in Lake Ohrid

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ABSTRACT: The macrophyte communities in Lake Ohrid have a key role in general maintaining of the lake's metabolism. They are particularly important for the distribution and structuring of rich benthic macroinvertebrate assemblages, in as much as they provide a constant stream of oxygen, are an important source of food and serve as shelter from predators. A survey at six sites along the coastal zone of Lake Ohrid was conducted in order to determine the role of macrophyte communities in structuring of the macrozoobenthos inhabiting the littoral zone of the lake. With respect to species composition, the results point to the Gastropoda, with 23 registered taxa, as the most diverse among the seven groups of benthic fauna. The second most diverse was the group of Insecta with 11 species, followed by Hirudinea and Oligochaeta with seven species, while six species from Crustacea were registered. The lowest biodiversity was registered for Bivalvia and Turbellaria – three species from each group. It was also found that mixed stands of Charophyta with other macrophytes where Charophyta species predominate represent the most attractive habitats, being inhabited by 54 species, versus homogenous stands of *Chara tomentosa*, where 36 species were registered. The most abundant species were *Dreissena presbensis* and *Radix relicta,* which reached their maximum densities on homogenous stands of *Chara tomentosa.*

Keywords: Lake Ohrid, macrophyte vegetation, macrozoobenthos, habitats

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INTRODUCTION

Macrophytes during their evolution have gained a set of adaptive strategies that now enables them to colonise a wide spectrum of different aquatic ecosystems, both freshwater and marine. The role of macrophytes in aquatic ecosystems is related to maintaining the level of general aquatic metabolism. They affect and mediate the cycling of chemical elements between sediments and the water by controlling the transport of nutrients actively through their retention or releasing by submerged leaves and roots (Meerhoff *et al.* 2003) or passively through reduction of nutrient release from sediments achieved by affording protection against wind action (Madsen *et al.* 2001). At the same time, macrophytes (especially rooted ones) promote shore stabilisation and reduction of erosion (Esteves *et al.* 1998). Macrophyte vegetation with its biomass represents a source of organic food for aquatic animals and serves as shelter from predators.

Macrophyte associations inhabiting the littoral of Lake Ohrid have a typical transitional distribution consisting of three main belts. The first belt is represented by emerged macrophytes, next comes the most developed belt, that of submerged macrophytes, while the least developed is the belt of floating plants.

Past research on Lake Ohrid has pointed out the huge importance of its macrophyte vegetation (Stanković 1960; Trajanovski 2005) for the macrozoobenthos, but no data have been published so far about the closer relationship of the given vegetation with the macrozoobenthos and

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its role in colonisation of the lake by macrozoobenthic organisms. Accordingly, the main goal of our research was to assess how the composition and abundance of macrophytes influence the composition and abundance of macrozoobenthic organisms, i.e., if any species-specific relationship is discernible between these components. For this purpose, different macrophyte communities such as Charophyta mixed with other macrophytes, as well as homogenous stands of *Chara tomentosa* Linnaeus 1753, were investigated at six different localities in the littoral of Lake Ohrid.

MATERIAL AND METHODS

Samples were collected by standard limnological methods for collecting benthic material and macrophyte vegetation (Wetzel 1975; Wetzel & Likens 1979; Lind 1985).

The material was collected from Lake Ohrid during the summer of 2015 at six different littoral sites (Fig.1). Sampling sites were selected in different geomorphological zones of the lake in order to obtain higher diversity of the macrophyte vegetation. Thus, the selected sites included one with a high slope (Velidab) and two that are totally flat (Struga, Ljubanista), while the rest (Radozda, Ohrid Bay and Metropol) can be considered as transitional between the sloping and flat sites. Samples were collected from two points of depth (5 and 10 m) on a muddy bottom covered with charophytes and other macrophytes and on meadows of *C. tomentosa* using a spider type grab and a Van Veen grab (400 cm^3).

