Acta Biol. Univ. Daugavp. 11 (1) 2011
ISSN 1407 - 8953

SEASONAL CHANGES IN ZOOPLANKTON COMMUNITY OF THE DAUGAVA RIVER

Rasma Deksne, Artūrs Škute, Arnita Meinerte

Deksne R., Škute A, Meinerte A. 2011. Seasonal changes in zooplankton community of the Daugava river. *Acta Biol. Universit. Daugavpil., 11 (1): 61-75.*

The seasonal dynamics of zooplankton (Rotifera, Cladocera, Copepoda) were studied in the Daugava River near Daugavpils, Latvia. During the spring, summer and autumn 2010 expeditions on the Daugava samples of zooplankton were gathered at both banks of the river, as well as in the middle, 4 places in total. Zooplankton samples were gathered and analyzed according to standard methods. Research on the zooplankton in the Daugava shows that in different stretches of the river in different seasons number of zooplankton species as well as zooplankton abundance and biomass can vary significantly. Fluctuations depend on synergy of biotic and abiotic factors. In the studied river section all in all 69 zooplankton taxa were found. In spring, summer and autumn dominant taxa have been divided into groups. The leading role in forming of zooplankton in the Daugava had *Keratella cochlearis*. During the year the quantitative dominating group of organisms in the Daugava zooplankton has been Rotifera, in summer the dominating group was Cladocera. When assessing the Daugava zooplankton according to its biomass, in spring the dominating role has taken Rotifera, in summer and autumn – Cladocera group of organisms. The streamline was characterized by lower densities and lower number of taxa. Abundance peaks were found to be characteristic with high densities in May–June and August.

Key words: large river, Rotifera, Cladocera, Copepoda, hydrological regime, temperature.

Arnita Meinerte, Rasma Deksne, Rezekne Higher Education Institution Latgale Sustainable Development Research Institute, Atbrīvošanas aleja 76, Rezekne, LV-4601, Latvia, rasma.deksne@ru.lv

Rasma Deksne, Artūrs Škute Institute of Ecology, Daugavpils University, Vienības 13, Daugavpils, LV-5401 Latvia, Arturs.Skute@du.lv

INTRODUCTION

Zooplankton in large rivers has been studied by several authors Lair (2006), Lazareva (2008, 2010), Viroux (1997), Thorp and Casper (2002, 2003), Holst et al. (2002), Dijk and Zanten (1995), Basu and Pick (1997), especially large number of studies are dealing with the river Danube in Austria (e.g. Reckendorfer et al. 1999; Vadadi-Fülöp et al. 2010, 2009).

The first major zooplankton studies in the Daugava river have been depicted in 1955 dissertation by Nora Sloka "Zooplankton of the lower part of the Daugava river basin". The Daugava saprobiological studies in Latvia have been disclosed in the monography "Hydrobiology of the Daugava river" by A.Kumsāre published in 1967 (Kumsare 1967). Comprehensive results of research on zooplankton in the Ķegums reservoir, the Daugava upper and middle parts, as well as parameters for its eventual affecting factors - water thermics, ionic and biogenic runoff etc. is contained in voluminous paper by N. Sloka „Hydrobiology and Fish Fauna of the Ķegums reservoir" published in 1969. Zooplankton studies in the Daugava river within the Daugavpils district have been performed starting from 1961 (Škute & Laganovska 1969). The Daugava zooplankton studies in length of 940 km from the river outlet to the Ķegums reservoir (including) at the Daugavpils University from 1960 to 1971 was carried out by Dr.biol. Renāte Škute. Results of the research are disclosed by the R.Škute dissertation „Zooplankton of the Daugava river (with exception the lower part) and its role in determination of the river productivity and sanitary- biological quality" (Škute 1971). From 1972 to 2011 in zooplankton studies of the Middle Daugava are taking part Dr.biol. R.Škute, prof. Dr.biol.A.Škute, Dr.biol. D. Gruberts, J.Paidere. Zooplankton studies of 1996 have been displayed in Dz. Guļāne master's thesis (Guļāne 1996), research of 2006 – in E. Kadakovska master's thesis (Kadakovska 2007).

Zooplankton organisms occupy a central position in the food webs of aquatic ecosystem. They do not only form an integral part of the lentic community but also contribute significantly to the biological productivity of the fresh water ecosystem (Wetzel 2001). In freshwater ecosystems, zooplankton plays a key role as efficient filter feeders on the phytoplankton and as a food source for other invertebrates and fish (Lampert 2006, Saha & Bandyopadhyay 2009). Therefore the zooplankton studies are quite important. Periodicity of plankton development is a consequence of seasonal changes in the environmental conditions. Climate, as a regulator of water flow, initiating changes in the river hydromorphology, exerts an important control over fluvial communities, and natural disturbances are the cause of large variations between rivers, as well as within and between reaches and years of the same river (Lair 2006). Huge basins of the intra-cascade reservoirs on the Volga River and on other large plains rivers like no other are dependent on the climate dynamics (Litvinov et al. 2005).

The aim of the study was to inquire into seasonal dynamics of zooplankton cenoses of the Daugava River.

MATERIAL AND METHODS

Belarus, Latvia, the Russian Federation and Lithuania share the basin of the Daugava River, also known as Dauguva and Western Dvina. The Daugava rises in the Valdai Hills (Russian Federation) and flows through the Russian Federation, Belarus, and Latvia into the Gulf of Riga. The total length of the river is 1005 km, 352 km of which or 35% of its total length fall to Latvia (The summary of overground waters' quality 2003). The Daugava basin with the watershed area of 87.900 km² stretches over the territory of five countries, Russia, Belarus, Lithuania, Estonia and Latvia with 24.700 km² or 28% of its total area falling to Latvia (Kavacs 1994).

