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Assessment by Macroinvertebrates of the Ecological Quality of Shallow Lake with Rich Sapropel Sediments

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Abstract. **In this research, the ecological quality of the Lake Vēveru (Latvia, Rēzekne district) according to macroinvertebrates was investigated. The Lake Vēveru has a large sapropel deposit. The Lake Vēveru is relatively little affected by human economic activity, the only moderate impact is sapropel mining in the lake in 2009-2012, it is planned to resume industrial sapropel mining in the lake. During the period of sapropel removal, a decrease in the transparency of water is noted due to the nutrient flow into the water mass, pH increases, the habitat of planktonic and benthic organisms is disturbed. Macroinvertebrates samples were collected and analyzed using standard methods in the open pelagic and littoral zones of the lake in different seasons. The ecological quality of the lake was assessed in accordance with the requirements of the European Water Framework Directive in Latvia. To characterize the ecological status of the lake the Latvian Lake Macroinvertebrate Multimetric Index was used. According to the Ecological Quality Ratio (EQR) the lake indicates a good ecological status of the water. However, a moderately low species diversity index indicates the dominance of certain taxa. In general, macroinvertebrates species that are often and widely found in Latvia and are environmentally tolerant have been found in the lake. Water temperature, pH, conductivity, dissolved oxygen, oxidation reduction potential, chlorophyll-α were measured with a *HACH OTT DS5* Probe. Water transparency was measured using a Secchi disc.**

Keywords*: *macroinvertebrates, sapropel, physical, chemical parameters of water.

I. INTRODUCTION

The EU's biodiversity strategy for 2030 is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. In 4 June 2021, Nairobi/Rome – leaders in global politics, science, communities, religion and culture united to officially introduce the UN Decade on Ecosystem Restoration - a rallying call for the protection and revival of millions of hectares of ecosystems all around the world for the benefit of people and nature. There has never been a more urgent need to revive damaged ecosystems than now. The ongoing accumulation of sediment in freshwater ecosystems is a problem that is continuing to develop at a worldwide scale [1]. Degraded lakes represent the loss of substantial economic benefits [2]. Water protection is one of the priorities in Latvian environmental protection policy.

Latvia has 2256 lakes with the water surface area over 1 ha [3]. 1126 lakes have been surveyed in Latvia, 655 of which have been recognized as sapropel deposits of industrial significance. The Latvian State Bureau of Geology indicates that the lake sapropel resources are more than 930 million m^3. Compared to other regions of Latvia, the largest total area of lakes is in Latgale - 331.5 km^2, and the total amount of sapropel identified in Latgale is 404822.1 thousand m^3 [4]. The large amount of sapropel in Latvia's lakes makes it a strategic natural resource of national level. Sapropel is a valuable product with a wide range of uses [5-9], however, its accumulation poses a threat to the lake ecosystem functioning - the area and depth of the lake decrease, the physico-chemical parameters of the water change, oxygen deficiency occurs

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in winter [10], biodiversity, including ichthyofauna decreases, lake succession takes place [11]. Finally a lot of oxygen is consumed for the oxidation of organic matter in silts in winter; as a result, its content at the bottom drops, which causes a sharp decrease in the biomass of benthos [12].

Lakes can be renovated (remediated) by extraction of organic sediment (sapropel) [13-14]. There is a double advantage of ecological recovery: a renovated lake and a valuable product sapropel which can be used for different purposes [15]. Deepening of the lake bed to deplete the sediments is an effective but aggressive method, because in its implementation there is a significant interference in the processes taking place in the lake ecosystem [13], [16]. Nevertheless, studies focused on the effects of sapropel removal on lake ecosystems are very limited and fragmentary. Removal of sapropel requires organization of spatio-temporal monitoring to control the state or disturbance of the existing ecosystems in the long term.

This research aims to determine the ecological quality of the sapropel-rich Lake Vēveru according to macroinvertebrates. The sapropel has been mined from 2009 to 2012 and it is planned to resume industrial sapropel mining. Thereby, this data could be the basis for further research on the impact of disturbance on the lake ecological quality.

