

# Potential Threats to Benthic Macroinvertebrate Fauna in Lake Ohrid Watershed: Water Pollution and Alien Species

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**Abstract:** Two of the key pressures and drivers of biodiversity loss in the aquatic ecosystems are the excessive nutrient load and pollution and the invasive alien species. The aims of our study were to assess the ecological status of the water based on the composition and structure of benthic macroinvertebrate community and to examine the occurrence of alien macrozoobenthic species in the littoral of Lake Ohrid and its watershed. The study was conducted in Lake Ohrid littoral area, six tributaries and the Crni Drim River, in 2013. A total of 79 taxa were recorded. The highest number of taxa (52%) belonged to Insecta, which was presented mostly in the tributaries, followed by Gastropoda (20%), presented in the lake littoral. All taxa were native, there was no any alien species recorded either in the lake or in its tributaries and outflow. The most abundant were the representatives of lower indicative value to pollution, such as *Tubifex tubifex*, *Chironomus plumosus*, and *Gammarus roeseli*. The ecological status of the lake littoral sites was significantly lower (bad and poor) in comparison with that of the sites along the tributaries (from poor to very good) and the Crni Drim River (good). These results may indicate a general decrease in the stability and functionality of the lake ecosystem, which would consequently reduce its natural resilience and resistance capacity against introduction and spread of invasive alien species.

**Key words:** Ecological status, invasive alien species, Lake Ohrid, tributaries, outflow, benthic fauna

## Introduction

Two of the key pressures and drivers of biodiversity loss worldwide are the excessive nutrient load and other forms of pollution and the invasive alien species (IAS) (CBD 2006). Some recent studies have shown that the aquatic ecosystems are more prone to biodiversity loss due to the land use and introduction of IAS (RICCIARDI & RASMUSSEN 1999), the latter being a major driver of the biodiversity decrease in rivers and lakes (SALA et al. 2000). The number of alien species established in Europe has been increasing in freshwaters (KELLER et al. 2009). The main pathways of their introduction are shipping and canals, as well as stocking and aquaculture (GHERARDI et al. 2009). The biodiversity

loss is the end result of the negative influence from the IAS, while the initial effects are related to the physical changes in the aquatic environments (STRAYER 2012), which may be direct or indirect, by restructuring of the food webs (PACE et al. 1999). Despite the insufficient study of the impact of alien species on the biodiversity and functionality of the ecosystems in ancient lakes, there are some examples in the past, which could be regarded ecological disasters owing to the introduction of such species (GOUDSWAARD et al. 2008 in ALBRECHT et al. 2013).

In the Lake Ohrid watershed, there are already unfavourable changes in the natural habitats reported,

such as water pollution and habitat fragmentation (TRAJANOVSKI et al. 2015). Although the general trophic status of the lake water has been assessed as oligotrophic (VELJANOSKA SARAFILOSKA et al. 2008, VELJANOSKA & PATCEVA 2012, PEVELING et al. 2015), deteriorated water quality has been registered at different localities, especially at the inflows of the tributaries and some littoral sites nearby the settlements. At these sites, the ecological status has been assessed as lower than a good ecological status (SCHNEIDER et al. 2014, PEVELING et al. 2015) as recommended by the Water Framework Directive (WFD) (EU 2000). The disturbed natural balance in ancient Lake Ohrid, which has been obtained over the long evolution of species and the lake ecosystem, weakens the capacity of the biotic resistance and may facilitate the introduction of IAS.