The biggest natural floodplain in Latvia is located within the Daugava valley stretch from Daugavpils City down to Jersika, where the river cuts through the Baltic Morainic Ridge and in its further course flows across the Eastern Latvian lowland. The territory of the floodplain which is outlined by the highest spring flood level encompasses 208.25 km^2 and includes the Middle Daugava and part of the ancient valley of Dviete, its left bank tributary (Škute et al. 2008). The territory is characterized by a temperate semi-humid climate influenced by the westerly transfer of oceanic air masses. The mean annual precipitation does not exceed the range of 600 to 700 mm yr^{-1}. Seasonal fluctuation of water level in the stretch of the Middle Daugava is determined mainly by natural factors, such as the amount of snow accumulated in the drainage area during winter, rate of the air temperature increase and snow melt in spring or formation of ice jams during the spring floods (Gruberts 2006). About half of the total mean annual amount of the Daugava runoff is formed during the spring floods (Briede

Table 1. GPS coordinates of sampling sites and dates

Sampling site	Geographic latitude	Geographic longitude	Sampling dates 2010
No.1 Krauja	55° 54.787 N	026° 40.059 E	16 May , 2 June, 17 June, 1 July, 12 July, 30 July, 19 August, 30 August, 16 October, 30 October
No.4 Šūņupe	55° 52.628 N	026° 30.093 E	2 June, 17 June, 1 July, 12 July, 30 July, 19 August, 30 August, 16October, 30 October
No.3 1.5 km below Daugavpils	55° 53.311 N	026° 28.401 E	16 May , 2 June, 17 June, 1 July, 12 July, 30 July, 19 August, 30 August, 16October, 30 October
No.4 Silupe	55° 57.322 N	026° 24.271 E	16 May , 2 June, 17 June, 1 July, 12 July, 30 July, 19 August, 30 August, 16 October, 30 October

et al. 2001).

During the expeditions to the Daugava River section from Krauja to Silupe in Latvia (4 sampling sites) in 2010 zooplankton was sampled at the right and left banks, as well as in the middle of the river (Fig. 1, Table 1).

Zooplankton samples were collected and analysed according to standard methods. Samples of zooplankton were collected by filtering 100 l of river water with the 65-μm mesh-sized plankton net. Collected samples were fixed in 4% formalin. A *Carl Zeiss* light microscope was used for the analysis of zooplankton; three subsamples (2 ml each) were examined at 100–400× magnification. The identification of Rotifera, Cladocera, and Copepoda taxa was the aim of the qualitative study, for which zooplankton determinants were used (Kutikova 1970, Borutsky 1960, Manuilova 1964).

Quantitative characteristics (abundance, biomass, number of taxa), the relation of zooplankton taxonomic groups and species diversity (Shannon-Wiener index derivative N_1 according to the number of organisms) were employed for the analysis of zooplankton community structure in the Daugava River. Species diversity was calculated according to the Shannon-Wiener index (Shannon 1948, Krebs 1999):

$$H' = \sum_{i=1}^{s} (p_i)(\log_2 p_i),$$

where S is the number of species, p_i is the proportion of individuals of the i^{th} species to the total number of species.

The Shannon-Wiener index may be expressed in another form (MacArthur 1965), in units of the number of species as

$$N_1 = e^{H'},$$

where e = 2, H' = Shannon-Wiener function, N_1 =number of equally common species that would produce the same diversity as H'.

Hill (1973) recommends using N_1 rather than H' because units (the number of species) are more clearly understandable to ecologists. Therefore N_1 is used in the present research.

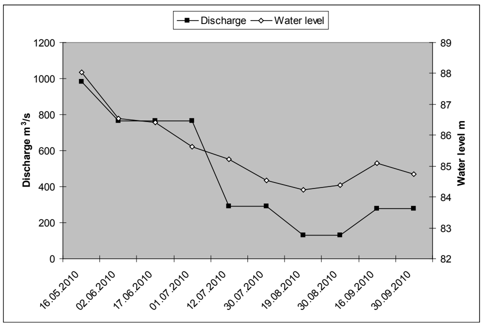

Fig. 1. Water discharge and level recorded during the study period (according to information provided by the company "Latvian Environment, Geology and Meteorology Centre").

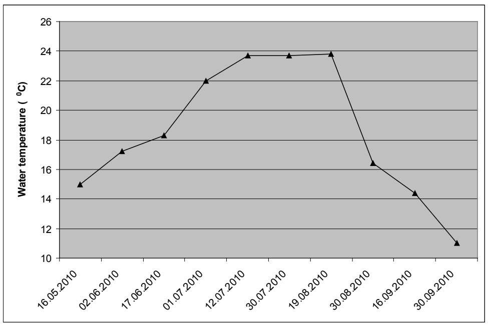

Fig. 2. Water temperature recorded during the study period (according to information provided by the company "Latvian Environment, Geology and Meteorology Centre").

RESULTS

During the study period, water discharge varied between 131 and 981 m^3/s, maximum was recorded in 16 May 2010, minimum in 30 August 2010 (Fig. 1). Maximum values of water temperature were observed in July–August (23.8°C) and minimum at the end of September (11.0°C) (Fig. 2). Water throughput rates during the season subject to research with exception of August were above the average perennial norm. Average water temperature was above or about the norm from the average perennial norm (Table 2).

A total of 69 taxa of zooplankton - 37 taxa of Rotifera, 24 taxa of Cladocera and 8 taxa of Copepoda were recorded in researched stretch of the river in spring, summer and autumn 2010 (Table 3). The ratio (in percents) among main zooplankton taxonomic groups Rotifera : Cladocera : Copepoda is 54 : 35 : 11.

