Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 15th International Scientific and Practical Conference. Volume I, 78-85

Changes in structure of zooplankton communities in the Daugava River and Pļaviņas Reservoir

Aija Brakovska
Laboratory of Hydroecology,
Department of Ecology
Institute of Life Sciences and Technologies
Daugavpils University
Daugavpils, Latvia
aija.brakovska@du.lv

Jana Paidere
Laboratory of Hydroecology
Department of Ecology
Institute of Life Sciences and Technologies
Daugavpils University
Daugavpils, Latvia
jana.paidere@du.lv

Rasma Tretjakova
Institute of Engineering
Faculty of Engineening
Rezekne Academy of Technologies
Rezekne, Latvia
rasma.tretjakova@rta.lv

Abstract. ***In general 26 taxa of Rotifera, 8 taxa Cladocera and 3 taxa Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2019, but 25 taxa of Rotifera, 6 taxa Cladocera and 2 taxa Copepoda group were found in the Daugava River in sampling site- Veczeļķi in 2019. In contrast, 26 taxa of Rotifera, 7 taxa Cladocera and 1 taxon Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2020, and 23 taxa of Rotifera, 1 taxa Cladocera group were found in the Daugava River in sampling site- Veczeļķi in 2020. 28 taxa of Rotifera, 13 taxa Cladocera and 4 taxon Copepoda group were found in the Pļaviņas Reservoir (sampling site- Gostiņi) in 2019, and 25 taxa of Rotifera, 7 taxa Cladocera group and 2 taxon Copepoda group were found in 2020. In the Daugava River in sampling site- Jēkabpils and Veczeļķi the highest percentage of Rotifera taxa were Synchaeta sp., Keratella cochlearis, Brachionus calyciflorus, Brachionus quadridentatus, Euchlanis sp., Polyarthra sp., which were typical species of the Daugava. Cladocera and Copepoda compared with Rotifera have very small percentage of representatives. Rotifera taxa of Pļaviņas Reservoir the highest percentage are Synchaeta sp., Brachionus calyciflorus, Keratella cochlearis, Keratella quadrata, Polyarthra sp. and Asplanchna priodonta. From Cladocera here were found typical of lake zooplankton taxa i.e Bosmina longirostris, Chydorus ovalis, Diaphanosoma brachyurum, Ceriodaphnia sp. Water temperature in the upper layer of the Daugava River and of the Plavinas Reservoir were 22 0C, the dissolved oxygen content 12 mg/l and chlorophyll α concentration 4 µg/l.***

Keywords: Daugava River, Pļaviņas Reservoir, zooplankton groups, Rotifera, Cladocera, Copepoda, water physico-chemical measurements

I. INTRODUCTION

Zooplankton include diverse microscopic taxa, such as Rotifera, Copepoda, and Cladocera are very sensitive to environmental changes and, hence, are considered good indicators of ecosystems [1]-[2]. A change in the physical–chemical and biotic parameters in aquatic systems resulted in a change in the relative composition and abundance of organisms thriving in the water. Many species of zooplankton, by filtering food, reduce the effects of eutrophication of the water body, because they control the amount of bacteria and algae by participating in the process of biological self-purification of water. Zooplankton are primary production consumers in waterbodies and one of indicators of waterbodies productivity as they serve as food for many fish, so the organisms are bioindicators, which show water quality [3]-[9]. In general zooplankton is a dynamic system in which the composition of species may significantly change during the season. Numerous abiotic (e.g. temperature, salinity, stratification, pollution) and biotic factors (eg., food, predation, competition) affect temporal changes in the composition of zooplankton species of the temperate climate zones [3]-[6], [8]-[25]. It is really necessary to perform long-term systematic observations for receiving true structure of the ecosystem and for evaluating its natural variation scene ecosystem. The exact and frequent plankton quantitative determination is a prerequisite for accurate evaluation of productivity in rivers and other waterbodies. It is therefore important to carry out such studies in order to check the current composition of zooplankton species at Pļaviņas Reservoir in the Daugava River and in Pļaviņas Reservoir. Qualitative and quantitative variations of zooplankton help to make conclusions about changes in environmental factors and their impact on living organisms.

The obtained data and further long-term research are significant because the conditions of waterbodies which

Print ISSN 1691-5402
Online ISSN 2256-070X
https://doi.org/10.17770/etr2024vol1.7987

affect zooplankton are very diverse and changeable, as a result the data may vary significantly from year to year, so in order to make fundamental conclusions, long-term studies are required.

II. MATERIALS AND METHODS

A. The study area and sampling

Daugava is one of the largest rivers in Eastern European. Daugava is 1005 km long with 87 900 km^2 large catchment area. It is one of the ten largest rivers in the Baltic Sea basin [26]. The Pļaviņas Reservoir is the largest reservoir in Latvia by volume, it is 509.5 million m^3. The area is 35 km^2, the average depth – 14.5 m, the maximum depth – 47 m. The length is 45 km, the maximal width about 2 km, which the minimal is 1 km [27] (Fig. 1).

The study summarizes the data collected during the research of seasonal studies 2019 (June – September) and 2020 (April – September). Zooplankton samples were collected and analysis according to standard method was made [28]-[29]. Zooplankton samples were taken in the three sampling sites: in the River Daugava upstream Pļaviņas Reservoir (sampling sites- Jēkabpils and Veczeļķi) and in the area of Pļaviņas Reservoir (sampling site- Gostiņi). The zooplankton samples were collected using Apstein type plankton net (65 µm), through which 100 liters of water were filtered from the water surface layer (0.5 - 1m depth) (Fig. 1).