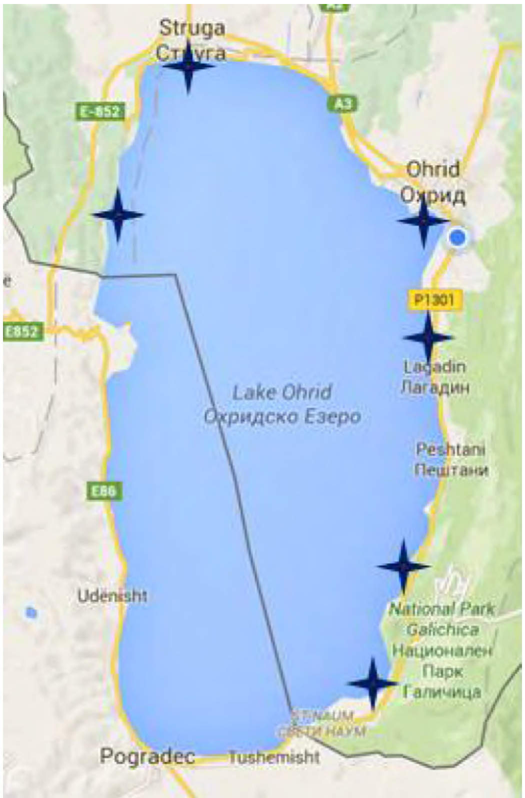

Figure 1. Sampling localities.

The benthic fauna was examined with a stereo microscope and determined using keys for identification of freshwater invertebrates (Polinski 1929; Snegarova 1954; Radoman 1955, 1983, 1985; Hubendick 1960, 1970; Shapkarev 1964; Hadžišče 1974; Karaman 1976; Lukin 1976; Brinkhurst & Jamieson 1978; Barnes 1980; Kerovec 1986; Kellogg 1994; Bodon *et al.* 2001; Glöer & Meier-Brook 2003, etc.).

Material collected from the macrophyte vegetation was identified to species level using different published floras and keys for vascular macrophytes (Hayek 1924-1933; Josifović 1970-1977) and charophytes (Corillion 1957, 1975; Wood & Imahori 1964, 1965; Golerbah & Krasavina 1983; Krause 1997; Schubert & Blindow 2003).

RESULTS AND DISCUSSION

As shown in Table 1, 59 species from the macrozoobenthos and 16 species from the macrophyte vegetation were identified at the sampling sites. Due to the significantly higher abundance of charophytes in the samples, two types of communities were considered, viz., mixed stands of Charophyta with other macrophytes and dense homogenous stands of *C. tomentosa.*

Qualitative composition of the macrozoobenthos included representatives from seven systematic groups (Fig. 2): Turbellaria, Oligochaeta, Hirudinea, Bivalvia, Gastropoda, Crustacea and Insecta. The highest diversity was noted for the group Gastropoda, with 23 out a total of 59 species, even 20 of which are endemic. The second most diverse was the class Insecta with 11 species, but none of them endemic. The least diverse was the class Turbellaria with three registered species, all of them endemic. In general, the level of endemism of the macrozoobenthos

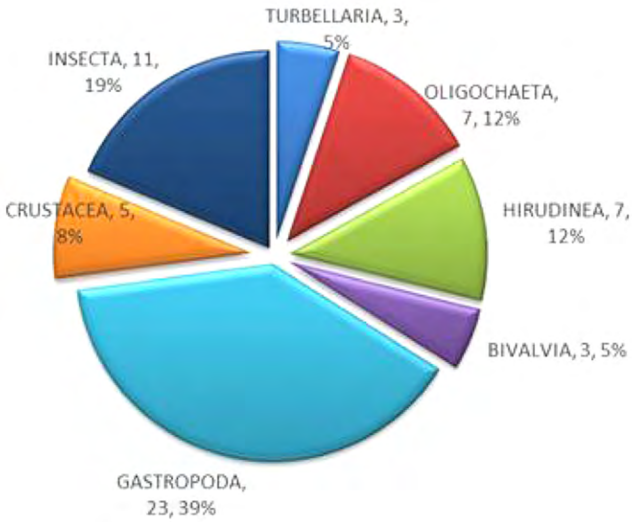

Figure 2. Composition of macrozoobenthos from Lake Ohrid.

Table 1. Macrozoobenthos and macrophyte species lists.