The macroinvertebrates of lakes are among the commonest, a very diverse and most widespread of freshwater fauna organisms and detritus decomposers. Macroinvertebrates have a broad taxonomic spectrum, different strategies of life histories, different habitat preferences and varied roles in the feeding web, also species composition changes with changing lake trophic status. Formation of the composition of macroinvertebrates, abundance and biomass also depend on macrophyte stands (species, density) and sediments [17], [18]. For example, in eutrophic lakes the composition of the macroinvertebrate fauna is characterized by the dominance of Gastropoda and Chironomidae. Therefore, they are very good indicators and highly useful in indicating the changes of aquatic ecosystems [19], [20].

II. MATERIALS AND METHODS

Lake Vēveru (Vieveru) is located in the Feimaņi hills of the Latgale highlands. The lake belongs to the Daugava catchment region, its catchment area is 80 ha. No ditch or river flows into Vēveru Lake, but on the A side a ditch flows into the neighbouring Kovališku Lake. According to the typology of Latvian lakes, the Lake Vēveru corresponds to type 1 very shallow (average depth less than 2 m) clear water (water colour less than 80 Pt-Co) lakes with high water hardness (water electrical conductivity greater than 165 µS cm^{-1}).

According to the 2018 data of The Latvian Geospatial Information Agency, the area of water surface of the Lake Vēveru is 7.82 ha. The largest length of the lake is 460 m, the largest width is 226 m and the length of the coastline is 1366 m. The greatest depth of the lake is 3.5 m, the average depth is 1.9 m. The water volume of the Lake Vēveru is approximately 0.15 million. m^3 [21].

After Lake Vēveru Mineral Passport (2020) a sapropel deposit consists of 5.99 ha with a sapropel layer thickness of 1.00-8.57 m, an average of 5.04 m.

The hydroecological studies of the Lake Vēveru were carried out in July and September 2021 and in February and May 2022 (Fig.1-2). The sampling of macroinvertebrates were performed in July, September (2021) and May (2022). Simultaneously measurements of the physicochemical parameters of water and water transparency (by a Secchi disk) were done. In February 2022, only the physicochemical parameters of water were measured when the lake was covered by ice.

Physico-chemical water parameters – water temperature °C, conductivity µS cm^{-1}, dissolved oxygen mg l^{-1}, chlorophyll α µg l^{-1} and oxidation-reduction potential mV – were measured in situ using a *HACH Hydrolab DS5* multiprobe. The measurements of physico-chemical water parameters at the deeper parts of the lake were performed starting from the lake surface to the bottom (up to limits of ± 1 m) with a measurement range of one meter and at the very shallow parts in a surface water layer (in ± 1.0 - 0.5 m limits). Surface water sampling (in ± 0.5 m limits) for detection of biological oxygen demand and their laboratory analysis was performed according to standard methods [22].

The sampling of macroinvertebrates was performed in the littoral/ inshore (at four to five sites) and the open water (at two sites) parts of the lake (Fig.1-2). Sampling sites were characterised by abundant stands of charophyta *Nitellopsis obtusa* in the deepest parts and mostly by *Nuphar lutea*, *Potamogeton* sp., *Phragmites australis*, *Typha* sp., by slough habitats in the shallow or inshore parts and by soft substrate (mud, detritus). Macrophytes were identified by Plants of Lake Shores [Ezeru krastmalu augi] (2016), online https://www.latvijasdaba.lv, and by Charophytes of Great Britain and Ireland. Botanical Society of the British Isles, London (1986).

Semi-quantitative (2021) and quantitative (2022) samples of macroinvertebrates were collected using a Hydrobios hand net with a mouth opening of 25x25 cm (500 µm mesh) in the wadeable (up to 0.5 m) depths by the sweeping technique [23]. Quantitative samples of zoobenthos on soft bottom were collected using Ekman grab sampler (225 cm^2) (2-3 replicate samples at each site), obtained samples were sieved through a 0.5 mm screen. The samples were preserved in ethanol (at least 70% solution) for latter identification and counting. Specimen identification was done with a *ZEISS Stemi 508doc* stereomicroscope using the literature: Timm 2015 [24], Kriska 2013 [25]. Animals were identified to the lowest taxonomic level where possible.

The ecological status according to European Water Framework Directive was measured using Latvian Lake Macroinvertebrate Multimetric Index [26], [27].

Fig. 1. Location of the study site.