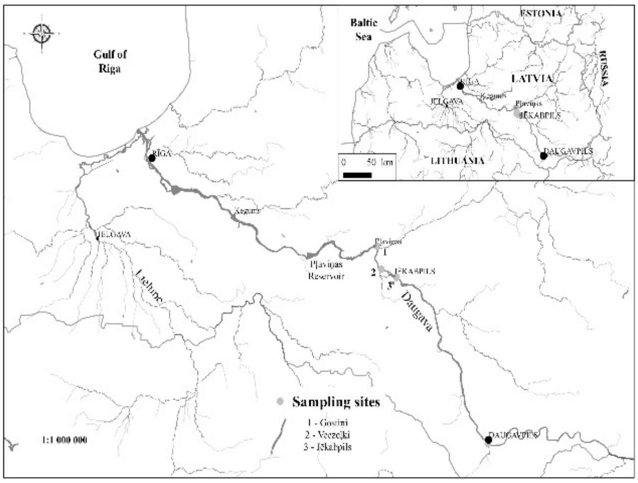


Fig. 1. Location of the sampling area.

B. Physical–Chemical analysis

Along with zooplankton sampling water physico-chemical parameters (water temperature (^{0}C), dissolved oxygen (mg^{-1}) and chlorophil α (µg^{-1}) were also carried out) which were determined at each site of waterbed using a *YSI Pro Plus Multi-Parameter Water Quality Meter* probe.

C. Zooplankton analysis

The collection of zooplankton samples and their quantitative and qualitative analysis was performed in accordance with the American Public Health Association (APHA) Standard method procedures for the water and wastewater analysis [28]-[29]. The quantitative estimation of the zooplankton was performed using a Sedgewick-Rafter chamber. A 1 ml sample was poured on a Sedgwick-Rafter cell, in total 6 ml sample's subvolume examined (1 ml x 6) from each sample [29]. The samples of zooplankton were analysed by using Zeiss Primo Star upright light microscope (100 - 400 x magnification). Having studied the samples in the light microscope the zooplankton organisms were then calculated and identified as species or families. The zooplankton identification was carried out according to the methods described in the zooplankton guides in [30]-[53].

The following formula was used to calculate the number of organisms in a sample:

$$N= (a \times b \times 1000) / (c \times d) /1000 \qquad (1)$$

where a - is a calculated number of organisms (average);
b - is a volume of concentrated sample;
c - is a sample volume;
d - is a volume of filtered water;
N - is a number of organisms per 1 l (litre).

D. Statistical analysis

The Shannon-Wiener function (H$'$) was used to calculate as [54]:

$$H' = -\sum_{i=1}^{S} (pi)(\ln pi) \qquad (2)$$

where H'- is the index of species diversity,
S - is the number of species, and
p_i - is a proportion of the total sample belonging to i th species.

Since the resulting equation is a measure of bits, we used the following equation to move from the bits unit to the species unit [55]-[56]:

$$N_1 = e^{H'} \qquad (3)$$

where e is equal to 2.71828 (base of natural logs),
H' - Shannon-Wiener function (calculated with base e logs), and
N_1 - the number of equally common species that would produce the same diversity as H'.

III. RESULTS AND DISCUSSION

In general 26 taxa of Rotifera, 8 taxa Cladocera and 3 taxa Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2019, but 25 taxa of Rotifera, 6 taxa Cladocera and 2 taxa Copepoda group were found in the Daugava River in sampling site- Veczeļķi in 2019 (Table 1, Fig. 2).

TABLE 1 DIVERSITY OF ZOOPLANKTON TAXA IN ALL SAMPLING SITES IN 2019

Species (taxa)	Gostiņi	Jēkabpils	Veczeļķi	Species common to all places
ROTIFERA	**28**	**26**	**25**	**19**
Asplanchna priodonta Gosse, 1850	+			
Brachionus angularis Gosse, 1851	+	+	+	+
Brachionus calyciflorus Pallas, 1766	+	+	+	+
Brachionus quadridentatus Hermann, 1783	+	+	+	+
Cephalodella gibba (Ehrenberg,1832)	+		+	
Conochilus sp. Ehrenberg, 1834	+	+	+	+
Dicranophorus Nitzsch, 1827	+	+	+	+
Euchlanis sp. Ehrenberg, 1832	+		+	
Filinia longiseta (Ehrenberg, 1834)	+	+	+	+
Gastropus stylifer (Imhof, 1891)	+	+	+	+
Keratella cochlearis (Gosse, 1851)	+	+	+	+
Keratella quadrata (Müller, 1786)	+	+	+	+
Lacinularia sp. Schweigger, 1820	+		+	
Lecane flexilis (Gosse, 1886)	+		+	
Lecane luna (Müller, 1776)	+	+	+	+
Lecane lunaris (Ehrenberg, 1832)	+	+	+	+
Lepadella sp. Bory de St. Vincent, 1826		+		
Mytilina mucronata (Müller, 1776)	+	+	+	+
Notholca acuminata (Ehrenberg, 1832)	+			
Polyarthra sp. Ehrenberg, 1834		+	+	
Proales sp. Gosse, 1886		+		
Rotifera sp. (Pallas, 1766)	+	+	+	+
Synchaeta sp. Ehrenberg, 1832	+	+	+	+
Taphrocampa selenura (Gosse, 1887)	+	+	+	+
Testudinella patina (Hermann, 1783)	+	+	+	+
Trichocerca capucina (Wierzejski & Zacharias, 1893)		+		
Trichocerca cylindrica (Imhof, 1891)		+	+	
Trichocerca longiseta (Schrank, 1802)	+			
Trichocerca porcellus (Gosse, 1851)	+	+		
Trichocerca pusilla (Jennings, 1903)		+		
Trichocerca rousseleti (Voigt, 1902)	+			
Trichocerca similis (Wierzejski, 1893)	+	+	+	+
Trichotria pocillum (Müller, 1776)	+	+	+	+
CLADOCERA	**13**	**8**	**6**	**5**
Acroperus harpae (Baird, 1835)	+	+	+	+
Bosmina (Bosmina) longirostris (O. F. Müller, 1776)	+	+	+	+
Ceriodaphnia sp. Dana, 1853	+	+	+	+
Chydorus ovalis (Kurz, 1875)	+	+	+	+
Chydorus sphaericus (O. F. Müller, 1776)	+			
Daphnia sp. (O. F. Müller, 1785)	+			
Diaphanosoma brachyurum (Liévin, 1848)	+	+	+	+
Eurycercus (Eurycercus) lamellatus (O. F. Müller, 1776)	+			
Kurzia latissima (Kurz, 1875)	+		+	
Pleuroxus (Peracantha) truncatus (O. F. Müller, 1785)	+	+		
Polyphemus pediculus (Linnaeus, 1758)	+			
Scapholeberis mucronata (O. F. Müller, 1776)	+	+		
Sida crystallina (O. F. Müller, 1776)	+	+		
COPEPODA	**4**	**3**	**2**	**1**
Acanthocyclops sp. Kiefer, 1927	+	+		
Macrocyclops sp. Claus, 1893	+			
Cyclops sp. Müller, 1785	+	+	+	+
Eucyclops sp. Claus, 1893	+	+		
Eudiaptomus sp. Kiefer, 1932			+	
Copepodite cyclopoid	+	+	+	+
Nauplii	+	+	+	+
Total taxa	**45**	**37**	**33**	**25**