List of macrozoobenthos species	List of macrophyte vegetation species
Phagocata ochridana (Stankovic & Komarek, 1927)	*Cladophora spec.* Kutz., 1843
Dendrocoelum maculatum (Stankovic & Komarek, 1927)	*Potamogeton perfoliatus* L.
Dendrocoelum lacteum (Müller, 1774)	*Potamogeton lucens* L.
Criodrilus lacuum Hoffmeister 1845	*Potamogeton pectinatus* L.
**Limnodrilus hoffmeisteri* Claparède, 1862	*Potamogeton pusillus* L.
Rhynchelmis komareki f. typical Hrabe 1927	*Potamogeton acutifolius* Link.
**Tubifex tubifex (Otto Friedrich Müller, 1774)*	*Potamogeton* x *nitens* Weber (*Potamogeton gramineus* x *P. perfoliatus*)
*Pothamotrix ochridanus (*Hrabe 1931)	*Zannichellia palustris* L.
Peloscolex stankovici f. litoralis Sapkarev, 1953	*Myriophyllum spicatum* L.
**Eiseniella tetraedra (*Savigny 1826)	*Elodea canadensis* Michx.
Glossiphonia pulchella Sket 1968	*Najas marina* All.
**Cystobranchus pawlowski* (Sket, 1968)	*Chara tomentosa* L.,1753
Glossiphonia maculosa Sket, 1968	*Chara globularis* Thuill, 1799
**Glossiphonia complanata complanata* (Linnaeus 1758)	*Chara imperfecta* A.Braun,1845
Dina krilata Sket 1989	*Chara ohridana* Kostic, 1936
**Erpobdella octoculata* (Linnaeus, 1758)	*Nitella opaca* (Bruzelius) C.Agardh 1824
Dina sp.	
Dreissena presbensis Kobelt, 1915	
**Pisidium sp.*	
**Sphaerium corneum*(Linnaeus, 1758)	
Chilopyrgula sturanyi (Brusina, 1896)	
Pyrgohydrobia grochmalickii (Polinski, 1929)	
Gocea ohridana Hadžišče 1956	
**Theodoxus fluviatilis* (Linnaeus 1758)	
**Viviparus viviparus* (Linnaeus, 1758)	
Valvata stenotrema Polinski, 1929	
Valvata rhabdota Sturanyi, 1894	
Ohridohoratia sturanyi (Westerlund 1902)	
Ohridohoratia pygmaea (Westerlund, 1902)	
*Ochridopyrgula macedonica macedonica (*Brusina, 1896)	
Ochridopyrgula macedonica charensis Radoman, 1978	
Gyraulus lychnidicus Hesse, 1928	
Gyraulus trapezoides Polinski, 1929	
Gyraulus albidus Radoman, 1953	
Radix relicta Polinski, 1929	
Ginaia munda munda (Sturany, 1894)	
Stankovicia pavlovici (Polinski, 1929)	
Stankovicia wagneri (Polinski, 1929)	
Planorbis macedonicus Sturanyi, 1894	
**Planorbarius corneus* (Linnaeus, 1758)	
Lyhnidia hadzii Hadžišče, 1959	
Ancylus scalariformis Stankovic & Radoman, 1953	
Xestopyrgula dybowskii (Polinski, 1929)	

List of macrozoobenthos species	List of macrophyte vegetation species
Gammarus ochridensis (Schäferna, 1926)	
**Asellus aquaticus* (Linnaeus, 1758)	
Gammarus roeseli triacanthus Gervais 1835	
Asellus djordjevici litoralis	
Asellus remyi Monod, 1932	
**Caenis macrura* Stephens 1835	
**Chironomus plumosus* (Linnaeus, 1758)	
Polypedilum bicrenatum KIEFFER, 1921	
**Cricotopus algarum* (Kieffer, 1911)	
*Haliplus tropsis**	
**Sialis lutaria* (Linnaeus, 1758)	
**Polypedilum pedestre (Meigen 1830)*	
**Procladius choreus* (Meigen, 1804)	
**Gomphus vulgatissimus* Linnaeus, 1758	
**Odontocerum albicorne* (Scopoli, 1763)	
**Cloeon simile* Eaton 1870	

Table 2. Density (ind/m^2) and diversity of the macrozoobenthos in different macrophyte communities.

