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Characterization of the Zooplankton Community of a Shallow Lake with Organic-Rich Sediment

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Abstract. **In this research, the ecological quality of the lake Vēveru (Latvia, Rēzekne district) according to zooplankton was investigated. Lake Vēveru has a large sapropel deposit with rich reserves of sapropel. Removal of sapropel requires organization of spatio-temporal monitoring to control the state or disturbance of the existing ecosystems in the long term. Zooplankton samples were collected and analyzed using standard methods in the open pelagic and littoral zones of the lake in different seasons. Quantitative samples of zooplankton in each sampling site were collected from the surface water layer at the depth of 0.5 m by filtering 100 l of water through an Apstein-type plankton net (64 µ). Biodiversity of zooplankton taxa in Lake Vēveru shows that the food base of juvenile and planktophagous fish is sufficient. The Shannon index according to the diversity of zooplankton taxa ranges from 0.84 to 1.52 by abundance, from 1.52 to 2.21 by biomass.**

Keywords: Lake Vēveru, sapropel, zooplankton, Rotifera, Cladocera, Copepoda.

I. Introduction

Lakes are a great national treasure (fresh water source can be used for hydroenergy production, recreation, fishery etc.). They are important from the natural and economic point of view. Yet lakes tend to age, bog up and disappear [1].

Latvia has 2256 lakes with the water surface area over 1 ha and the total area about 1001 km^2, which is 1.5 % of the territory of Latvia. A significant part of lakes contains sapropel deposits. Sapropels are dark and exceptionally organic-rich sediments typically deposited under highly anoxic conditions where deep water ventilation is absent [2]. Sapropel continues to accumulate, reducing the average depth of the lake by 3-5 millimeters every year. In such lakes fish feeding and spawning conditions deteriorate rapidly. Fish feeding objects – zooplankton and zoobenthos – decrease in diversity and biomass resulting in suboptimal feeding and growth conditions. The decrease in macrophyte diversity and total hard/sandy bottom area lead to a loss of spawning substrate for the majority of fish species. In addition, fish and wind induced organic sediment resuspenison leads to higher oxygen consumption and increase in internal phosphorus loading [3]-[4].

Sapropel extraction is mentioned as one of the lake recovery measures. Restoration of Lakes through Sediment Removal has been conducted e.g. in Sweden, Czech Republic [1], [5]-[6]. During the period of sapropel removal, increase in the water turbidity is noted due to the nutrient flow into the water mass, pH increases, the habitat of planktonic and benthic organisms is disturbed [7]. Turbidity correlated negatively with abundance of Cladocera and biomass of Copepoda [8]. Unfortunately, very few studies assessing the effectiveness of this approach are available, hence there is no comprehensive confidence [6]. There are no scientifically based, long term studies on the impact of sapropel removal on Latvian lake ecosystems.

Zooplankton is one of the important components of the ecosystem. Zooplankton is an important food base for juvenile and planktophagous fish [9]-[12], and also serves as an ecological monitoring object for water bodies, determining the trophic state of the lake. Zooplankton is a dynamic system in which species composition can change significantly during the season. In the temperate climate zone, changes in the zooplankton species composition of lakes are influenced by many factors, including temperature, food, competition, predation and exposure to

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anthropogenic factors [9]-[20]. Zooplankton, especially Cladocera and Copepoda and macroinvertebrates are the organisms with the greatest filter-feeding capacities. Filter-feeding organisms feed on algae, suspended detritus, and other particles in the water column and through this activity may substantially affect water clarity, nutrient concentrations and sedimentation rates [21]-[22].

Aim of research – to evaluate the composition of zooplankton community of a shallow lake Vēveru with organic-rich sediment as a potential food base for fish.

II. MATERIALS AND METHODS

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 404 822.1 thousand m^3 [23].

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 East side a ditch flows into the neighboring Kovališku Lake. According to the typology of Latvian lakes, Vēveru lake corresponds to very shallow (average depth less than 2 m) clear water (water color less than 80 Pt-Co) lakes with high water hardness (water electrical conductivity greater than 165). According to the 2018 data of The Latvian Geospatial Information Agency, the area of water surface of 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 3.1 m, the average depth is 1.9 m. The water volume of Lake Vēveru is approximately 0.15 millions m^3 [24]. After Lake Vēveru Mineral Passport (2020) a sapropel deposit of 5.994 ha in Lake Vēveru with total sapropel reserves of 30300 tons (sapropel layer thickness 1.00-8.57 m, average 5.04 m).