In contrast, 26 taxa of Rotifera, 7 taxa Cladocera and 1 taxon Copepoda group were found in the Daugava River in sampling site- Jēkabpils in 2020, and 23 taxa of Rotifera, 1 taxa Cladocera group were found in the Daugava River in sampling site- Veczeļķi in 2020 (Table 2, Fig.3). There were only subadult specimens - nauplii and Copepodite from Copepoda group.

TABLE 2 DIVERSITY OF ZOOPLANKTON TAXA IN ALL SAMPLING SITES IN 2020

Species (taxa)	Gostiņi	Jēkabpils	Veczeļķi	Species common to all places
ROTIFERA	**25**	**26**	**23**	**17**
Asplanchna priodonta Gosse, 1850	+			
Brachionus angularis Gosse, 1851	+	+	+	+
Brachionus calyciflorus Pallas, 1766	+	+	+	+
Brachionus quadridentatus Hermann, 1783	+	+		
Cephalodella gibba (Ehrenberg,1832)	+	+	+	+
Conochilus sp. Ehrenberg, 1834			+	
Dicranophorus sp.Nitzsch, 1827	+	+	+	+
Euchlanis sp. Ehrenberg, 1832	+	+	+	+
Filinia longiseta (Ehrenberg, 1834)			+	
Kellicottia longispina Kellicott, 1879	+	+	+	+
Keratella cochlearis (Gosse, 1851)	+	+	+	+
Keratella quadrata (Müller, 1786)		+	+	
Lacinularia sp. Schweigger, 1820		+		
Lecane flexilis (Gosse, 1886)	+	+		
Lecane luna (Müller, 1776)	+	+		
Lecane lunaris (Ehrenberg, 1832)	+	+		
Lecane sp. Nitzsch, 1827			+	
Lepadella (Lepadella) ovalis (Müller, 1786)	+	+	+	+
Mytilina mucronata (Müller, 1773)		+		
Notholca acuminata (Ehrenberg, 1832)	+	+	+	+
Notholca squamula (Müller, 1786)	+		+	
Polyarthra sp. Ehrenberg, 1834	+	+	+	+
Pompholyx sulcata Hudson, 1885	+	+	+	+
Rotifera sp. (Pallas, 1766)	+	+	+	+
Synchaeta sp. Ehrenberg, 1832	+	+	+	+
Taphrocampa selenura (Gosse, 1887)	+	+	+	+
Testudinella patina (Hermann, 1783)	+	+	+	+
Trichocerca cylindrica (Imhof, 1891)	+	+	+	+
Trichocerca porcellus (Gosse, 1851)	+	+	+	+
Trichocerca similis (Wierzejski, 1893)	+	+		
Trichotria pocillum (Müller, 1776)	+	+	+	
CLADOCERA	**7**	**7**	**1**	**1**
Acroperus harpae (Baird, 1835)		+		
Bosmina (Bosmina) longirostris (O. F. Müller, 1776)	+	+		
Ceriodaphnia sp. Dana, 1853	+	+		
Chydorus ovalis (Kurz, 1875)	+	+	+	+
Diaphanosoma brachyurum (Liévin, 1848)	+			
Kurzia latissima (Kurz, 1875)	+	+		
Pleuroxus (Peracantha) truncatus (O. F. Müller, 1785)		+		
Polyphemus pediculus (Linnaeus, 1758)	+			
Scapholeberis mucronata (O. F. Müller, 1776)		+		
Sida crystallina (O. F. Müller, 1776)	+			
COPEPODA	**2**	**1**	**0**	**0**
Acanthocyclops sp. Kiefer, 1927	+	+		
Copepodite cyclopoid	+	+		
Cyclops sp. Müller, 1785	+			
Nauplii	+	+	+	+
Total taxa	**34**	**34**	**24**	**18**

28 taxa of Rotifera, 13 taxa Cladocera and 4 taxon Copepoda group were found in the Pļaviņas Reservoir (sampling site- Gostiņi) in 2019 (Table 1, Fig.4), and 25 taxa of Rotifera, 7 taxa Cladocera group and 2 taxon Copepoda group were found in 2020 (Table 2, Fig. 4).