	Sampling localities											
	Radozda		Struga		Ohrid Bay		Metropol		Velidab		Ljubanista	
	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m
Macrophyte species	*Potamogeton perfoliatus, P. lucens, Myriophyllum spicatum, Elodea canadensis, Chara tomentosa, Cladophora sp.*	*Chara tomentosa*	*Potamogeton perfoliatus, P. lucens, P. pectinatus, Myriophyllum spicatus, Cladophora sp, Chara imperfecta, C. tomentosa*	*Chara tomentosa, C. ohridana*	*Chara imperfecta, C. ohridana, C. tomentosa, Nitella opaca, Potamogeton perfoliatus, P. pectinatus*	*Chara tomentosa*	*Potamogeton perfoliatus, P. pectinatus, P. nitens, Chara tomentosa, C. ohridana, C. imperfecta, Cladophora sp.*	*Chara tomentosa*	*Potamogeton perfoliatus, P. pusillus, Zannichellia palustris, Myriophyllum spicatum, Elodea canadensis, Cladophora sp., Chara tomentosa, C. globularis.*	*Chara tomentosa*	*Chara tomentosa, C. ohridana, Potamogeton acutifolius, P. perfoliatus, Myriophyllum spicatum, Elodea canadensis, Najas marina, Zannichellia palustris*	*Chara tomentosa*
Macroz. Density	8233	18082	5003	14870	4704	6747	17482	6056	5862	8625	1942	1332
No. spec. macroz.	17	16	20	18	21	17	23	21	29	28	12	12

examined during the research was high, reaching 59% of the total number of registered species.

Fifty-four out of the 59 species were registered in the investigated mixed stands of Charophyta with other macrophytes, while 36 species were registered on the dense homogenous meadows of *C. tomentosa.*

Such a composition of the macrozoobenthic communities is a result of the structuring effect of macrophyte vegetation on the macrozoobenthos and is closely related to the importance of that vegetation as a food resource providing both living matter for the food webs of grazers and scrapers and organic dead material for detritivorous food webs, thereby increasing the overall diversity of macrozoobenthic communities.

Table 2. presents the composition of macrophyte vegetation at different localities from the littoral part of Lake Ohrid, the number of species of the benthic fauna and their abundances.

It is evident that mixed macrophyte communities where charophytes predominate are invariably found at the shallower depth, i.e., 5 m, while the deeper points at all localities are always inhabited by *C. tomentosa,* which forms dense meadows that are mostly homogenous (with the exception of the locality of Struga, where at 10 m it is in association with *Chara ohridana*). As for horizontal diversity of the macrophyte vegetation, it is fairly uniform around the lake's littoral. Thus, it varies between six species in Ohrid Bay to eight species at the localities Velidab and Ljubanista in the southern part of the lake.

Analysis of macrozoobenthos structure clearly shows that higher biodiversity of the macrozoobenthos always coincides with higher diversity of the macrophyte vegetation, i.e., with the mixed stands of Charophyta with other macrophytes occurring at a depth of 5 m. The higher diversity of the macrophyte vegetation increases complexity of the habitat, thus ensuring conditions for increased colonisation. According to Tews *et al.* (2004), a correlation between habitat heterogeneity and diversity of the macrobenthos was recorded in 85% of the studies conducted up to then.

This was not the case with density. Thus, the general average density at 5 m was 7204 ind/m^2 and was lower than the general average density at 10 m, which attained a value of 9285 ind/m^2. The highest density – 18082 ind/m^2 – was registered at 10 m at the locality of Radozda. Even 36% of the total density belongs to *Dreissena presbensis* Kobelt 1815. With an average density of 2942 ind/m^2, this species is the most abundant and it comprises 40-50% of the total macrozoobenthos density. What is interesting in regard to the density of this species is that 93% of it is distributed on the homogenous meadows of *C. tomentosa*. However, we cannot conclude that a species-specific relationship exists between *C. tomentosa* and *D. presbensis* due to the fact that most of the specimens were juvenile and used Chara branches as a temporary attaching substrate. The highest densities of adults of this species in Lake Ohrid were previously recorded in or at the beginning of the shell zone (Trajanovski 2005). The higher macrozoobenthos density on homogenous *C. tomentosa* meadows under conditions of lower diversity could be caused by a lack of competition for food among the macrozoobenthos species. In general, bearing in mind that the increased density is due to the high number of *D. presbensis* specimens, we can conclude that *C. tomentosa* with its dense branches disables the access of predators of this species, thereby providing shelter to it.