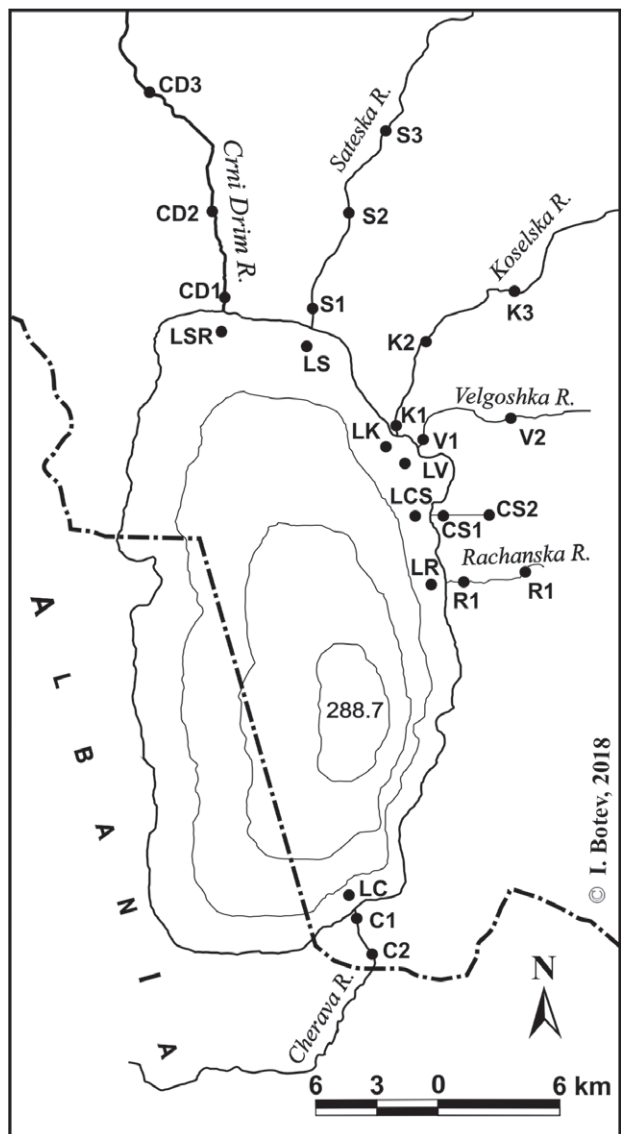
Considering the fact that Lake Ohrid is part of the Drim River Basin, which also comprises Lake Skadar, and the mutual connection between the two lakes through a system of rivers (Crni Drim, Beli Drim and Bojana), there is a possibility of introduction and spread of alien species in the immediate catchment area and Lake Ohrid itself. Furthermore, the role of the four tributaries (the rivers Sateska, Koselska, Velgoshka (Grashnica) and Cherava), together with the only outflow (the Crni Drim River) is rather significant with regard to the sustaining of the water balance in Lake Ohrid. Since the intensification of the industrial development in the lake watershed in the early 1970s the negative influence of the tributaries in terms of water quality and habitat destruction has been reported for the littoral of Lake Ohrid (PEVELING et al. 2015). However, until recently, those tributaries and the outflow have not been considered as factors that could directly assist the introduction of alien species.

The aims of our study were to assess the ecological status of the water based on the composition and structure of benthic macroinvertebrate community and to examine the occurrence of alien macrozoobenthic species in the littoral of Lake Ohrid and in the lake watershed (its tributaries and outflow). The results will contribute to the evaluation of the potential threats to the benthic macroinvertebrate fauna in Lake Ohrid watershed.

## Materials and Methods

The sampling sites were selected both in the littoral zone of Lake Ohrid and in the lake watershed.

Four permanent tributaries (Sateska River, Koselska River, Velgoshka/ Grashnica River, and Cherava River), one temporary tributary (Rachanska River), one canal (Studenchishta) and the only outflow



**Fig. 1.** Map of the sampling sites in Lake Ohrid and its watershed. For codes of the sampling sites see Table 1

of the lake (Crni Drim River) were studied (Fig. 1, Table 1). Three sampling sites were selected in the Crni Drim River, and in the tributaries Sateska and Koselska. In the rest of the rivers, the samples were taken from two sampling sites. The sampling sites were selected based on the hydromorphological characteristics of the river beds, and differences in the potential anthropogenic pressure along the river courses.

In Lake Ohrid, seven sites located in the littoral zone, close to the inflows of the studied rivers were sampled (Table 1).

The samples were collected in May 2013 from the rivers and in October 2013 from the lake's littoral zone.

The sampling was carried out using the standard limnological methods for benthic macroinvertebrates: multihabitat kick and swipe

**Table 1.** List of the sampling sites in Lake Ohrid and its watershed

Water body	Site code	Site
Lake Ohrid	LSR	Littoral Struga, outflow of the Crni Drim River
	LS	Littoral, inflow of the Sateska River
	LK	Littoral, inflow of the Koselska River
	LV	Littoral, inflow of the Velgoshka (Grashnica) River
	LCS	Littoral, Canal Studenchishta
	LR	Littoral, inflow of the Rachanska River
	LC	Littoral, inflow of the Cherava River
Crni Drim River	CD1	Struga Town, lake outflow
	CD2	Moroiski Most, the bridge on the road to Moroishta Village
	CD3	Dobovjani Village
Sateska River	S1	Lowermost reaches
	S2	Volino Village
	S3	Mesheishta Village
Koselska River	K1	Lowermost reaches, Daljan, camping
	K2	Orman Village
	K3	Kosel Village
Velgoshka (Grashnica) River	V1	Lowermost reaches, Ohrid Town
	V2	Near Velgoshti Village
Canal Studenchishta	CS1	Lowermost reaches
	CS2	Near the PSI Hydrobiological Institute Ohrid and Biljana's springs
Rachanska River	R1	Lowermost reaches
	R2	Racha District
Cherava River	C1	Lowermost reaches
	C2	Near Ljubanishta Village