Big zooplankton biodiversity in the Daugava River and in the Pļaviņas Reservoir is due to the Daugava large catchment area - 87,900 km^2 [57], which includes tributaries and the water system. When water level in the river changes the exchange of plankton fauna takes place between these water bodies. In the 60-ies of 20th century, Škute [58] carried out a research of 28 Daugava River tributaries and noted that the the upper reaches of the Daugava River tributaries have a significant effect on the Daugava zooplankton cenosis, zooplankton quantity even doubled in some of the tributaries of the river. Rotifera usually dominates in river plankton both qualitatively and quantitatively [59]-[68]. The results of our research show that the greatest diversity of zooplankton taxa is in Rotifera group both in the Daugava River and at the Pļaviņas Reservoir. The greatest diversity of zooplankton taxa was also established among Rotifera species that were found in the Daugava near Daugavpils [60]-[61], [68]. However, these authors in their studies mentioned that sometimes during the summer and autumn Cladocera group is also widely represented. In our case, taxa of Rotifera group were observed at the Pļaviņas Reservoir in July, however in September the number of taxa rapidly decreased, while many of Cladocera group taxa- *Acroperus harpae, Chydorus ovalis, Ceriodaphnia* sp., *Pleuroxus truncatus* taxa appeared in September.

However, taking into account that the weight of the majority of Cladocera and Copepoda representatives exceeds the weight of representatives of Rotifera group, it can be concluded in terms of biomass that all zooplankton groups in the Daugava are equally well represented. It should be noted that throughout all the stages of rivers and reservoir under research, the variation among zooplankton quantity is similar. Such variation is also determined by the influence of water body hydrological, hidrometreological factors, for example water temperature ^{0}C, the dissolved oxygen content, chlorophyll α concentration, where the thermal water regime and water level fluctuations are of particular importance, as well as overgrowth of the water body and the pollution degree.

The sections of the river where there are a lot of macrophyte in the coastal zone, macrophytes become the decisive factor for the formation of the river zooplankton [63], [69]. When compared quantitative and qualitative parameters of taxa (by Shannon-Wiener diversity) both in the Daugava before the Pļaviņas Reservoir and in the Pļaviņas Reservoir (Fig. 4). By contrast, there is no such a big diversity of taxa in the reservoir, but the dominance of certain taxa appears there, which is not typical of the river plankton. The number of the species does not only depend on the sampling time, habitat diversity, but also on the sampling frequency during the season and on the size of the water body [70]. Several authors in their researches [63], [71]-[73] noted the influence of fish on zooplankton cenosis, but the influence of fish is significant only in small rivers. The main influencing factors in large rivers that determine the number of zooplankton, in particular crustaceans, is the river hydrology and predators [63], [66], [69], [74]-[78].

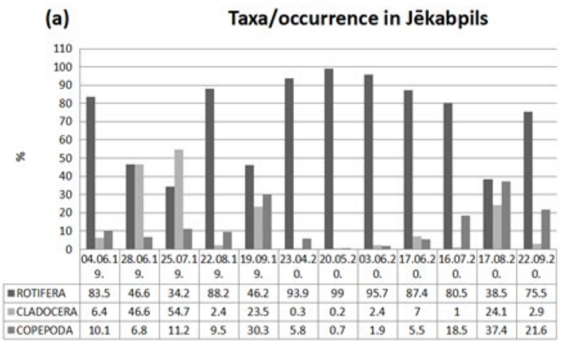
The sections of the river where there are a lot of macrophyte in the coastal zone, macrophytes become the decisive factor for the formation of the river zooplankton [63], [69]. When compared quantitative and qualitative parameters of taxa (by Shannon-Wiener diversity) both in the Daugava before the Pļaviņas Reservoir and in the Pļaviņas Reservoir (Fig. 5). By contrast, there is no such a big diversity of taxa in the reservoir, but the dominance of certain taxa appears there, which is not typical of the river plankton. The number of the species does not only depend on the sampling time, habitat diversity, but also on the sampling frequency during the season and on the size of the water body [70]. Several authors in their researches [63], [71]-[73] noted the influence of fish on zooplankton cenosis, but the influence of fish is significant only in small rivers. The main influencing factors in large rivers that determine the number of zooplankton, in particular crustaceans, is the river hydrology and predators [63], [66], [69], [74]-[78].

IV. CONCLUSIONS

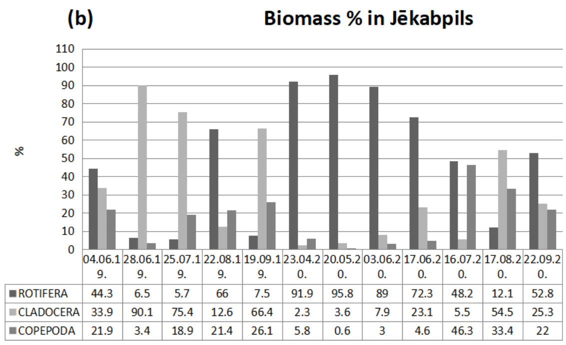
From the study, it can be concluded that there are variations in the number and diversity of species in the samples collected in the Daugava River and in the Pļaviņas Reservoir. Zooplankton taxa in the Daugava River are typical of moving water bodies, but zooplankton in the Pļaviņas reservoir is more characteristic for stagnant water masses. A large diversity of the Rotifera taxa was found in the Daugava River and in the Pļaviņas reservoir, but no taxa dominated in the River, however in the Pļaviņas Reservoir the dominance of certain taxa was identified. The diversity of Cladocera taxa in the Daugava River is very low, whereas, in the Pļaviņas Reservoir this diversity is much bigger. The dominance of individual taxa was also observed among the Cladocera group. Mainly subadult copepodite of Copepoda group were identified both in the Daugava River and in the Pļaviņas Reservoir. The identified differences could be due to the fact that zooplankton species are very sensitive to various changes in environmental factors, such as weather conditions, change in each specific place vegetation, overgrow, depth and physico-chemical parameters of the properties as well as with biological characteristics of each species, such as seasonality.