The species occurring during all three seasons of the year include *Keratella cochlearis, Keratella*

Table 2. Environmental characteristics of surveyed sites

2010	Vegetation	Water throughputs from average perennial norm (%)	Interval of the water level fluctuations (m)	Mean temperature of the water from average perennial norm (ºC)
May	Watercourse is unobstructed, in some places vegetation development begun on the banks	111	0.9-1.9	Exceeded by 1.0-1.5
June	Watercourse is unobstructed, aquatic plants noticed only in some places near banks	160	0.4-1.2	About the norm
July	Watercourse is unobstructed, aquatic plants noticed only in some places near banks	108	0.7-1.5	Exceeded by 2.0- 4.0
August	Watercourse is unobstructed, aquatic plants noticed only in some places near banks	62	0.2-0.3	Exceeded by 1.0-3.0
September	Watercourse is unobstructed, aquatic plants noticed only in some places near banks	112	0.3-1.0	About the norm

Table 3. List of zooplankton taxa and average abundance (ind. /m^3) in the Daugava River, 2010

Taxa	Spring	Summer			Autumn
	May	June	June	August	September
ROTIFERA 37	**10143**	**8390**	**3080**	**12326**	**2202**
Asplanchna priodonta (Gosse, 1850)		81	11		
Ascomorpha ecaudis (Perty, 1850)	204			34	
Ascomorpha ovalis (Bergendal, 1892)				308	
Bdelloidea	50	64	343	359	129
Brachionus angularis angularis (Gosse, 1851)	101	82	45	860	
Brachionus bennini (Leissling, 1924)			299	523	
Brachionus quadridentatus quadridentatus (Hermann, 1783)			683	2281	40
Brachionus calyciflorus calyciflorus (Pallas, 1766)			47	1713	
Cephalodella gibba (Ehrenberg, 1830)			45	40	20
Cephalodella exigua (Gosse, 1886)			23	43	
Cephalodella sp.			23		
Conochilus hippocrepis (Schrank, 1803)	50		22	128	
Conochilus unicornis (Rousselet, 1892)				21	
Colurella uncinata (O.F. Müller, 1773)			13	58	
Euchlanis dilatata (Ehrenberg, 1832)	102		199	2040	1228
Filinia longiseta (Ehrenberg, 1834)		39		40	
Filinia maior (Colditz, 1914)		20		120	
Keratella cochlearis cochlearis (Gosse, 1851)	3854	5636	355	701	313
Keratella tecta (Gosse, 1851)	51	84	13	313	
Keratella valga (Ehrenberg, 1834)			36		
Keratella quadrata quadrata (O.F Müller, 1786)	1013	419	62	60	58
Kellicottia longispina (Kellicott, 1879)	154	431	26		
Lecane bulla (Gosse, 1851)		20	37	557	60
Lecane luna luna (O.F Müller, 1776)		42	87	82	18
Lecane lunaris (Ehrenberg, 1832)		63	24	40	20
Lepadella ovalis (O.F Müller, 1896)	101		13	140	
Platyas quadricornis (Ehrenberg, 1832)			22		
Polyarthra dolichoptera (Idelson, 1925)	665	19		19	
Polyarthra vulgaris (Carlin, 1943)	304	374	38	123	110
Pompholyx sulcata (Hudson, 1885)	602	478	450	1077	38
Synchaeta sp.	2793	518		127	53
Testudinella patina patina (Hermann, 1783)				20	
Trichocerca capucina (Wierzejskiet, zacharias, 1893)		20			
Trichocerca rattus (O.F Müller, 1776)			82	164	38
Trichocerca similis (Wierzejski, 1893)				296	36
Trichocerca uncinata (Voigt, 1902)			12		
Trichotria pocillum (O.F Müller, 1776)	100		68	39	42
CLADOCERA 24	**102**	**334**	**482**	**52304**	**907**
Alona affinis (Leydig, 1860)		20			
Acroperus harpae (Baird, 1834)				490	160
Alona rectangula (Sars, 1862)					53
Alona sp.				40	
Bosmina longirostris (O.F Müller,1785)		253	12	142	52
Bosmina longispina (Leydig, 1860)		60		96	
Ceriodaphnia affinis (Lilljeborg, 1900)				742	
Ceriodaphnia pulchella (Sars, 1862)				17157	42
Ceriodaphnia reticulata (Jurine, 1820)			186	18973	

Chydorus ovalis (Kurz, 1875)	102			1519	171
Chydorus sphaericus (O.F Müller, 1785)			25	1066	110
Diapanasoma brachyurum (Liévin, 1848)			69	1172	92
Daphnia cucullata (Sars, 1862)			25		
Daphnia cristata (Sars, 1861)			13	22	
Eurycercus lamellatus (O.F Müller, 1776)				42	
Macrothrix hirsuticornis (Norman & Brady, 1867)				715	
Macrothrix laticornis (Jurine, 1820)				430	
Pleuroxus trigonellus (O. F. Müller, 1776)				21	22
Pleuroxus truncatus (O.F Müller, 1785)					18
Polyphemus pediculus (Linnaeus, 1761)				61	
Rhynchotalona rostrata (Koch, 1841)				158	98
Scapholeberis mucronata (O.F. Müller, 1776)			62	55	18
Sida crystallina (O.F.Müller, 1776)			91	9031	73
Simocephalus vetulus (O.F. Müller, 1776)				371	
COPEPODA 8	**1378**	**302**	**560**	**4183**	**1181**
Canthocamptus staphylinus (Jurine, 1820)	52	20	24	60	18
Cyclops vicinus (Ulyanin, 1875)				21	
Cyclops sp.		46	41	143	102
Eucyclops macruroides (Lilljeborg, 1901)				137	55
Eucyclops serrulatus (Fischer, 1851)			11	465	163
Macrocyclops albidus (Jurine, 1820)			11		
Copepodite	151	87	78	787	283
Nauplii	1175	149	395	2569	561
IN TOTAL 69	**11622**	**9026**	**4122**	**68813**	**4290**

Table 4. Relative amount (%) of the leading Daugava zooplankton taxa (>5%) in the Daugava River during different seasons

Taxa	May	June	June	August	September
Rotifera					
Bdelloidea			11		6
Brachionus angularis angularis (Gosse, 1851)				7	
Brachionus bennini (Leissling, 1924)			10		
Brachionus calyciflorus calyciflorus (Pallas, 1766)				14	
Brachionus quadridentatus quadridentatus (Hermann, 1783)			22	18	
Euchlanis dilatata (Ehrenberg, 1832)			6	17	56
Kellicottia longispina (Kellicott, 1879)		5			
Keratella cochlearis cochlearis (Gosse, 1851)	38	67	12	6	14
Keratella quadrata quadrata (O.F Müller, 1786)	10				
Pompholyx sulcata (Hudson, 1885)	6	6	15	9	
Polyarthra dolichoptera (Idelson, 1925)	7				
Polyarthra vulgaris (Carlin, 1943)					5
Synchaeta sp.	28	6			
Cladocera					
Alona rectangula (Sars, 1862)					6
Alona affinis (Leydig, 1860)		6			
Acroperus harpae (Baird, 1834)					18
Bosmina longispina (Leydig, 1860)		18			
Bosmina longirostris (O.F Müller, 1785)		76			6