The hydroecological studies of Lake Vēveru were carried out in July and September 2021 and in February and May 2022. The sampling of zooplankton were performed in July, September (2021) and May (2022).

The sampling of zooplankton were performed in the littoral/ inshore (at four to five sites) and the open water (at two sites) parts of the lake (see 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).

Quantitative samples of zooplankton in each sampling site were collected from the surface water layer at the depth of 0.5 m by filtering 100 l of water through an Apstein-type plankton net (64 μ). The samples were preserved in ethanol (at least 70% solution) APHA Plankton 10200, 2005 [25]). The analysis of zooplankton samples was conducted using *ZEISS Axiovert 40C* microscope (100-400 x magnification). The zooplankton 1 ml subsamples were analysed 6x repeatedly using gridded Sedgewick Rafter counting chambers, in total 6 ml sample's subvolume was examined APHA Plankton 10200 (2005) [25]. Specimens of zooplankton were determined by species, genus or family applying relevant identification guides - [27], [29]-[43]. The individual biomass of zooplankton taxa was obtained from information available in literature sources [38], [44].

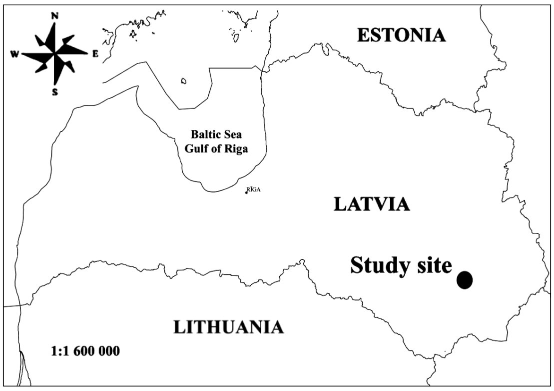

Fig. 1. Location of the study site.

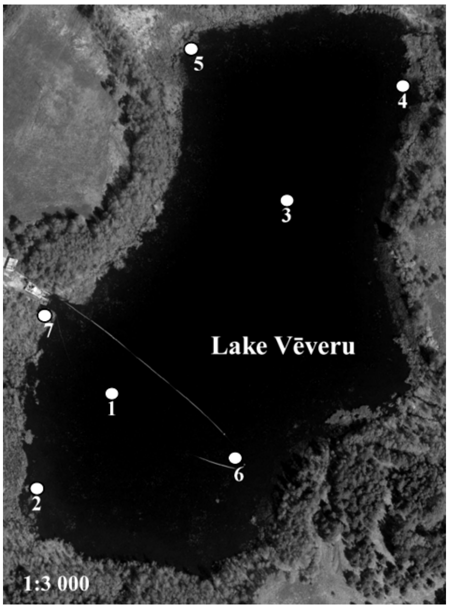

Fig. 2. Sampling sites in the Lake Veveru.

III. RESULTS AND DISCUSSION

The biological diversity of zooplankton taxa in Lake Vēveru, according to the obtained data, shows that the food base of juvenile and planktophagous fish is sufficient, as zooplankton taxa were found in the lake, which feed on both juvenile and planktophagous fish. For example, taxa of the Rotifera group, such as *Brachionus angularis*, *Polyarthra vulgaris*, *Keratella cochlearis*, *Rotifera* sp., are more important in the growth process for juvenile fish. For example, having analysed results in more details of experimental data with juvenile fish (carps) feeding, which taxons have been eaten up, it can be seen that after the experiment, the number of Rotifera group taxons *Brachionus angularis*, *Polyarthra vulgaris*, *Rotifera* sp has decreased. The number of Cladocera group taxa, as well as the number of adult Copepodita and Nauplii, is also slightly reduced. In the control samples, the most common taxa have been *Keratella cochlearis*, *Polyarthra vulgaris*, *Synchaeta* sp., *Pompholux sulcata*, *Bosmina longirostris*, *Bosmina longispina*, Copepodits and Nauplii. In this case, the results of the experiment also confirm that juvenile fish mainly use smaller zooplankton organisms as feed [45]-[46]. While for adult fishes food base are more important taxa of the Cladocera such as *Daphnia cucullata*, *Bosmina longirostris*, *Diaphanosoma brachyurum* etc. taxa and Copepoda such as *Cyclops*, *Eudiaptomus graciloides* etc. group taxa [45], [47]-[51].