ACKNOWLEDGMENTS

This study was partly supported by the DU Research Project No. 14-95/2024/4 "Spatial structural and functional variations of the zooplankton and macroinvertebrates communities in the River Daugava"



	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
ROTIFERA	83.5	46.6	34.2	88.2	46.2	93.9	99	95.7	87.4	80.5	38.5	75.5
CLADOCERA	6.4	46.6	54.7	2.4	23.5	0.3	0.2	2.4	7	1	24.1	2.9
COPEPODA	10.1	6.8	11.2	9.5	30.3	5.8	0.7	1.9	5.5	18.5	37.4	21.6



	04.06.19.	28.06.19.	25.07.19.	22.08.19.	19.09.19.	23.04.20.	20.05.20.	03.06.20.	17.06.20.	16.07.20.	17.08.20.	22.09.20.
ROTIFERA	44.3	6.5	5.7	66	7.5	91.9	95.8	89	72.3	48.2	12.1	52.8
CLADOCERA	33.9	90.1	75.4	12.6	66.4	2.3	3.6	7.9	23.1	5.5	54.5	25.3
COPEPODA	21.9	3.4	18.9	21.4	26.1	5.8	0.6	3	4.6	46.3	33.4	22

Fig.2. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling site Jēkabpils.

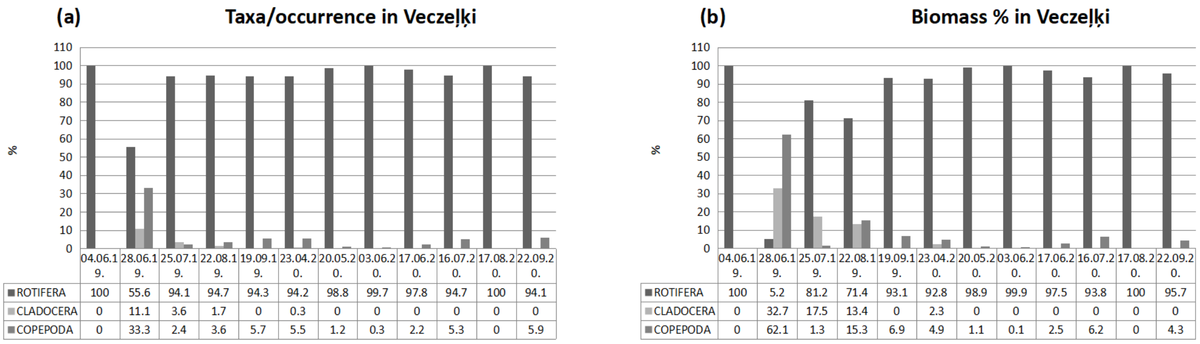


Fig. 3. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling site Veczeļķi.

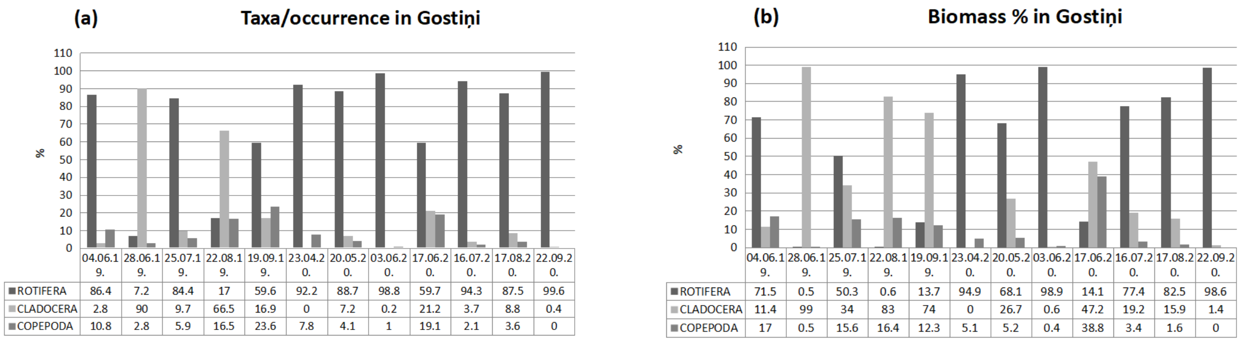


Fig. 4. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling site Gostiņi.

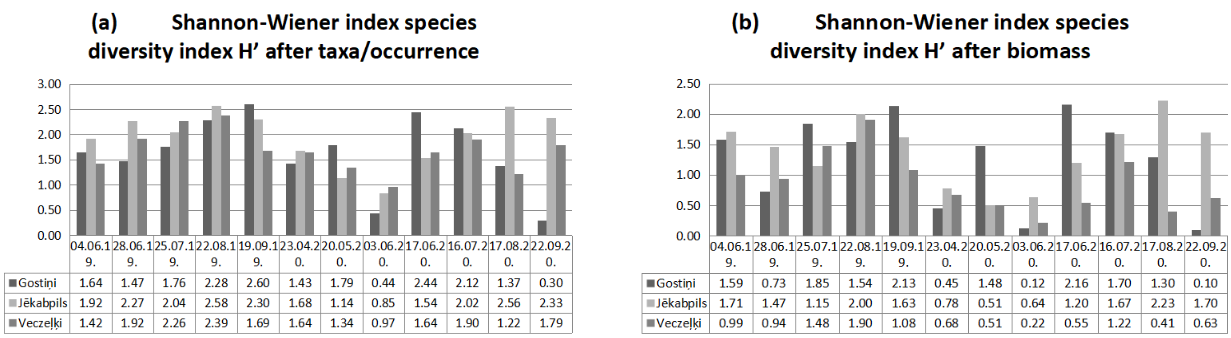


Fig. 5. Shannon-Wiener diversity index of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in sampling sites Gostiņi, Jēkabpils and Veczeļķi).