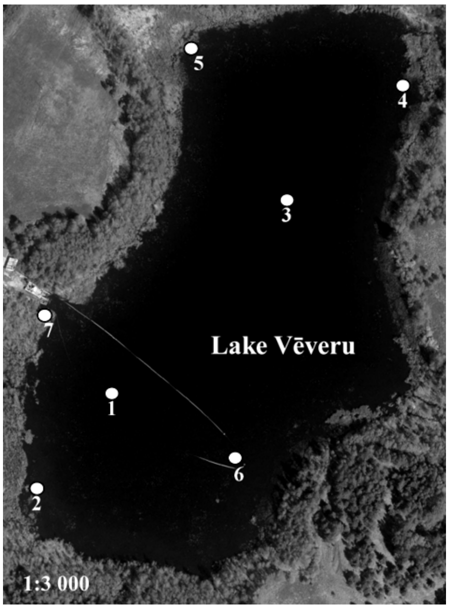

Fig. 2. Sampling sites in the Lake Vēveru.

III. RESULTS AND DISCUSSION

A. Physico-chemical parameters

Average water temperature in the deepest part (2.7 m) of the lake seasonally ranged between 25.00°C in 2021 summer (July) and 2.78°C in 2022 winter (February). Average dissolved oxygen concentrations were lowest in winter 1.16 mg l^{-1} (lowest 0.35 mg l^{-1} near sediments) and the higher in 2022 spring (May) and summer 9.66 and 9.42 mg l^{-1} respectively. In winter, low dissolved oxygen is a common phenomenon in ice-covered lakes, and anoxic conditions of winter are characteristic of shallow eutrophic lakes with high oxygen depletion [28]. Also, biochemical oxygen demand was higher in winter 7.25 mg l^{-1}, in spring was 4.95 mg l^{-1} and in autumn (2021 September) 2.18 mg l^{-1} due to phytoplankton, bacterioplankton, and decomposition of organic matter. Secchi depth ranged between 1.90 m in summer and 2.20 m in autumn to 1.10 in spring which mainly depend on phytoplankton. Accordingly, the highest concentrations of chlorophyll-a were observed in spring (average 3.94 µg l^{-1}). High concentrations also were in winter under ice cover (maximum 11.00 µg l^{-1}) because there is an internal nutrient supply, especially phosphorus which may increase under anoxic conditions in winter [29]. Value of pH was typical for Latvian lakes (average pH 7.45), only in winter under ice cover average pH was 6.75, and similarly also oxidation reduction potential decreased (average 218 mV), and indicated low oxygen conditions in winter [30]. In common, the hard (average electro conductivity 418 µS cm^{-1}) clear-water lakes with such chlorophyll-a concentrations correspond to good - moderate ecological status [26].

B. Macroinvertebrates

Thirty-seven taxa of macroinvertebrates, belonging to Annelida, Mollusca, Insects and Crustacea were recorded from four sites during the sampling period (Tab. 1) in the lake. The macroinvertebrate community was found to be influenced by the type of substrate. The most considerable species diversity was obtained using the sweeping technique between macrophytes. Ekman grab sampling at sites 2 and 3 was impacted by rich detritus layer and abundant stands of charophyta *Nitellopsis obtusa* respectively and macroinvertebrates was not obtained. Only from the soft substrate at site 1 (the depth 2.2 m) four taxa were recorded (Tab. 1). It is noted that macroinvertebrate species composition and richness were mainly affected by habitat conditions [31], [32], [18]. For example, in similar research of shallow charohyta lakes dominant species in Chara stands were the gastropods *Valvata piscinalis* and *Bithynia tenticulata* [17]. Also, the abundance of individuals was low. In 2021 summer and autumn, it was 180 specimens m^{-2} and 40 specimens m^{-2} respectively. In 2022 spring, it was 40 specimens m^{-2} at site 1 and in the littoral part at site 5 and 7 it was from 42 to 157 specimens m^{-2} respectively. In 2022 spring the Crustacea, Coleoptera and Trichoptera were the most abundant across the sites (39%, 24% and 10%, respectively) and more diverse were Coleoptera (Dysticidae, Hydrophilidae) and Trichoptera (Limnephilidae), dominant was crustacean *Asellus aquaticus*. In general, in the Lake Vēveru has been found macroinvertebrate taxa that are often and widely distributed in Latvian freshwaters and are more or less environmentally tolerant [20], [24], [32], [33]. The macroinvertebrate composition of the Lake Vēveru corresponds from high to moderate ecological status (Chironomidae (Diptera), Ephemeroptera – *Cloeon dipterum*; Trichoptera - Limnephilidae, *Limnephilus* spp.; Gastropoda – *Bithynia* sp., Planorbidae; Crustacea – *Asellus aquaticus*; Odonata – Libellulidae, Aeshnidae, *Erythromma najas*, Coenagrionidae; Hydracarina) [34], [35]. One of Dytiscidae, *Cybister (Scaphinectes) lateralimarginalis* which is the only species of the Cybisterini tribe in Latvia and mainly occurred in the Eastern Latvian freshwaters, also was obtained in the Lake Vēveru. This lake is suitable habitat for the species because it prefers habitats with a high percentage of plant cover, with mud and medium coarse detritus. In small and shallow lakes surrounded by forests and swamps, the species tends to be found throughout the lake area [36], [37].