method with a D-shape net (500 µm) was used in the rivers, while a Van Veen grab (400 cm<sup>3</sup>) was used on the mostly soft bottom in the littoral part of the lake (WETZEL 1975, WETZEL & LIKENS 1979, LIND 1985, AQEM 2002).

The identification of species was made with the application of the following keys: POLINSKI (1929), SNEGAROVA (1954), STANKOVIC & RADOMAN (1955), HUBENDICK (1960, 1970), SAPKAREV (1964), BRINCHURST & JAMIESON (1971), HADZISCE (1974), LUKIN (1976), RADOMAN (1983, 1985), KEROVEC (1986), and KRSTANOVSKI (1994).

The abundance was calculated as individuals per square meter, while the relative abundance as percentage of the total abundance calculated separately for Lake Ohrid, for the Crni Drim River and for the tributaries. The frequency of occurrence (pF) coefficient was also calculated separately for the lake, its outflow and its tributaries.

The ecological status was assessed based on the Biological Monitoring Working Party (BMWP) and Average Score per Taxon (ASPT) system (ARMITAGE et al. 1983), which considers the sensitivity of benthic macroinvertebrates to pollution. The families were assigned scores from 1 to 10, accordingly.

## Results and Discussion

The results of the diversity, abundance and frequency of occurrence of the benthic macroinvertebrate taxa in Lake Ohrid, its tributaries and its outflow are presented in Table 2. A total number of 79 taxa were registered. They belonged to eight taxonomic groups: Turbellaria, Oligochaeta, Hirudinea, Isopoda, Amphipoda, Insecta, Gastropoda, and Bivalvia. The diversity of taxa in the tributaries (51 taxa) was much higher than this in the upper littoral of the lake (34) and its outflow (27). As regards the share of the particular groups in the overall diversity, that of Insecta was the highest (41 taxa or 52%), its representatives being present mostly in the lake tributaries. The second most diverse group was that of Gastropoda (16 taxa or 20%) whose representatives were registered mainly in the upper lake littoral (Table 2).

Most frequently found in the lake littoral was the oligochaete *Tubifex tubifex* (85.71%), followed by *Chironomus plumosus*, *Gammarus roeseli*, and the molluscs *Pyrgohydrobia grochmalickii* and *Sphaerium corneum* (57.14% each) (Table 2). *Tubifex tubifex* was also the most abundant species in the

**Table 2.** Taxa of benthic macroinvertebrates in Lake Ohrid littoral, lake's tributaries and outflow recorded in 2013. RA – relative abundance (in %); FD – frequency of occurrence (in %); \* – endemic species