According to the obtained data of Lake Vēveru in percentage terms of the summer, autumn and spring in 2022, by the number of taxa/occurrence between the sampling sites, the Rotifera group was the most widely represented, followed by the Copepoda and Copepoda groups (Fig. 3-5). In the summer samples of 2021, the Rotifera group was from 76.8% (place No. 5) to 43.2% (place No. 1), followed by the Copepoda group from 48.6% (place No. 3) to 20.8% (place No. 5) and Cladocera group from 2.3 % (place No. 5) to 11.3 % (place No. 1). On the other hand, the Rotifera group was from 85.2% (place No. 6) to 81.7% (place No. 4) in the autumn samples of 2021, followed by the Copepoda group from 14.6% (place No. 3) to 11.3% (place No. 1) and Cladocera group from 6% (place No. 1) to 1.8% (place No. 6). It should be noted that the Copepoda group had a large number of immature specimens - Nauplii and Copepodita, in terms of the number of taxa/occurrence, which was also the basis for the higher obtained percentage result. In the spring samples of 2022 in Lake Vēveru, the percentage distribution of the number of taxa/occurrence between the sampling sites was similar to the distribution of the summer and autumn of 2021, i.e. the Rotifera group was the most widely represented from 94.3% (place No. 5) to 81.6% (place No. 4), followed by the Copepoda group from 18.2% (place No. 4) to 5.7% (place No. 5) and the Cladocera group from 0.2 % (places No. 3 and No. 4) to 0.1 % (places No. 1 and No. 5). The Copepoda group had a large number of immature specimens - Nauplii and Copepodita, in terms of the number of taxa/occurrence also in spring, which was also the basis for the higher obtained percentage result.

According to the obtained taxon biomass data in the summer of 2021, autumn and spring of 2022 (Fig. 3-5), it can be seen that the percentage of biomass is made up by the taxa of the Copepoda and Cladocera groups, as they are significantly larger and heavier compared to the taxa of the Rotifera group. In the summer of 2021, the percentage distribution of Copepoda by biomass was from 61.4 % (place No. 2) to 46.5 % (place No. 1; No. 6), followed by the Cladocera group from 50.6 % (place No. 1) to 33 % (place No. 4) and Rotifera group from 12.1 % (place No. 5) to 2.8 % (place No. 1). In the autumn of 2021, the percentage distribution of Copepoda by biomass was from 67.2 % (place No. 6) to 38.5 % (place No. 5), followed by the Cladocera group from 45.3 % (place No. 5) to 18 % (place No. 6) and Rotifera group from 16.2% (place No. 5) to 9.9% (place No. 4). But in the spring of 2022 the percentage distribution of Copepoda by biomass was from 16% (place No. 1) to 5.9% (place No. 5), followed by the Cladocera group from 0.5% (places No. 1 and No. 4) to 0.1% (place No 5) and the Rotifera group from 94% (place No. 5) to 83.6% (place No. 1).

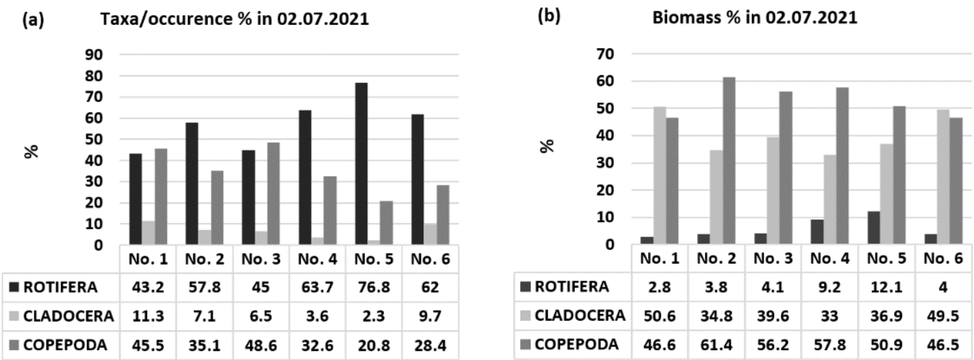

Fig. 3. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in summer 2021 (sampling sites No. 1-6).