TABLE 1 MACROINVERTEBRATES COMPOSITION AND OCCURRENCE OF THE LAKE VĒVERU

Taxa	**A score of Biological Monitoring Working Party (BMWP), taxa composition and occurrence among sampling dates and sites**						
	BMWP	***Date***	***No. 1***	***No. 4***	***No. 5***	***No. 7***	***Total taxon***
Annelida							
Haemopis sanguisuga (Linnaeus, 1758)	3	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Bivalvia							
Sphaerium corneum (Linnæus, 1758)	3	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Gastropoda							
Planorbis carinatus O.F.Mueller	3	02.07.21.					+
		17.09.21.		+	+		
		09.05.22.					
Planorbarius corneus (Linnaeus, 1758)	3	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Bithynia sp. Leach, 1818	3	02.07.21.			+		+
		17.09.21.					
		09.05.22.			+	+	
Viviparus contectus (Millet, 1813)	6	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Valvata (Cincinna) piscinalis (O.F. Muller, 1774)	3	02.07.21.	+				+
		17.09.21.					
		09.05.22.					
Arachnida							
Hydrachnidia Gen. sp.	1	02.07.21.		+	+		+
		17.09.21.					
		09.05.22.			+	+	
Ephemeroptera							
Baetidae*, Cloeon dipterum* (Linnaeus, 1761)	4	02.07.21.			+		+
		17.09.21.			+		
		09.05.22.				+	
Odonata							
Anisoptera*, Libellula quadrimaculata* Linnaeus, 1758	8	02.07.21.					+
		17.09.21.					
		09.05.22.			+		
Anisoptera*, Brachytron pratense* (Muller, 1764)	8	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Anisoptera*, Brachytron pratense* (Muller, 1764)	8	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Zygoptera, Coenagrionidae, *Enallagma* sp. Charpentier, 1840	6	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Zygoptera, Coenagrionidae, *Erythromma najas* (Hansemann, 1823)	6	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Zygoptera, Coenagrionidae, *Ischnura* sp. Vander Linden, 1820	6	02.07.21.	+				+
		17.09.21.					
		09.05.22.					
Odonata *Gen*. sp	6	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Hemiptera							
Cymatia coleoptrata (Fabricius, 1777)	5	02.07.21.					+
		17.09.21.			+		
		09.05.22.					
Ilyocoris cimicoides (Linnaeus, 1758)	5	02.07.21.			+	+	+
		17.09.21.			+	+	
		09.05.22.				+	
Notonecta (Notonecta) glauca Linnaeus, 1758	5	02.07.21.				+	+
		17.09.21.					
		09.05.22.					
Nepa cinerea Linnaeus, 1758	5	02.07.21.			+		+
		17.09.21.					