REFERENCES

[1] C. De Vargas, S. Audic, N. Henry, J. Decelle, F. Mahé, R. Logares, E. Lara, C. Berney, N. Le Bescot, I. Probert, et al., “Eukaryotic plankton diversity in the sunlit ocean,” Science, pp. 348, 2015.

[2] S.K. Mukhopadhyay, B. Chattopadhyay, A.R. Goswami and A. Chatterjee, “Spatial variations in zooplankton diversity in waters contaminated with composite effluents,” J. Limnol, pp. 66, 97, 2007.

[3] K.H. Chang and T. Hanazato, “Diel vertical migrations of invertebrate predators (Leptodora kindtii, Thermocyclops taihokuensis, and Mesocyclops sp.) in a shallow, eutrophic lake,” Hydrobiologia, vol. 528, pp. 249–259, October 2004.

[4] P. Cimdiņš, *Limnoekoloģija*, [Limnoecology] Rīga: Mācību apgāds, 2001.

[5] P. D.N. Hebert, “Competition in zooplankton communities,” Annales Zoologici Fennici, vol. 19, pp. 349-356, 1982.

[6] B. J. Malone and D. J. McQueen, “Horizontal patchiness in zooplankton populations in two Ontario kettle lakes,” Hydrobiologia, vol. 99, pp. 101–124, 1983.

[7] B.M. Padedda, N. Sechi, G.G. Lai, M.A. Mariani, S. Pulina, M. Sarria, C.T. Satta, T. Virdis, P. Buscarinu and A. Lugliè, “Consequences of eutrophication in the management of water resources in Mediterranean reservoirs: a case study of Lake Cedrino (Sardinia, Italy) ,” Glob. Ecol. Conserv., vol.12, pp. 21–35, 2017.

[8] B. Pinel-Alloul, “Spatial heterogeneity as a multiscale characteristic of zooplankton community,” Hydrobiologia, vol. 300, pp. 17-42, March 1995.

[9] R.G. Wetzel, Limnology. *Lake and River Ecosystems*. Third Edition. Academic Press, 2001.

[10] J. Bengtsson, “Life histories, interspecific competition between three Daphnia species in rockpools,” Journal of Animal Ecology, vol. 55, no.2, pp. 641–655, 1986.

[11] J. Bertilsson, B. Bērziņš and B. Pejler, “Occurrence of limnic micro-crustaceans in relation to temperature and oxygen,” Hydrobiologia, vol. 299, pp. 163-167, 1995.

[12] B. Bērziņš and B. Pejler, “Rotifer occurrence in relation to pH,” Hydrobiologia, vol. 147, pp. 107- 116, 1987.

[13] B. Bērziņš and B. Pejler, “Rotifer occurrence in relation to temperature,” Hydrobiologia, vol. 175, pp. 223-231, 1989a.

[14] B. Bērziņš and B. Pejler, “Rotifer occurrence in relation to oxygen content,” Hydrobiologia, vol. 183, pp. 165-172, 1989b.

[15] R. Escribano and P. Hidalgo, “Spatial distribution Spatial distribution of copepods in the north of the Humboldt Current region off Chile during coastal upwelling,” Journal of the Marine Biological Association of the UK, vol. 80, pp. 283-290, 2000.

[16] M.J. Fernandez-Rosado and J. Lucena, “Space-time heterogeneities of the zooplankton distribution in LaConcepción reservoir (Istán, Málaga; Spain),” Hydrobiologia, vol. 455, pp. 157–170, 2001.

[17] T. Hanazato, “Pesticides as chemical agents inducing helmets formation in Daphnia ambigua,” Freshwater Biology, vol. 26, pp. 419–424, 1991.

[18] K.D.M. Harris, N.J. Bartlett, and V.K. Lloyd, “*Daphnia* as an emerging epigenetic model organism,” Genetic Research International, ID 147892, 2012.

[19] J. Horppila, T. Malinen, L. Nurminen, P. Tallberg, and M. Vinni, “A metalimnetic oxygen minimum indirectly contributing to the low biomass of cladocerans in Lake Hiidenvesi – a diurnal study on the refuge effect,” Hydrobiologia, vol. 436, pp. 81–90, 2000.

[20] P. Larsson and S.I. Dodson, “Chemical communication in planktonic animals”. Archiv für Hydrobiologie, vol. 129, pp. 129–155, 1993.

[21] A. Locke and W.G. Sprules, “Effects of pH, food quality and quantity on survival and condition of Bosmina longirostris and Daphnia pulex,” Hydrobiologia, vol. 437, pp. 187–196, 2000.

[22] N.R. Simões, M.A.M. Colares, F.A. Lansac-Tôha and C.C. Bonecker, “Zooplankton species richness-productivity relationship: confronting monotonic positive and hump-shaped models from a local perspective,” Austral Ecol., vol. 38, pp. 952–958, 2013.

[23] J. Seda and M. Devetter, “Zooplankton com¬munity structure along a trophic gradient in a canyon-shaped dam reservoir,” Journal of Plankton Research, no. 22, no. 10, pp. 1829–1840, 2000.

[24] P. Tallberg, J. Horppila, A. Väisänen and L. Nurminen, “Seasonal succession of hyto-plankton and zooplankton along a trophic gradient in a eutrophic lake – implications for food web management,” Hydrobiologia, vol. 412, pp. 81–94, 1999.

[25] L. J. Weider and J. Pijanowska, “Plasticity of Daphnia life histories in response to chemical cues from predators”, Oikos, vol. 67, no. 3, pp. 385–392, 1993.

[26] Daugavas upju baseinu apgabala apsaimniekošanas plāns un plūdu riska pārvaldības plāns 2022.-2027. gadam. [Daugava river basin area management plan and flood risk management plan for the year from 2022 to 2027], Rīga, Latvijas Vides, ģeoloģijas un meteoroloģijas centrs, pp. 464, 2021. .http://www.videscentrs.lvgmc.lv/files/Daugavas_UBA.pdf (accessed 16 January 2024).