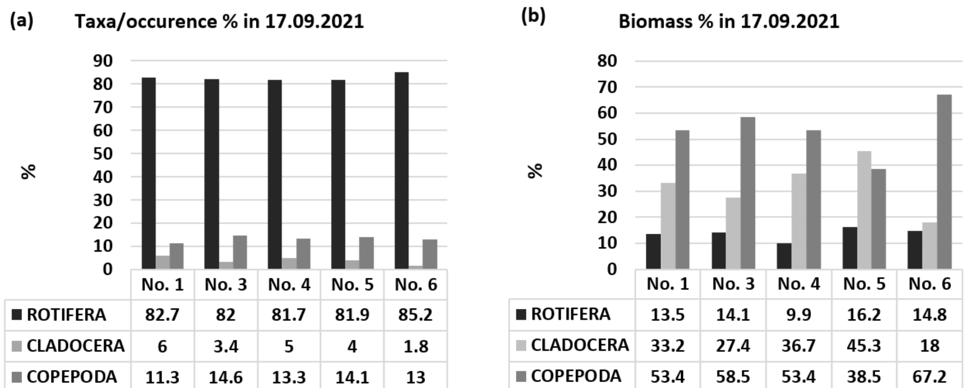

Fig. 4. The percentage of taxa (a) and biomass (b) of Rotifera, Cladocera & Copepoda groups in autumn 2021 (sampling sites No. 1, 3, 4-6).

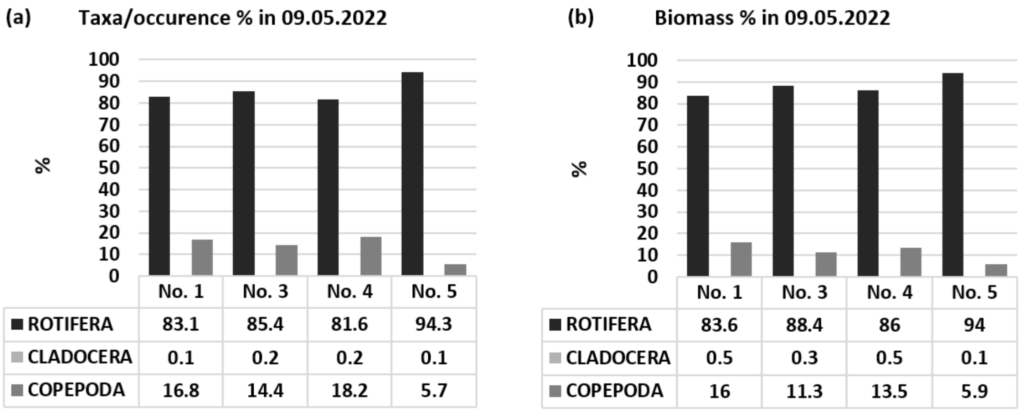

Fig. 5. The percentage of taxa (a) and biomass (b) of Rotifera, Cladocera & Copepoda groups in spring 2022 (sampling sites No. 1, 3-5).

Shannon's biodiversity index [52]-[54] according to the diversity of zooplankton taxa ranged from 0.84 to 1.52 in summer, from 1.07 to 1.52 in autumn, and from 1.55 to 1.96 in spring. Accordingly, the Shannon Biodiversity Index, according to biomass, ranged from 1.52 to 1.88 in summer, from 1.46 to 2.21 in autumn, and from 0.56 to 1.23 in spring.

Analyzed the diversity of zooplankton taxa from the obtained data in summer, autumn and spring by sampling sites covering the entire lake (Table 1), can be concluded that the Rotifera group was the most numerically represented, i.e. from 10 to 14 taxa in summer, where at all sampling sites have 6 in common, from 12 to 20 taxa in autumn and from 10 to 12 taxa in spring. All sampling sites have 8 taxa in autumn, and 10 in spring. The second largest group in terms of taxon diversity in summer and autumn was Cladocera, i.e. 5 to 8 taxa in summer, with only one taxon in common, and 3 to 9 taxa in autumn, with 2 taxa in common. In spring, the second largest group in terms of taxon diversity is Copepoda, i.e. from 1 to 4 taxa, where 1 taxon is common. On the other hand, in both summer and autumn, Copepoda was third with 3 taxa, while in spring Cladocera was third with 2 to 3 taxa, with 1 taxon in common. It should be added here that a large number of juveniles (Nauplii and Copepodites) were found in all samples, which are also used as food by both planktophagous fish and juvenile fish. In general, a similar percentage distribution of zooplankton groups in terms of number and biomass can also be observed in other lakes of Eastern Latvia [55]-[61]. Accordingly, the obtained data confirm that, at the given moment, the fish food base in Vēveru lake is favorable for the development of both juvenile fish and planktophagous fish.