Taxa	A score of Biological Monitoring Working Party (BMWP), taxa composition and occurrence among sampling dates and sites						
	BMWP	***Date***	***No. 1***	***No. 4***	***No. 5***	***No. 7***	***Total taxon***
		09.05.22.					
Coleoptera							
Dytiscidae*, Hyphydrus ovatus* (Linnaeus, 1761)	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Dytiscidae*, Hygrotus* sp. Stephens, 1828	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Dytiscidae*,* sp.	5	02.07.21.					+
		17.09.21.				+	
		09.05.22.				+	
Dytiscidae*, Cybister (Scaphinectes) lateralimarginalis* (De Geer, 1774)	5	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Hydrophilidae, *Hydrochara caraboides* (Linnaeus, 1758)	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Hydrophilidae, *Enochrus* sp. Thomson, 1859	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Noteridae, *Noterus* sp. Clairville, 1806	5	02.07.21.					+
		17.09.21.				+	
		09.05.22.				+	
Hydrophilidae*, Coelostoma (Coelostoma) orbiculare* (Fabricius, 1775)	5	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Haliplidae, *Haliplus* sp. Latreille, 1802	5	02.07.21.		+	+		+
		17.09.21.					
		09.05.22.					
Trichoptera							
Polycentropodidae, *Cyrnus flavidus* McLachlan, 1864	7	02.07.21.		+			+
		17.09.21.	+				
		09.05.22.					
Limnephilidae, *Limnephilus flavicornis* (Fabricius, 1787)	7	02.07.21.					+
		17.09.21.					
		09.05.22.			+	+	
Limnephilidae, *Limnephilus* sp. Leach, 1815 (*L. stigma*)	7	02.07.21.			+		+
		17.09.21.					
		09.05.22.			+		
Diptera							
Chironomus sp. Meigen, 1803	2	02.07.21.	+		+		+
		17.09.21.					
		09.05.22.	+				
Brachycera, Stratiomyidae, *Stratiomys* sp. Geoffroy, 1762	3	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Lepidoptera							
Larvae		09.05.22.			+		+
Crustacea							
Gammaridae*, Synurella ambulans* (Muller, 1846)	6	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Isopoda, *Asellus aquaticus* (Linnaeus, 1758)	3	02.07.21.					+
		17.09.21.			+	+	
		09.05.22.			+	+	

No. 1 (by Ekman grab), No. 4 (by hand net), No. 5 (by hand net), No. 7 (by hand net), + (occurrence)

The assessment of the ecological status of the Lake Vēveru was based on the littoral samples of macroinvertebrates in 2022 spring. The littoral zone of lakes plays a crucial and dynamic role in regulating the flows of nutrients and materials from the watershed [32], [20]. The ecological status of the Lake Vēveru by the Latvian Lake Macroinvertebrate Multimetric Index was estimated as good (Tab. 2). Only the Shannon-Wiener species diversity index characterises the lake as a bad ecological status lake because the dominant taxa in spring was *Asellus aquaticus*. It is noted that the isopod *Asellus aquaticus* shows the strongest association with high total phosphorus concentrations in lakes [32].

TABLE 2 INDICATORS OF ECOLOGICAL QUALITY ASSESSMENT OF THE LAKE VĒVERU

Indicators	**Parameters of assessment of ecological quality**		
	Value of index	***Ecological quality ratio (EQR)***	***Assessment of ecological quality***
BMWP[1] index Haemopidae (count 1) score 3 Bithyniidae (1) 3 Hydrachnidia (1) 1 Baetidae (1) 4 Libellulidae (1) 8 Coenagrionidae (1) 6 Naucoridae (1) 5 Dytiscidae (3) 5 Hydrophilidae (2) 5 Noteridae (1) 5 Limnephilidae (2) 7 Chironomidae (1) 2 Stratiomyidae (1) 3 Gammaridae (1) 6 Isopoda (1) 3	82	-	good (light organic pollution)
Total number of taxa	20	0.57	good
EPTBO[2] taxa	12	0.59	good
ASPT[3] index	5.40	0.68	good
Shannon-Wiener species diversity index H’	2.00 (1.70-2.30)	0.38	bad
Average EQR		0.55	good

[1] BMWP - Biological Monitoring Working Party
[2] EPTBO - Ephemeroptera, Plecoptera, Trichoptera, Bivalvia, and Odonata taxa
[3] ASPT - Average Score Per Taxon index

CONCLUSIONS

Overall, the ecological status of the Lake Vēveru by the Latvian Lake Macroinvertebrate Multimetric Index and by the macroinvertebrate composition of Lake Vēveru was estimated as good. The obtained data can be the basis for further research on disturbance impact on the lake ecological quality if the Lake Vēveru will be used for the industrial sapropel mining.

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