[27] A. Tidriķis, “Pļaviņu Ūdenskrātuve,” [Pļaviņas Reservoir] In *Latvijas Daba*, vol. 4, Rīga: Preses Nams, pp. 166–167, 1997.

[28] Standard Methods Committee of the American Public Health Association, American Water Works Association, and Water Environment Federation, “10200 Plankton,” in Standard Methods For the Examination of Water and Wastewater, 21st ed., A.D. Eaton, M. A. H. Franson, L.S. Clesceri, E.W. Rice, A.E. Greenberg, Eds. Washington DC: APHA Press, 2005.

[29] R.G. Wetzel and G.E.Likens, *Limnological Analyses.* Springer Science: Business Media, 2000.

[30] J.A.H. Benzie, “Cladocerans: The Genus Daphnia (Including Daphniopsis),” in *Guide to the Identification of the Microinvertebrates of the Continental Waters of the World*, vol. 21. H.J.F. Dumont, Ed., Leiden: Backhuys Publishers, 2005.

[31] M. Dagg, “The Biology of Calanoid Copepods,” The Biology of Calanoid Copepods, 1977.

[32] H. J. Dumont and V. Negrea, Introduction to the Class Branchiopoda. Guides to the Identification of the Microinvertebrates of the Continental Waters of the World, Vol.19. Leiden: Backhuys Publishers, 2002.

[33] B.H. Dussart and D. Defaye, “Introduction to the Copepoda,” in *Guides to the identification of the microinvertebrates of the continental waters of the world*, 2nd ed., vol. 16. H.J.F. Dumont, Ed., Leiden: Backhuys Publishers, 2001.

[34] D. Flössner, *Die Haplopoda und Cladocera (ohne Bosminidae) Mitteleuropas*. [The Haplopoda and Cladocera (excluding Bosminidae) of Central Europe] Leiden: Backhuys Publishers. 2000.

[35] D. Flössner, *Die Haplopoda und Cladocera Mitteleuropas*. [The Haplopoda and Cladocera of Central Europe] Leiden: Backhuys Publishers. 2002.

[36] I. Hudec, Fauna Slovenska. Anomopoda, Ctenopoda, Haplopoda, Onychopoda (Crustacea, Brachiopoda). Bratislava: VEDA, 2010.

[37] A.A. Kotov, *Cladocera: Family Ilyocryptidae (Branchiopoda: Cladocera: Anomopoda)*, Leiden: Kenobi Productions, Ghent & Backhuys Publishers, 2006.

[38] D. Krauter, H. Streble, *Das Leben im Wassertropfen. Mikroflora und Mikrofauna des Süßwassers* [Life in drops of water. Freshwater microflora and microfauna], Kosmos: Stuttgart, 1988.

[39] U. Lieder, *Crustacea: Cladocera/Bosminidae. Süsswasserfauna von Mitteleuropa* [Freshwater fauna of Central Europe], Bd. 8, H. 2-3, Ed., Ulm: G.Fischer, Stuttgart, Jena, Lübeck, 1996.

[40] T. Nogrady and H. Segers H, “Rotifera 6: Asplanchnidae, Gastropodidae, Lindiidae, Microcodidae, Synchaetidae, Trochospohaeridae and Filinia.,” in *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World 18*. H.J. Dumont, Ed. Leiden: Backhuys Publishers, 2002.

[41] J. Paidere and R. Škute, Virpotāji (Rotifera) un to fauna Latvijā [Rotifera and their fauna in Latvia], Daugavpils: Daugavpils University, 2011.

[42] R.M. Pontin, A Key to the Freshwater Planktonic and Semi-planktonic Rotifera of the British Isles. Freshwater Biological Association, United Kingdom: Association Scientific Publication, 1978.

[43] I. Bielańska-Grajner, J. Ejsmont- Karabin, S. Radwan, *Rotifers (Rotifera): Freshwater Fauna of Poland*. Łódź: Jagiellonian University Press, 2015.

[44] I.K. Rivier, The predatory Cladocera (Onychopoda: Podonidae, Polyphemidae, Cercopagidae) and Leptodoridae of the world, Amsterdam: Backhuys Publ, 1998.

[45] A.Ruttner-Kolisko, *Plankton Rotifers: Biology and Taxonomy*. Stuttgart: Schweizerbart, 1974.

[46] D.J. Scourfield and J.P. Harding, *A Key to the British Species of Freshwater Cladocera, with Notes on their Ecology. Publication*, 3rd ed., vol. 5 United Kingdom: Freshwater Biological Association Scientific, 1994.

[47] H. Segers, “Rotifera 2. The Lecanidae (Monogononta),” in *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World 6*, H.J. Dumont and T. Nogrady, Eds. The Netherlands: SPB Academic Publishing, 1995.

[48] H. Segers, Annotated checklist of the rotifers (Phylum Rotifera) with notes on nomenclature, taxonomy and distribution. Zootaxa, vol. 1564, no. 1, pp. 1-104. Auckland, New Zealand: Magnolia Press, Aug 2007.

[49] N. Sloka, Latvijas PSR Dzīvnieku noteicējs. Latvijas zarūsaiņu (Cladocera) fauna un noteicējs [A Key to Animals of the Latvian SSR. Fauna of the Cladocera and a key of Latvia]. P. Stučkas, Ed. Rīga: Latvijas valsts universitāte, 1981.

[50] N.N. Smirnov, *Cladocera: the Chydorinae and Sayciinae*. Amsterdam: Backhuys Publ., 1996.

[51] L.A. Kutikova, Коловратки фауны СССР [Fauna of Rotifera USSR]. Leningrad: Nauka, 1970.

[52] L.A. Kutikova and Ya.I. Starobogatov, Определитель пресноводных беспозвоночных Европейской части СССР [The key to freshwater European part of the USSR (plankton and benthos)]. Leningrad: Hydrometoizdat, 1977.