The rich diversity and high density of the macrozoobenthos inhabiting the macrophyte vegetation in Lake Ohrid can be understood in light of the role played by this vegetation as a factor ensuring maintenance of general stability of the lake's ecosystem. Radoman (1985) has pointed out its importance for the macrozoobenthos, especially Gastropoda. Its vertical zonal distribution positively affects general heterogeneity of the bottom, ensuring conditions for the creation of micro habitats, with consequent enrichment of food webs (Trajanovski 2005). Richness of the macrozoobenthos in the macrophyte vegetation, especially in the stands of charophytes, could also be due to the fact that Charophyta in Lake Ohrid persist throughout the whole year (Trajanovska 2002), thereby with low biomass ensuring a continuous food supply and shelter for the macrozoobenthic communities. The structuring effect of macrophyte vegetation on the macrozoobenthos starts with initial colonisation and use of the vegetative parts of macrophytes (leaves, stems, roots) as substrate for algae and other microorganisms. This initial habitat provides shelter for many macrozoobenthic species such as juveniles of *Dreissena presbensis* and insect larvae that later attract predators, thus leading to further diversification of the community's structure.

Reduction of habitat complexity, i.e., lowering of the diversity of macrophyte vegetation, resulting from introduction of invasive macrophyte species such as *Elodea canadensis,* which was previously registered at some localities in Lake Ohrid (Trajanovski 2013) could logically lead to the creation of homogenous macrophyte habitats and loss of general biodiversity.

CONCLUSION

In the present study, the lake's macrophyte vegetation was found to be a major factor in structuring of the macrozoobenthic communities in Lake Ohrid. A positive correlation was identified between the complexity of macrophyte vegetation and the level of diversity of the macrozoobenthic communities. Thus, mixed stands of Charophyta with other macrophytes proved to be a more attractive habitat for the macrozoobenthos than homogenous stands represented by dense meadows of *C. tomentosa*. Serving as a food resource, supplying oxygen and offering shelter from predators and protection from other dangers inherent in the habitat are only a few ways in which the macrophyte vegetation promotes the existence of dense and diverse macrozoobenthic communities.

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Botanica SERBICA

REZIME

Makrofitska vegetacija kao strukturni faktor u zajednicama makrozoobentosa u Ohridskom jezeru

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Makrofitske zajednice Ohridskog jezera imaju ključnu ulogu u održavanju jezerskog metabolizma. One su posebno važne za strukturu i distribuciju bogatih bentalnih zajednica makroinvertebrata, jer obezbeđuju konstantan protok kiseonika, predstavljaju važan izvor hrane i omogućavaju zaštitu od predatora. Istraživanje za potrebe ovog rada urađeno je na 6 lokaliteta dužinom krajbrežne linije u litoralu Ohridskog jezera, sa ciljem da se utvrdi uloga makrofitskih zajednica u strukturiranju zajednica makrozoobentosa koje naseljavaju litoralni deo jezera. Rezultati istraživanja su pokazali da je diverzitet kod 7 registrovanih grupa makrozoobentosa, najveći u klasi Gastropoda gde su registrovane 23 vrste. Na drugom mestu je grupa Insecta sa 11, pa slede Hirudina i Oligochaeta sa 7 i Crustacea sa 6 vrsta. Najmanji broj vrsta registrovan je u klasi Turbellaria i Bivalvia - po tri. Utvrđeno je da su mešovite zajednice Charophyta sa ostalim makrofitskim vrstama u kojima Charophyta dominiraju, atraktivnije stanište naseljeno sa 54 vrste, u odnosu na homogene zajednice *Chara tomentosa* gde je registrovano 36 vrsta. Najabundantnije vrste makrozoobentosa su bile *Dreissena presbensis* i *Radix relicta* čije su maksimalne gustine registrovane u homogenim zajednicama gustih livada *Chara tomentosa*.

Ključne reči: Ohridsko jezero, makrofitska vegetacija, makrozoobentos, staništa