Taxon	Lake Ohrid		Crni Drim River		Lake Ohrid tributaries	
	RA%	FD%	RA%	FD%	RA%	FD%
<b>Turbellaria</b>						
* <i>Dendrocoelum adenodactylosum</i> Stanković & Komárek, 1927	0.68	14.29				
* <i>Dendrocoelum maculatum</i> Stanković & Komárek, 1927	0.23	14.29				
<b>Oligochaeta</b>						
<i>Criodrilus lacuum</i> Hoffmeister, 1845					0.79	7.14
* <i>Criodrilus ochridensis</i> Georgevitch, 1950	0.46	14.29				
<i>Limnodrilus hoffmeisteri</i> Claparède, 1862	1.37	14.29	1.01	33.33	0.14	14.29
* <i>Pelosclex stankovici</i> Hrabě, 1931	2.50	14.29				
<i>Potamothrix hammoniensis</i> (Michaelsen, 1901)	0.68	14.29				
<i>Stylodrilus</i> sp.					1.07	21.43
<i>Tubifex tubifex</i> (Müller, 1774)	19.22	85.71				
<b>Hirudinea</b>						
* <i>Dina krilata</i> Sket, 1989	0.91	42.86	0.34	33.33	0.14	14.29
<i>Erpobdella octoculata</i> (Linnaeus, 1758)	0.68	28.57			0.65	42.86
<i>Glossiphonia complanata</i> (Linnaeus, 1758)					0.09	14.29
<i>Haemopsis sanguisuga</i> (Linnaeus, 1758)	0.46	14.29			0.46	21.43
<i>Piscicola geometra</i> (Linnaeus, 1761)					0.14	14.29
<b>Isopoda</b>						
<i>Asellus aquaticus</i> (Linnaeus, 1758)	2.28	42.86				
<i>Asellus</i> sp.					0.46	7.14
<b>Amphipoda</b>						
* <i>Gammarus ochridensis</i> (Schäferna, 1926)	4.55	28.57				
<i>Gammarus roeselii</i> Gervais, 1835	5.01	57.14	50.34	100	12.4	28.57
<i>Gammarus</i> sp.	10.00	28.57			2.74	14.29
<b>Insecta</b>						
Ephemeroptera						
<i>Baetis vernus</i> Curtis, 1834			0.34	33.33	4.51	57.14
<i>Caenis macrura</i> Stephens, 1836					0.14	14.29
<i>Ecdyonurus venosus</i> (Fabricius, 1775)					0.46	28.57
<i>Epeorus</i> sp.					0.19	7.14
<i>Ephemera danica</i> Müller, 1764					3.62	35.71
<i>Ephemerella</i> sp.					0.28	7.14
<i>Leptophlebia</i> sp.					0.05	7.14
<i>Rhithrogena</i> sp.					1.07	7.14
<b>Odonata</b>						
<i>Aeshna grandis</i> (Linnaeus, 1758)					0.14	14.29
<i>Calopteryx maculata</i> (Beauvois, 1805)			6.08	66.67	0.09	14.29
<i>Coenagrion</i> sp.					0.05	7.14
Coenagrionidae			1.69	33.33		
<i>Gomphus vulgatissimus</i> (Linnaeus, 1758)	0.23	14.29	4.39	100	0.33	35.71
<i>Platycnemis pennipes</i> (Pallas, 1771)			2.03	66.67		
Plecoptera						
<i>Isoperla</i> sp.					0.19	21.43
<i>Leuctra</i> sp.					0.09	14.29
Nemouridae					0.09	7.14
<i>Perla marginata</i> (Panzer, 1799)					0.65	7.14
<b>Heteroptera</b>						