Ceriodaphnia pulchella (Sars, 1862)				33	
Ceriodaphnia reticulata (Jurine, 1820)			38	36	
Chydorus sphaericus (O.F Müller, 1785)			5		12
Chydorus ovalis (Kurz, 1875)	100				19
Daphnia cucullata (Sars, 1862)			5		
Diapanasoma brachyurum (Liévin, 1848)			14		10
Rhynchotalona rostrata (Koch, 1841)					11
Scapholeberis mucronata (O.F. Müller, 1776)			13		
Sida crystallina (O.F.Müller, 1776)			19	17	8
Copepoda					
Cyclops sp.		15	7		9
Canthocamptus staphylinus (Jurine, 1820)		7			
Eucyclops serrulatus (Fischer, 1851)				11	14
Copepodite	11	29	14	18	24
Nauplii	85	49	70	61	47

quadrata, *Polyarthra vulgaris, Pompholyx sulcata,* Bdelloidea, *Canthocamptus staphylinus,* nauplii and copepodite (Table 3). According to abundant dominant taxa were *Euchlanis dilatata, Keratella cochlearis, Pompholyx sulcata, Brachionus quadridentatus, Bosmina longirostris, Ceriodaphnia reticulate, Sida crystallina, Cyclops sp.,* nauplii and copepodite (Table 4).

Average zooplankton abundance ranged between 1140 (at the beginning of July) and 89353 ind./m^3 (in the middle of August), whereas maximum density reached 364233 ind./m^3 on 19 August 2010 1.5 km below Daugavpils at the left bank. Shannon - Wiener diversity values ranged within a large-scale interval (2.1–8.3), highest diversity and evenness values were measured in the middle of August (Fig. 3). The Daugava's streamline was characterized by lower abundance, biomass and lower number of taxa in comparison with the river bank, however, there were also differences between the left and the right banks (Fig. 4).

In the middle of May 2010 when water temperature fluctuated between 15.0^{0}C and 17.0^{0}C (Fig. 2), 19 taxa of zooplankton were found: 15 of Rotifera, 1 of Cladocera and 3 of Copepoda. Predominant taxa from the Rotifera group were *Keratella cochlearis, Keratella quadrata, Pompholyx sulcata, Polyarthra dolichoptera, Synchaeta sp* from *Cladocera* group- *Chydorus ovalis,* from Copepoda – nauplii, copepodite (Table 3).

The biggest diversity of zooplankton species, the highest abundance as well as biomass were established in August when water temperature was between 16.4^{0}C and 23.8^{0}C (Fig.2). In August 57 zooplankton taxa were found – 30 taxa of Rotifera, 20 of Cladocera and 7 of Copepoda (Table 3). The most common Rotifera taxa were *Brachionus angularis*, *Brachionus calyciflorus, Brachionus quadridentatus, Euchlanis dilatata, Keratella cochlearis, Pompholyx sulcata,* Cladocera taxa diversity and numbers were significantly increased with *Ceriodaphnia reticulate, Ceriodaphnia pulchella, Sida crystallina* being predominant and the most widespread taxa of *Copepoda* group were *Eucyclops serrulatus,* nauplii and copepodite (Table 4).

In September 2010 with water temperatures lowering down to fluctuations between 11.0^{0}C and 14.4^{0}C (Fig. 2) and gradual die-off of higher vegetation, diversity of species and abundance reduced sharply, 33 zooplankton taxa - 15 Rotifera, 12 Cladocera, 6 Copepoda were found (Table 3). Predominant Rotifera taxa were Bdelloidea, *Euchlanis dilatata, Keratella cochlearis, Polyarthra vulgaris.* Distribution of the Cladocera taxa was more even, *Alona rectangular, Acroperus harpae, Bosmina longirostris, Chydorus sphaericus*, *Chydorus ovalis, Diapanasoma brachyurum, Rhynchotalona rostrata, Sida crystalline. Cyclops sp., Eucyclops serrulatus,* nauplii and copepodite were the most widespread of Copepoda group (Table 4).

During spring, autumn and summer months in

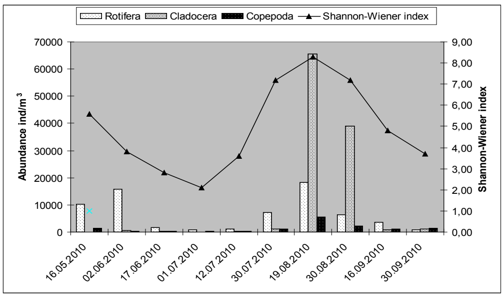

Fig. 3. Abundance of zooplankton taxonomic groups and Shannon-Wiener index in the Daugava River during different seasons.

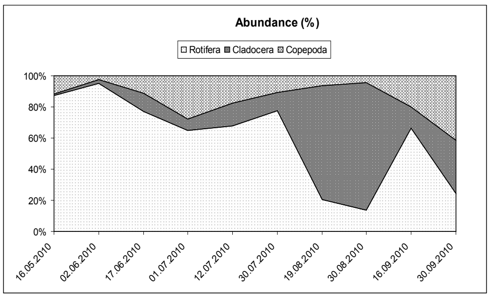

Fig. 5. The share (in percentage terms) of taxonomic groups in the Daugava River zooplankton abundance during different seasons.