CONCLUSIONS

According to the data obtained from our research, the quantitative and qualitative composition of zooplankton in the Lake Vēveru is not homogeneous. The distinguishing feature of the zooplankton species is seasonality, for example, some species are found only during a particular season or, in turn, occur throughout the season, but reach their peak in a given season. The obtained data confirm that, at the given moment, the fish food base in Vēveru lake is favorable for the development of both juvenile fish and planktophagous fish, because zooplankton taxa were found in the lake, which feed on both juvenile and planktophagous fish.

TABLE 1 COMPOSITION OF ZOOPLANKTON TAXA IN LAKE VĒVERU

Species (taxon)	***Site***						
ROTIFERA	***Date***	***No. 1***	***No. 2***	***No. 3***	***No. 4***	***No. 5***	***No. 6***
Dicranophorus sp. Nitzsch, 1827	02.07.21.						
	17.09.21.					+	+
	09.05.22.						
Cephalodella gibba (Ehrenberg, 1832)	02.07.21.						
	17.09.21.						+
	09.05.22.						
Cephalodella sp. Bory de St.Vincent, 1826	02.07.21.						
	17.09.21.					+	
	09.05.22.						
Trichocerca capucina (Wierzejski & Zacharias, 1893)	02.07.21.				+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+					
Trichocerca cylindrica (Imhof, 1891)	02.07.21.	+	+	+		+	
	17.09.21.			+	+	+	+
	09.05.22.						
Trichocerca longiseta (Schrank, 1802)	02.07.21.						
	17.09.21.						
	09.05.22.						
Trichocerca similis (Wierzejski, 1893)	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+

Species (taxon)	***Site***						
	09.05.22.						
Trichocerca sp. Lamarck, 1801	02.07.21.						
	17.09.21.						+
	09.05.22.						
Gastropus stylifer (Imhof, 1891)	02.07.21.	+		+	+	+	+
	17.09.21.			+	+	+	+
	09.05.22.						
Ascomorpha ecaudis Perty, 1850	02.07.21.						
	17.09.21.						
	09.05.22.	+		+	+	+	
Polyarthra sp. Ehrenberg, 1834	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Ploesoma hudsoni (Imhof, 1891)	02.07.21.						
	17.09.21.	+		+	+		
	09.05.22.						
Synchaeta sp. Ehrenberg, 1832	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Asplanchna priodonta Gosse, 1850	02.07.21.	+		+	+		+
	17.09.21.	+		+	+		
	09.05.22.	+		+	+	+	
Lecane luna (Müller, 1776)	02.07.21.						
	17.09.21.					+	+
	09.05.22.						
Lecane lunaris (Ehrenberg, 1832)	02.07.21.						
	17.09.21.			+		+	+
	09.05.22.						
Lecane flexilis (Gosse, 1886)	02.07.21.						
	17.09.21.			+			
	09.05.22.						
Lecane sp. Nitzsch, 1827	02.07.21.						
	17.09.21.					+	
	09.05.22.						
Lepadella ovalis (O.F. Müller, 1786)	02.07.21.		+			+	
	17.09.21.	+				+	+
	09.05.22.	+				+	
Lepadella patella (Müller, 1773)	02.07.21.	+					
	17.09.21.						
	09.05.22.						
Squatinella sp. Bory de St. Vincent, 1826	02.07.21.						
	17.09.21.				+	+	
	09.05.22.						
Euchlanis dilatata Ehrenberg, 1832	02.07.21.						
	17.09.21.					+	+
	09.05.22.						
Brachionus angularis Gosse, 1851	02.07.21.					+	
	17.09.21.						
	09.05.22.	+		+	+	+	
Brachionus calyciflorus Pallas, 1766	02.07.21.						
	17.09.21.						
	09.05.22.	+		+	+	+	
Keratella cochlearis Gosse, 1851	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Keratella quadrata Müller, 1786	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Kellicottia longispina Kellicott, 1879	02.07.21.	+		+	+		+
	17.09.21.						
	09.05.22.	+		+	+	+	
Notholca acuminata (Ehrenberg, 1832)	02.07.21.						
	17.09.21.						
	09.05.22.					+	
Conochilus sp. Ehrenberg, 1834	02.07.21.	+	+	+	+	+	+
	17.09.21.					+	+
	09.05.22.						
Collotheca sp. Harring, 1913	02.07.21.		+		+		
	17.09.21.						
	09.05.22.						