Table 2. Continuation

Taxon	Lake Ohrid		Crni Drim River		Lake Ohrid tributaries	
	RA%	FD%	RA%	FD%	RA%	FD%
<i>Aphelocheirus aestivalis</i> (Fabricius, 1794)			1.01	33.33	0.14	14.29
Coleoptera						
<i>Dytiscus</i> sp.					0.05	7.14
<i>Limnius</i> sp.			0.34	33.33	0.37	28.57
<i>Platambus maculatus</i> (Linnaeus, 1758)			3.38	33.33	0.09	7.14
Trichoptera						
<i>Hydropsyche</i> sp.			0.34	33.33	0.51	21.43
<i>Leptocerus</i> sp.					3.49	28.57
<i>Limnephilus</i> sp.			0.34	33.33	2.51	50.00
<i>Sericostoma</i> sp.			0.34	33.33	0.51	21.43
<i>Silo</i> sp.					0.14	7.14
Diptera						
<i>Atheryx</i> sp.			0.34	33.33	0.84	35.71
<i>Bezzia</i> sp.					0.05	7.14
<i>Blepharicera</i> sp.					0.09	7.14
<i>Chironomus plumosus</i> (Linnaeus, 1758)	3.64	57.14				
<i>Chironomus thummi</i> (Kieffer, 1911)	1.14	28.57	2.70	33.33		
<i>Chironomus</i> sp.			0.68	33.33	6.04	71.43
<i>Culex</i> sp.					51.6	7.14
<i>Hermetia</i> sp.					0.09	14.29
<i>Ormosia</i> sp.					0.05	7.14
<i>Polypedilum bicrenatum</i> Kieffer, 1921	0.68	14.29				
<i>Polypedilum pedestre</i> (Meigen, 1830)	0.46	14.29				
<i>Simulium</i> sp.					0.46	14.29
<i>Tabanus</i> sp.					0.09	14.29
<i>Tipula</i> sp.			0.68	33.33	0.56	50.00
<b>Gastropoda</b>						
<i>Amphimelania holandrii</i> (C. Pfeiffer, 1828)			5.41	33.33		
<i>Ancylus fluviatilis</i> O. F. Müller, 1774					0.09	14.29
* <i>Chilopyrgula sturanyi</i> (Brusina, 1896)	0.46	14.29				
* <i>Gyraulus (Gyraulus) albidus</i> Radoman, 1953	0.23	14.29	0.68	33.33		
* <i>Gyraulus (Carinogyraulus) lychnidicus</i> Hesse, 1928	0.68	14.29				
* <i>Gyraulus (Carinogyraulus) paradoxus</i> Sturany, 1894					0.05	7.14
<i>Lymnaea stagnalis</i> (Linnaeus, 1758)			0.68	33.33	0.51	14.29
* <i>Ohridohoratia (Polinskiola) sturanyi</i> (Westerlund, 1902)	7.28	28.57				
* <i>Ohridopyrgula macedonica</i> (Brusina, 1896)	3.87	42.86				
<i>Planorbarius corneus</i> (Linnaeus, 1758)	0.23	14.29	0.68	33.33	0.46	7.14
* <i>Pyrgohydrobia (Pyrgohydrobia) grochmalickii</i> (Poliński, 1929)	14.11	57.14				
* <i>Radix relicta</i> Poliński, 1929	2.28	28.57	1.35	66.67		
* <i>Stankovicia (Macedopyrgula) pavlovici</i> (Poliński, 1929)	1.37	14.29				
<i>Theodoxus fluviatilis dalmaticus</i> Sowerby	0.91	14.29	2.36	100	0.14	7.14
* <i>Valvata stenotrema</i> Poliński, 1929	2.96	42.86	7.77	66.67		
* <i>Xestopyrgula dybowskii</i> (Poliński, 1929)	0.46	14.29				
<b>Bivalvia</b>						
* <i>Dreissena carinata</i> (Dunker, 1853)	5.01	42.86	4.39	33.33		
<i>Pisidium</i> sp.	1.82	42.86				
<i>Sphaerium corneum</i> (Linnaeus, 1758)	3.19	57.14	0.34	33.33		

lake littoral. Relatively high abundance had also the amphipods *G. roeseli*, *G. ochridensis* and *Gammarus* sp., as well as the molluscs *P. grochmalicki*, *Polinskiola sturanyi* and *Dreissena carinata* (Table 2). Our previous results from 2010 showed a slightly different qualitative and quantitative composition of the macrozoobenthic community in Lake Ohrid at 0.5 m depth. In that study period, the amphipod *G. ochridensis* had the highest relative abundance, followed by the insects *Caenis macrura* and *Elmis* sp., the mussel *D. carinata* and the isopod *Proasellus arnautovici arnautovici* (Remy, 1932, 1941). Most frequently found was *D. carinata*, *Theodoxus fluviatilis* and *Elmis* sp. (unpublished data). The present results may be due to local changes in ecological conditions and fluctuations in the benthic community.

The species *G. roeseli*, *Gomphus vulgarissimus* and *T. fluviatilis* were found at all three sites in the Crni Drim River, of them most abundant was *G. roeseli* (Table 2).

In the Lake Ohrid tributaries, most frequent was *Chironomus* sp. (71.43%), followed by the mayfly *Baetis vernus* (57.14%), and by *Erpobdella octuculata*, *Limnephilus* sp., and *Tipula* sp. (50% each). Most abundant was *Culex* sp. High relative abundance had also *G. roeseli*, *Chironomus* sp., and the mayflies *B. vernus* and *Ephemera danica* (Table 2).

Most of the taxa recorded were cosmopolitan. We recorded only 18 endemic species, belonging mainly to Gastropoda (Table 2). All taxa were native, there was no any alien species recorded either in the lake or in its tributaries and outflow (Table 2). In a previous study, two alien gastropod species have been reported from Lake Ohrid for the period 2003–2011: *Physella acuta* (Draparnaud, 1805) and *Ferrissia fragilis* (Tryon, 1863) (ALBRECHT et al. 2014). *Physella acuta* was found at three sites (out of 386 sampling sites) in the Macedonian part of the lake, while *F. fragilis* occurred only in the Albanian part of the lake (ALBRECHT et al. 2014). Based on our results, we may assume that the two species still have limited distribution and low abundance in the Lake Ohrid littoral area. The possible pathways for introduction of alien species in the Lake Ohrid watershed may be intentional or unintentional introduction by humans through stocking, aquaculture or aquarium release, as well as by natural dispersal of individuals that have been introduced by any other pathways within the watershed through the river systems and lakes (Lake Skadar, and the rivers Crni Drim, Beli Drim, and Bojana), and through the neighbouring stagnant artificial water bodies (reservoirs Globochica, Spilje, Strezhevo, Slatino, etc.).