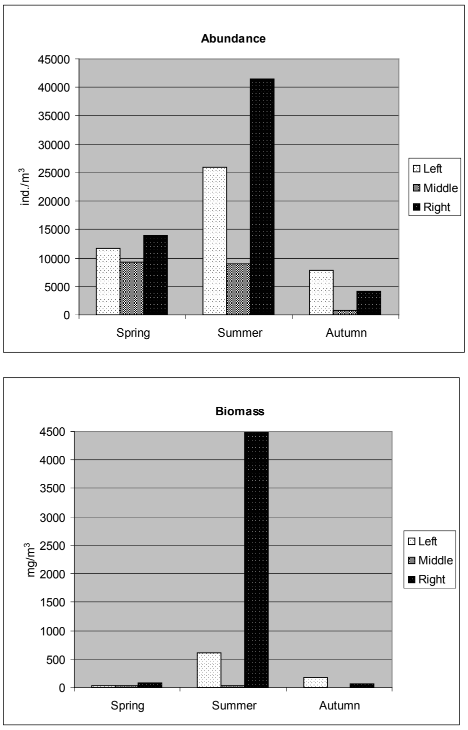

Fig. 4. The mean distribution of zooplankton organisms along the banks and in the middle of the Daugava River in spring, summer and autumn months of 2010.

the abundance predominant group of organisms in the Daugava river zooplankton was Rotifera, only during second part of August, following a growth of macrophytes, predominant group of organisms was Cladocera (Fig. 5).

According to zooplankton biomass in May and

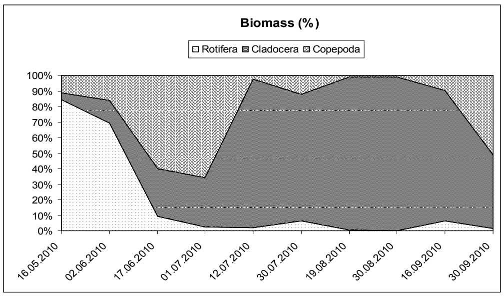

Fig. 6. The share (in percentage terms) of taxonomic groups in the Daugava River zooplankton biomass in different seasons.

at the beginning of June, Rotifera was the most prevalent, in the middle of June, at the beginning of July and at the end of August – Copepoda, from July to the middle of September – Cladocera (Fig. 6).

DISCUSSION

Temperature has significantly affected reproduction of some species (Deksne unpublished). *Keratella quadrata*, *Keratella cochlearis, Polyarthra vulgaris* were present all the year round but they have reached the peak in spring when the water temperature was about 15.0 - 17.2 ºC (Table 3, Fig. 2). In years with cold summer, these species have reached the autumn peak earlier – in September, while in years when summer is warm – later in October or November (Škute 1971). The optimal development temperature for *K.quadrata* and *K.cochlearis* is 15-20ºC. It has to be said, that for *K. cochlearis* development in Daugava important factor is not only temperature but also nutrition. The best development conditions for this species are in macrophyte stands along the banks with slow flow velocity (Škute 2007). Average summer temperature in 2010 has exceeded the norm, therefore *K. quadrata*, *K. cochlearis, P. vulgaris* autumn peak at the end of September was not observed (Table 3).

Brachionus quadridentatus abundance grew as temperature increased to 20-22^{0}C and peaked in August 2010 (Table 3, Fig. 2). During the years when water temperature does not exceed 19^{0}C *B. quadridentatus* in the Daugava river zooplankton is rarely found (Škute 2007).

In 2010 *Euchlanis dilatata* reached maximum at the end of August, beginning of September, when temperature fluctuated between 23.0 - 14.4^{0}C (Table 3, Fig. 2). The favourable temperature for *E. dilatata* development is 18.5 - 20.0^{0}C, but it must not exceed 20^{0}C. The most widespread *E.dilatata* was along the banks with growths of macrophyte (Škute 1976).

Chydorus sphaericus has reached its abundance peak in August 2010 (Table 3). The most important factor in development of this species is nutrition, not temperature, and this is why in the biggest amounts this species is found in macrophyte stands along the banks (Škute 1971).

Cladocera species such as *Acroperus harpae Daphnia cucullata, Daphnia cristata, Ceriodaphnia reticulata, Ceriodaphnia affinis, Ceriodaphnia pulchella, Chydorus sphaericus, Eurycercus lamellatus, Diapanasoma brachyurum, Macrothrix hirsuticornis Macrothrix laticornis Pleuroxus trigonellus Pleuroxus truncatus Polyphemus pediculus Rhynchotalona rostrata Scapholeberis mucronata Sida crystallina Simocephalus vetulus* appeared in plankton only during the second part of the summer when water temperature reached 19.0 – 23.8^{0}C (Table 3, Fig. 2). Positive correlation between these species and the temperature was observed also during the 2008, 2009 and 2010 zooplankton studies (Deksne unpublished). The massive increase in these species is correlated not only to the rise in temperature but also to the growth of macrophytes that served as a good feed base. The positive effect of macrophytes on zooplankton development is pointed out by a few authors (Nilsson et al. 1989, Hamilton et al. 1990, Lair 2005, Czerniawski & Domagała 2010 a, b). Copepodite and nauplii occurred during all season. The presence of nauplii instars of cyclopoids in plankton samples provides evidence of more stable habitats in which mating is possible (Lair 2006).

During the research season the leading role in the Daugava zooplankton cenosis was played by Rotifera. The dominance of Rotifera in rivers was attributed to their short developmental rate and fish predation on larger zooplankton (Gbemisola 2003, Lair 2006, Thorp & Mantovani 2005). Pace et al. (1992) confirmed the general trend for smaller-sized plankton (e.g. rotifers and bosminid cladocera) being favoured in rivers and suggested this reflected advantages from shorter generation times. Pourriot et al. (1997) concluded that dominance of small rotifers in the River Marne resulted from both species differences in generation time and fish predation on larger zooplankton.

Like in 2008 and 2009 studies (Deksne 2009, 2010) seasonal dynamics was defined by abundance peaks, which were found to be characteristic for the Daugava River with high densities in May–June and August (Figure 3). High abundance of zooplankton in the springtime could be explained by lack of predators. Campbell (2002) claims that high water flow and current speed favour the abundance of zooplankton as in such conditions it is more difficult for the fish to catch zooplankton. During the spring rapid development of spring phytoplankton is taking place, being the zooplankton's feed resource. In spring the amount of zooplankton increases mainly at the expense of Rotifera, which might be explained by lack of pressure from predators, such as metazoan zooplankton. Rotifers require shorter water retention times in rivers for somatic and reproductive growth than do microcrustaceans (e.g. Pace et al. 1992, Kobayashi 1997). In the lower Rhine studies Dijk and Zanten (1995) specify that in spring, the rotifer density and water temperature and rotifer density and chlorophyll *a* concentration were positively correlated. In the Daugava river studies the Rotifera correlation with temperature was not significant (Deksne unpublished). Kutikova (1970) mentions that majority Rotifera is eurythermal. Bdelloidea layer rotifers are able to adapt for survival within a wide temperature interval. Bērziņš & Pejler (1989) published a paper that summarized the temperature preferences and tolerances of 225 species of planktic, periphytic and benthic rotifers from diverse waters in south and central Sweden. They concluded that rotifers generally have a very wide tolerance of temperature, many common species remaining abundant at temperatures ranging from 1 to 22°C. Also in studies of Galkovskaya et al. (1988) correlation between Rotifera abundance and water temperature has not been found. However, the authors express the idea that the number of periodical oscillation of frequency and amplitude depends on temperature.