[53] E.F. Manuilova, Ветвистоусые рачки фауны СССР [Fauna of Cladocera of the USSR]. Moscow- Leningrad: Nauka, 1964.

[54] D.R. Margalef, “Information theory in ecology”. General Systems, vol. 3, pp. 36- 71, 1958.

[55] J.Ch. Krebs, *Ecological Methodology*. Second Edition. Addison Wesley Longman, 1999.

[56] R.H. MacArthur, "Patterns of species diversity," Biological Reviews, vol. 40, pp. 510-533, 1965.

[57] G. Kavacs, *Latvijas daba: enciklopēdija*,[Encyclopaedia of Latvia's Nature] 1. sēj. Rīga: Latvijas enciklopēdija: Preses nams, 1994.

[58] R. J. Škute, *Зоопланктон реки Даугавы (кроме низовий) и его роль в продуктивности и санитарно-биологической оценке реки*. [Zooplankton of the River Daugava and its role in the productivity and biological evaluating of the river] Doctoral theses. Tartu:Tartu University, 1971.

[59] A. Akin-Oriola Gbemisola, "Zooplankton associations and environmental factors in Ogunpa and Ona Rivers, Nigeria," Revista de biologia tropical, vol. 51, no. 2, pp. 391–398, 2003.

[60] R. Deksne, "Influence of waste water on zooplankton communities in the Daugava River upstream and downstream of Daugavpils over the last 50 years," Knowledge and Management of Aquatic Ecosystems, vol. 402, no. 07, pp. 1 – 17, 2011.

[61] R. Deksne, A. Škute and J. Paidere, "Changes in structure of zooplankton communities in the Middle Daugava (Western Dvina) over the last five decades," Acta Zoologica Lituanica, vol. 20, no. 3, pp. 190 -208, 2010.

[62] A. Brakovska, J. Paidere, and A. Škute, "Number and dynamics of zooplankton taxa in the Daugava river and Pļaviņas reservoir," Acta Biologica Universitatis Daugavpiliensis*,* vol. 16, no. 1, pp. 15 – 29, 2016.

[63] N. Lair, "A review of regulation mechanisms of metazoan plankton in riverine ecosystems: aquatic habitat versusbiota,"River Research and Applications, vol. 22, pp. 567–593, 2006.

[64] M. L. Pace, S. E. G. Findlay and D. Lints, "Zooplankton in advective environments: the Hudson River community and a comparative analysis," Canadian Journal of Fishery and Aquatic Science, vol. 49, pp. 1060–1069, 1992.

[65] J. H. Thorp, M. C. Thoms and M. D. Delong, "The riverine ecosystem synthesis: biocomplexity in river networks across space and time, " River Research and Applications, vol. 22: pp. 123–147, 2006.

[66] J. H. Thorp and S. Mantovani, "Zooplankton of turbid and hydrologically dynamic prairie rivers," Freshwater Biology, vol. 50, pp. 1474–1491, 2005.

[67] R. Pourriot, C. Rougier and A. Miquelis, "Origin and development of river zooplankton: Example of the Marne," Hydrobiologia, vol. 345, pp. 143–148, 1997.

[68] R. J. Škute, Районирование реки Даугавы по зоопланктону. [Regionalism of the Daugava River according to zooplankton]. In: Škute R. J. (ed.) Ecological and biological investigations of water animals, Riga: Zvaigzne. pp. 43-55, 1976.

[69] L. Viroux, "Seasonal and longitudinal aspects R. Czerniawski and J. Domagała, of microcrustacean (Cladocera, Copepoda) dynamics in a lowland river," Journal of Plankton Research, vol. 24, 281–292, 2002.

[70] V. I. Lazareva, Структура и динамика зоопланктона Рыбинского водохранилища, [Zooplankton structure and dynamics in the Rybinsk Reservoir] Moscow: KMK Scientific Press Ltd., 2010.

[71] R. Czerniawski and J. Domagała, "Zooplankton communities of two lake outlets in relation to abiotic factors," Central European Journal of Biology, vol. 5, no. 2, pp. 240–255, 2010 a.

[72] R. Czerniawski and J. Domagała, "Similarities in zooplankton community between River Drawa and its two tributaries (Polish part of River Odra)," Hydrobiologia, vol. 638, pp. 137–149, 2010 b.

[73] K. H. Chang, H. Doi, H. Imai, F. Gunji and S. I. Nakano, "Longitudinal changes in zooplankton distribution below a reservoir outfall with reference to river planktivory," Limnology, vol. 9, pp. 125–133, 2008.

[74] C. Baranyi, T. Hein, C. Holarek, S. Keckeis and F. Schiemer, "Zooplankton biomass and community structure in a Danube River floodplain system: effects of hydrology," Freshwater Biology, vol. 47, pp. 473–482, 2002.

[75] B. K. Basu and F. R. Pick "Factors regulating phytoplankton and zooplankton biomass in temperate rivers," Limnological Oceanography, vol. 41, pp. 1572–1577, 1996.

[76] K. H. Chang, S. J. Hwang, M. H. Jang, H. W. Kim, K. S. Jeong and G. J Joo, "Effect of juvenile fish predation on the zooplankton community in the large regulated Nakdong River, South Korea," Korean Journal of Limnology, vol. 34, pp. 310–318, 2001.

[77] J. F. Saunders and W. M. Jr. Lewis, "Zooplankton abundance in the Caura River, Venezuela," Biotropica, vol. 20, pp. 206–214, 1988.

[78] J. H. Thorp and A. F. "Casper Importance of biotic interactions in large rivers: an experiment with planktivorous fish, dreissenid mussels and zooplankton in the St. Lawrence River," River Research Application, vol. 19, pp. 265–279, 2003.