**Table 3.** Ecological status of the studied sites in Lake Ohrid littoral, lake's tributaries and outflow assessed in 2013. For site codes see Table 1. ASPT – Average Score per Taxon index according to ARMITAGE et al. (1983)

Site	Site code	ASPT index	Ecological status
Lake Ohrid	LC	3.6	Good
	LK	3.1	Good
	LR	3.3	Good
	LCS	2.7	Poor
	LV	2.8	Poor
	LSR	2.7	Poor
	LS	3.4	Good
Crni Drim River	CD1	5.2	Very good
	CD2	5.2	Very good
	CD3	5.8	Very good
Sateska River	S1	7.5	Very good
	S2	5.5	Very good
	S3	7.7	Very good
Koselska River	K1	6.2	Very good
	K2	6.2	Very good
	K3	4.3	Good
Velgoshka (Grash-nica) River	V1	6.0	Very good
	V2	4.5	Good
Canal Studenchishta	CS1	3.8	Good
	CS2	4.0	Good
Rachanska River	R1	3.2	Good
	R2	5.6	Very good
Cherava River	C1	4.8	Good
	C2	4.9	Good

The ecological status of the studied sites is shown in Table 3. The ecological status of the lake littoral sites was significantly lower in comparison with that of the sites along the tributaries. Three of the sites were assessed as bad ecological status, and four of the sites as poor ecological status. On the contrary, the ecological status of the Crni Drim River was assessed as good at all sampling sites, meeting the requirements of the WFD (EU 2000) (Table 3). Among the tributaries, the lowest ecological status was registered in the Canal Studenchishta, where the sites were assessed as poor ecological status. These results were most likely due to natural excessive decomposition of the native vegetation, as well as anthropogenic influence, such as accidental spillage of waste water from the neighbouring hatchery of the PSI Hydrobiological Institute Ohrid. Good, and even very good ecological status was registered

along the Sateska River (Table 3), despite the fact that this river flows through agricultural areas. The period of sampling, early spring, coincided with the higher water level and velocity (especially in the Sateska River), and with a lower intensity of the agricultural activities around the tributaries. The lowest ecological status was generally recorded in the inflows of the tributaries (Koselska, Velgoshka, Cherava) (Table 3), and could be a result of their long-term accumulative effects. Due to the differences in temperature and velocity of water from the rivers (colder water) and the lake (warmer water) over time, there has been a decrease in the water mixing. This has caused an increased deposition of allochthonous materials, entering the lake through the tributaries, such as: communal and farm waste water, fertilisers, other solid waste, and suspended material. The changes in the water quality in the littoral region of the lake could be the first signs of changes in the stability and general functionality of the ecosystem and may indicate a decrease in the resistance capacity of the natural habitats against introduction and spread of alien species.

## Conclusions

With 79 taxa identified, the upper littoral of Lake Ohrid and its tributaries still can be considered as sites of enhanced biodiversity in terms of benthic macroinvertebrates. However, among the nine taxonomic groups, the most abundant were representatives of lower indicative value (sensitivity) to pollution, such as *Tubifex tubifex*, *Chironomus plumosus*, and *Gammarus roeseli*. Only 22% of the identified species were endemic, most of them representatives of Gastropoda. Despite the starting hypothesis that the tributaries could be a harbour and/or pathways for introduction of alien species into the lake, and the already existing records of alien gastropods in Lake Ohrid, no alien species were registered during our study. This may show that the existing alien benthic macroinvertebrate species still have limited distribution and low abundance in the Lake Ohrid littoral area. On the other hand, the long-term and permanent anthropogenic pressure in the Lake Ohrid littoral and its watershed have resulted in changes in the ecological status, especially in the littoral zone where the sampling sites were assessed with low and bad ecological status. This may be an indicator of general decrease in the stability and functionality of the lake ecosystem, which would consequently reduce its natural resilience and resistance capacity against introduction and spread of invasive alien species.

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