Lair (2006) indicates that Rotifers are more numerous in spring and cladocerans in summer, spring pulses in the plankton being linked to spring floods and reflecting lacustrine situations. Such patterns may be reproduced in rivers where the floodplain provides permanent ponds, billabongs etc., on condition that they remain connected to the river during plankton growth. In springs, when water level in the Daugava is high, in the system of flood-lands occurs hydrological compatibility between the river and lakes, therefore zooplankton in its drainage phase flows into from lakes. During the spring months in 2010 when water level in the Daugava was high, Rotifera abundance correlated positively with discharge, which could be explained by the fact that rotifers could be washed up from flood-lands lakes (Deksne unpublished). In the Daugava section Krauja (before the Daugava flood-lands) – Berezovka mouth in seasonal studies 2005-2008 and in spring 2007 during the meltwater (in March) in the section Rugeli-Dunava the carried out studies prove the fact that at the Berezovka mouth, where the meltwaters from the Dviete and Ilukste flood-land rivers and lakes are flown into, has the bigger number of taxa and organisms (Paidere 2010). A similar sight is also observed in other river flood-lands systems (Jose de Paggi & Paggi 2007, Keckeis et al. 2003). Floodplain areas and adjacent water bodies seem to be rather important sources of plankton biomass (Saunders & Lewis 1989, Schiemer et al. 2001, Zsuga et al. 2004, Vadadi-Fülöp 2009).

During the second half of June abundance of zooplankton sharply decreases, probably due to active eating up by fish larvae having developed up to this time. In the summer period, low abundances might indicate a regulation by biotic factors. The impact of grazing by zooplankton is discussed, on the basis of observations of zooplankton (Gosselain et al. 1994).

The second peak for abundance of zooplankton is observed during the second half of August, when the macrophytes stands have been developed and water temperature was sufficiently high, favourable conditions for the growth of Cladocera have been developed and zooplankton densities have increased mainly at the expense of Cladocera. Watercourses with their bed overgrown with macrophytes permit proliferation of zooplankton, thus in such watercourses the zooplankton density is much higher, especially for the Cladocera (Davidson et al. 2000, Czerniawski 2004, Škute 1971). Vadadi-Fülöp (2009) underlines the importance of adjacent lentic areas as sources of planktonic crustaceans. Also the low discharge in August 2010 (Fig. 1) had a favourable effect on the growth of Cladocera. Thorp and Mantovani (2005) Ohio and St Lawrence Rivers Crustacean densities were positively related to the degree of hydrological retention (negatively to current velocities) throughout the study, but rotifer densities were significantly depressed by current velocities only when river discharge was high, making slackwaters that much more valuable.

It has to be taken into consideration that annual amount of atmosphere precipitation, temperature and other zooplankton cenosis influencing factors varies from year to year, therefore the zooplankton productivity strongly varies from year to year (Deksne 2010 unpublished). Zaicev et al. (1989) mentions that zooplankton's abundance and biomass from year to year depends on the time of the low temperature period in spring and water level.

CONCLUSIONS

The Rotifera taxa are playing a leading role within the Daugava River zooplankton community during the vegetation season. Seasonal dynamics is defined by abundance peaks found to be characteristic for the Daugava River with high densities in May–June and August. Major biodiversity according to Shannon-Wiener is identified in August. Pursuant to abundance the dominant group of organisms in the Daugava zooplankton has been Rotifera, only during the second half of August the dominant group is Cladocera, and at the end of September - Copepoda. Assessing the Daugava zooplankton according to its biomass, in spring the dominating role is played by Rotifera (May – middle of June), in summer (July - middle of September) – by Cladocera and in autumn – by Copepoda. The streamline is characterized by lower zooplankton densities and lower number of taxa.

ACKNOWLEDGEMENTS

The author would like to thank Dr. biol. Renāte Škute for her help with the identification of zooplankton.

This work has been supported by the European Social Fund within the Project
«Support for the implementation of doctoral studies at Daugavpils University»
Agreement Nr. 2009/0140/1DP/1.1.2.1.2/09/IPIA/VIAA/015

REFERENCES

Basu B.K. and Pick F.R. 1997. Phytoplankton and zooplankton development in a lowland, temperate river. Journal of Plankton Research, 19 (2):237-253.

Bērziņš B. and Pejler B. 1989. Rotifer occurrence in relation totemperature. Hydrobiologia, 175: 223-232.

Briede A., Kļaviņš M., Rodinovs V. and Kokorīte I. 2001. Seasonal and long-term discharge changes in Latvian rivers. Geographical articles, 9: 20-32. [Briede, A., Kļaviņš, M., Rodinovs, V., Kokorīte, I. 2001. Upju noteces sezonālās un ilglaicīgās izmaiņas Latvijā. Ģeogrāfiski raksti 9: 20-32.].

Borutsky E. V. 1960. Key to identification of wild freshwater crawfish of the USSR and contiguous countries from fragments in fish intestines. Moscow: Academy of Sciences of the USSR. [Боруцкий, Е. В. 1960. Определитель свободноживущих пресноводных веслоногих раков СССР и сопредельных стран по фрагментам в кишечниках рыб. Москва: Изд-во АН СССР.]

Campbell C.E. 2002. Rainfall events and downstream drift of microcrustacean zooplankton in a Newfoundland boreal stream. Canadian Journal of Zoology, 80: 997-1003.