Species (taxon)	***Site***						
	02.07.21.	+					
Pompholyx sulcata Hudson, 1885	17.09.21.						
	09.05.22.					+	
	02.07.21.						
Filinia longiseta (Ehrenberg, 1834)	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
	02.07.21.	+				+	
Testudinella patina (Hermann, 1783)	17.09.21.					+	+
	09.05.22.						
	02.07.21.	+	+				
Bdelloid sp. Hudson, 1884	17.09.21.	+					
	09.05.22.						
	02.07.21.				+		
Rotifera sp. Scopoli, 1777	17.09.21.				+		+
	09.05.22.						
CLADOCERA	***Date***	***Site No. 1***	***Site No. 2***	***Site No. 3***	***Site No. 4***	***Site No. 5***	***Site No. 6***
	02.07.21.	+	+		+	+	+
Diaphanosoma brachyurum (Liévin, 1848)	17.09.21.	+		+	+	+	
	09.05.22.						
	02.07.21.						
Sida crystallina (O. F. Müller, 1776)	17.09.21.					+	
	09.05.22.						
	02.07.21.			+	+		
Daphnia (Daphnia) cucullata Sars, 1862	17.09.21.				+		
	09.05.22.						
	02.07.21.		+	+	+	+	+
Ceriodaphnia sp. Dana, 1853	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+		
	02.07.21.		+	+		+	
Scapholeberis mucronata (O. F. Müller, 1776)	17.09.21.						
	09.05.22.						
	02.07.21.			+	+		+
Graptoleberis testudinaria (Fischer, 1851)	17.09.21.						
	09.05.22.						
	02.07.21.	+	+			+	
Acroperus harpae (Baird, 1835)	17.09.21.			+		+	+
	09.05.22.						
	02.07.21.		+				
Alonella nana (Baird, 1843)	17.09.21.			+	+		+
	09.05.22.						
	02.07.21.						
Alona sp. Baird, 1843	17.09.21.			+		+	
	09.05.22.						
	02.07.21.	+	+	+			+
Chydorus ovalis (Kurz, 1875)	17.09.21.					+	
	09.05.22.			+		+	
	02.07.21.	+	+	+	+		+
Bosmina (Bosmina) longirostris (O. F. Müller, 1776)	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
	02.07.21.						
Eurycercus (Eurycercus) lamellatus (O. F. Müller, 1776)	17.09.21.			+			+
	09.05.22.						
	02.07.21.						
Pleuroxus (Peracantha) truncatus (O. F. Müller, 1785)	17.09.21.					+	+
	09.05.22.						
	02.07.21.		+		+	+	
Polyphemus pediculus (Linnaeus, 1758)	17.09.21.					+	
	09.05.22.						
COPEPODA	***Date***	***Site No. 1***	***Site No. 2***	***Site No. 3***	***Site No. 4***	***Site No. 5***	***Site No. 6***
	02.07.21.	+	+	+	+		+
Acanthocyclops sp. Kiefer, 1927	17.09.21.	+					+
	09.05.22.	+		+	+	+	
	02.07.21.						
Cyclops sp. Müller, 1785	17.09.21.						
	09.05.22.						
	02.07.21.						
Mesocyclops sp. Kiefer, 1927	17.09.21.						
	09.05.22.	+		+	+		
Thermocyclops oithonoides (G.O.Sars, 1863)	02.07.21.		+	+	+		+
	17.09.21.						

Species (taxon)	***Site***						
	09.05.22.						
Eudiaptomus graciloides (G.O. Sars, 1863)	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+		+
	09.05.22.			+	+		
Copepodite	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Nauplii	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+					

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