Czerniawski R. 2004. Zooplankton exported from Lake Adamowo by the river Drawa. Zoologica Poloniae, 49: 129–147.

Czerniawski R. and Domagała J. 2010 a. Zooplankton communities of two lake outlets in relation to abiotic factors. Central European Journal of Biology, 5 (2): 240–255.

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

Davidson N.L., Kelso W.E. and Rutherford A.D. 2000. Characteristics of cladoceran and copepod communities in floodplain habitats of the Atchafalaya River Basin. Hydrobiologia, 435: 99-107.

Deksne R., Škute A. and Škute R. 2009. Seasonal dynamics of zooplankton of the middle Daugava. [Международная научная конференция «Теоретические и прикладные аспекты современной лимнологии». Минск, 13.-16].

Deksne R. and Meinerte A. Zooplankton dynamics at the Daugava river stretch Krāslava – Dunava in 2009. Collected articles of the DU 52nd International Scientific Conference. [Zooplanktona dinamika Daugavas posmā Krāslava – Dunava 2009. gadā. DU 52. Starptautiskās zinātniskās konferences rakstu krājums. Daugavpils (unpublished)].

Deksne R., Škute A. and Paidere J., 2010. Changes in structure of zooplankton communities in the middle Daugava (western Dvina) over the last five decades. Acta Zoologica Lituanica, 20(3): 190-208.

Deksne R. and Škute A. The influence of ecohydrological factors on the cenosis of the Daugava zooplankton(unpublished). Acta Zoologica Lituanica.

Dijk G.M. and Zanten B. 1995. Seasonal changes in zooplankton abundance in the lower Rhine during 1987–1991. Hydrobiologia, 304(1): 29-38.

Galkovskaya G., Golovchic V. and Mityanina I. 1988. Ekological-biological principles of Rotifera mass cultivation. Minsk: Science and Technology. [Галковская, Г. А., Головчиц, В. А., Митьянина, И. Ф. 1988. Эколого-биологические основы массового культивирование коловраток. Минск: Наука и техник , 140 с].

Gbemisola A. Akin-Oriola 2003. Zooplankton associations and environmental factors in Ogunpa and Ona rivers, Nigeria. Rev. Biol. Trop, 51(2): 391-398.

Gosselain V., Descy J. and Everbecq E. 1994. The phytoplankton community of the River Meuse, Belgium: seasonal dynamics (year 1992) and the possible incidence of zooplankton grazing. Hydrobiologia, 289(1-3): 179-191.

Gruberts D. 2006. The flood pulse concept in the ecology of floodplain lakes of the Middle Daugava. Summary of the thesis for applying for the doctoral degree in biology (specialty ecology). Daugavpils, Daugavpils University: Saule, p. 79.

Guļāne D. 1996. Zooplankton of the Daugava River and its tributaries in the stretch from Piedruja to Pļaviņas. [Daugavas upes un tās pieteku zooplanktons posmā no Piedrujas līdz Pļaviņām. Daugavpils: Daugavpils Pedagoģiskā Universitāte].

Hamilton S. K., Sippel S. J., Lewis W. M. and Saunders J. F. 1990. Zooplankton abundance and evidence for its reduction by macrophyte mats in two Orinoco floodplain lakes. Journal of Plankton Research, 12: 345–363.

Holst H., Zimmermann-Timm H. and Kausch H. 2002. Longitudinal and transverse distribution of plankton rotifers in the Potamal of the River Elbe (Germany) during late summer. International Revue der Gesamten Hydrobiologie, 87: 267–280.

José De Paggi S.J. and Paggi JC. 2007. Zooplankton. In: Iriondo M.H., Paggi J.C. and Parma M.J. (eds.): The Middle Paraná River: limnology of a subtropical Wetland, New York: Springer. Pp. 229-245.

Kadakovska E. 2007. Zooplankton of the Daugava River in the stretch from Krāslava to Daugavpils. [Daugavas zooplanktons posmā no Krāslavas līdz Daugavpilij. Daugavpils: Daugavpils Universitāte, 56 lpp].

Kavacs G. 1994. Encyclopaedia of Latvia's Nature. Riga: Latvian encyclopaedia publishers. Pp. 214-217 [Kavacs, G. 1994. Latvijas daba: enciklopēdija 1. sēj, Rīga: Latvijas enciklopēdija: Preses nams, 214-217.]

Keckeis S., Baranyi C., Hein T., Holarek C., Riedler P. and Schiemer F. 2003. The significance of zooplankton grazing in a floodplain system of the River Danube. Plankton Research, 25: 243-253.

Kobayashi T. 1997. Associations between environmental variables and zooplankton body masses in a regulated Australian river. Marine and Freshwater Research, 48: 523–529.

Kumsare A. J. 1967. Hydrobiology of the Daugava River. Riga: Science, 186 p. [Кумсаре А. Я., 1967. Гидробиология реки Даугавы. Рига: Зинатне, 186 с].

Kutikova L. A. 1970. Rotifera of the USSR fauna. Key to fauna of the USSR. Leningrad: Nauka, 744 p. [Кутикова Л. А., 1970. Коловратки фауны СССР. Определители по фауне СССР, издав. Зоол. Ин-том АН СССР. Вып. 104. Ленинград: Наука, 744 с.].

Lair N. 2006. A review of regulation mechanisms of metazoan plankton in riverine ecosystems: aquatic habitat versus biota. River Research and Applications, 22: 567–593.

Lampert W. 2006. Daphnia: model herbivore, predator and prey. Polish. J. Ecol., 54(4): 607–620.

Lazareva V. I. 2008. Distribution and Special Traits of Naturalization of New and Rare Zooplankton Species in Waterbodies of the Upper Volga Basin. Inland Water Biology, 1: 76–83.

Lazareva V.I. 2010. Zooplankton structure and Dynamics in the Rybinsk Reservoir, Moscow: KMK Scientific Press Ltd., 183 p. [Лазарева В.И., 2010. Структура и динамика зоопланктона Рыбинского водохранилища. М: Товарищество научных изданий КМК, 183 с.].

Litvinov A.S., Devyatkin V.G., Roschupko V.F. and Shihova N.M. 2005. Perennial changes in characteristic features of the Rybinsk reservoir ecosystem. Topical issues of reservoirs. Rybinsk: Publishing house OAO „Rybinskiy Dom Pechati" [Литвинов А.С., Девяткин В.Г., Рощупко В.Ф., Шихова Н.М. 2005. Многолетние изменения характеристик экосистемы Рыбинского водохранилища. Актуальные проблемы водохранилищ. Рыбинск: Изд-во ОАО «Рыбинский дом печати»/, с. 190-199].

Manuilova E. F. 1964. Cladocera of the USSR fauna. Moscow-Leningrad: Nauka. [Мануйлова, Е. Ф. 1964. Ветвистоусые рачки (Cladocera) фауны СССР. Москва-Ленинград: Наука].

Nilsson C., Grelsson, G., Johansson M. and Sperens U. 1989. Patterns of plant species richness along riverbanks. Ecology, 70: 77–84.

Pace M., Findlay S., Stuart E.G. and Links D. 1992. Zooplankton in advective environments: the Hudson River community and a comparative analysis. Canadian Journal of Fisheries and Aquatic Sciences, 49: 1060–1069.

Paidere J. 2010. Zooplankton during meltwaters and floods in the Daugava stretch of Krauja-Dunava in 2005-2008. In: I. Plikša (ed.): LU 68th Scientific conference, Climate changes and water, Works collection. Riga: LU. Pp. 67. [Paidere J. 2010. Zooplanktons palu, plūdu laikā Daugavas posmā Krauja-Dunava 2005.-2008. gadā, LU 68 zinātniskā konference, Klimata mainība un ūdeņi, Rakstu krājums: 67 lpp. Rīga: LU].

Reckendorfer W., Keckeis H., Winkler G. and Schiemer F. 1999. Zooplankton abundance in the River Danube, Austria: the significance of inshore retention. Freshwater Biology, 41: 583–591.

Saha T. and Bandyopadhyay M. 2009. Dynamical analysis of toxin producing Phytoplankton–Zooplankton interactions. Nonlinear Anal- Real, 10: 314–332.

Saunders J. F. III and Lewis W. M. Jr. 1988. Zooplankton abundance in the Caura River, Venezuela. Biotropica, 20: 206–214.

Schiemer F., Keckeis H., Reckendorfer W. and Winkler G. 2001. The „inshore retention concept" and its significance for large rivers. Large Rivers, 12: 509–516.

Škute R. and Laganovska R. 1969. The Daugava River Zooplankton in the Daugavpils district. [Daugavas zooplanktons Daugavpils rajonā. Latvijas PSR Zinātņu akadēmijas Vēstis, 4 (261): 68-74].

Škute R. J., 1971. Zooplankton of the River Daugava and its role in the productivity and biological evaluating of the river. Dissertation. Tartu: Tartu University, 233 p. [Шкуте, Р. Я. 1971. Зоопланктон реки Даугавы (кроме низовий) и его роль в продуктивности и санитарнобиологической оценке реки. Диссертация. Тарту. 233 с.].

Škute R. J., 1976. Regionalism of the Daugava River according to zooplankton. In: Škute R. J. (ed.): Ecological and biological investigations of water animals. Riga: Zvaigzne, 43-55. [Шкуте, Р. Я. 1976. Районирование реки Даугавы по зоопланктону. В кн. Экологические и биологические исследование водных животных. Рига: Даугавпилсский педагогический институт, Звайгзне, 43-55.].

Škute R., Škute A. and Kadakovska E. 2007. The dynamics of Daugava zooplankton. LU 65th Scientific Conference. Pp. 330-331.

Škute A., Gruberts D., Soms J. and Paidere J. 2008. Ecological and hydrological functions of the biggest natural floodplain in Latvia. Ecohydrology and Hydrobiology, 8(2-4): 291-306.

The summary of overground waters' quality. 2003. Latvian Environment, Geology and Meteorology Centre (on line), available from http://www.meteo.lv produkti/sowq_lv/2003/ (Accessed 3 February 2010).[Virszemes ūdeņu kvalitātes pārskats. 2003. Latvijas Vides, ģeoloģijas un meteoroloģijas centrs (on line), Pieejams http://www.meteo.lv/produkti/sowq_lv/2003/ (Piekļuve 03.02.2010).

Thorp J.H. and Casper A.F. 2002. Potential effects on zooplankton from species shifts in planktivorous mussels: a field experiment in the St. Lawrence River. Freshwater Biology, 47: 107-119.

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

Thorp J. H. and Mantovani S. 2005. Zooplankton of turbid and hydrologically dynamic prairie rivers. Freshwater Biology, 50: 1474–1491.

Vadadi-Fülöp Cs. 2009. Zooplankton (Cladocera, Copepoda) dynamics in the River Danube upstream and downstream of Budapest, Hungary Opusc. Zool. Budapest, 40 (2): 87–98.

Vadadi-Fülöp Cs., Hufnagel L. and Zsuga K. 2010. Effect of sampling effort and sampling frequency on the composition of the planktonic crustacean assemblage: a case study of the river Danube. Environ Monit Assess, 163:125–138.

Viroux L. 1997. Zooplankton development in two large lowland rivers, the Moselle (France) and the Meuse (Belgium), in 1993. Journal of Plankton Research, 19(II):1743-1762.

Wetzell R. G. 2001. Limnology: Lake and river Ecosystem, 3rd ed. Academic Press.

Zaycev Y., Garkavaya G., Pavlenko A., Alexandrov B. and Rusnak E. 1989. The active surface 'river-sea' as a specific biotope.

Hydrobiology, 25(6): 23-24. [Зайцев, Ю. П., Гаркавая, Г. П., Павленко, А. Д., Александров, Б.Г., Руснак, Е.М. 1989. Активная поверхность "река - море", как специфический биотоп. Гидробиол. журн. 25(6): 23-24.].

Zsuga K., Tóth A., Pekli J., Udvari Z. S. 2004. Zooplankton development of the Tisza river basin since the 1950s. Hidrológiai Közlöny, 84: 175–178.

Received: 18.04.2011.
Accepted: 01.08.2011.