Water chemical characteristics and the spatio-temporal patterns of zooplankton assemblages in a side arm of the Danube (rkm 1437-1440, Hungary)

DINKA MÁRIA, SCHÖLL KÁROLY, ÁGOSTON-SZABÓ EDIT, KISS ANITA, BERCZIK ÁRPÁD[1]

Keywords: Danube, floodplain, chemical characteristics, zooplankton

1 Introduction

Natural river-floodplain systems are characterised by a large variety of aquatic habitats (Junk et al. 1989). The physico-chemical characteristics and zooplankton dynamics of these habitats are highly dependent on the hydrological regime (Baranyi et al. 2002, Mitsch & Gosselink 2007). Changes in the river discharge, patterns of expansion and contraction are the main determining factors of the biological diversity and the habitat heterogeneity in the floodplain water bodies (Tockner et al. 2000).

The features of these water bodies can vary from lotic to lentic depending on the degree of connectivity and the hydrological fluctuations in the main arm. The hydrological linkage between the side arms and the main arm is essential with regard to the nutrient cycle. Side arms isolated from the main channel for most of the year have a lentic character and a longer water residence time; hence, internal processes (i.e. internal nutrient cycle) are promoted and there is a higher nutrient retention potential (Glińska-Lewczuk 2009).

Nutrient retention of the wetlands situated along the Danube has been elucidated in many previous works (Cristofor et al. 1993, Garnier et al. 2002, Hein et al. 2004 etc.), while there are only a few respective data of the Gemenc and Béda-Karapancsa floodplains.

The aim of this study was to examine the habitat conditions based on the physico-chemical features of the water and the zooplankton dynamics in the Külső-Béda plesiopotamal side arm in function of changes in water discharge of the main arm. The Külső-Béda is a side arm, with high natural value situated in the Béda-Karapancsa Landscape Protection Area of the Danube-Dráva National Park. It came into existence in the 19th century during river regulation and flood control works on the Danube, which induced drainage and alterations of the ecological conditions in the side arm.

2 Materials and Methods

Study site and sampling time

The Külső-Béda is a plesiopotamal type side arm, i.e. having limited connectivity with the main channel, with junctions with the Danube at rkm 1440.5 (upstream) and rkm 1437.5 (mouth). Its open water area is 4 km long, 90 m wide on average and about 2.5 m deep (Fig. 1). The threshold water level of its mouth is 120 cm at Mohács and only at high water levels (630 cm at Mohács, rkm 1447) water is flowing from the junction.

The physico-chemical characteristics and the zooplankton assemblages (Rotifera, Cladocera, Copepoda) were examined in the Külső-Béda (BDU) at six sampling sites: BDU1, BDU2, BDU22, BDU3, BDU4, BDU5, situated at 450-750 m distance from each other (Fig. 1) and at four sampling times (Fig. 2). Reference samples were taken simultaneously from Danube at rkm 1447.

[1] Hungarian Danube Research Station of the Hungarian Academy of Sciences, H-2163-Vácrátót, Alkotmány u.2-4, Hungary, e-mail: dm@botanika.hu

Water chemistry

The temperature, pH, electrical conductivity and oxygen concentration of the water were determined in situ with Multi 340i meter (WTW). The sodium, potassium, calcium, magnesium, ammonium, chloride, nitrite, nitrate and sulphate concentrations were determined by DX-120 ionchromatograph (Dionex); the dissolved organic (DOC), inorganic (DIC), total (DTC) carbon and the dissolved total nitrogen (DTN) concentrations by TOC analyser (Elementar-liqui-TOC); the CO_3^{2-}, HCO_3^-, chlorophyll-a, suspended matter, soluble reactive (SRP) and the dissolved total phosphorus (DTP) concentrations of the water were determined in the laboratory by standard analytical methods (Golterman et al. 1978).

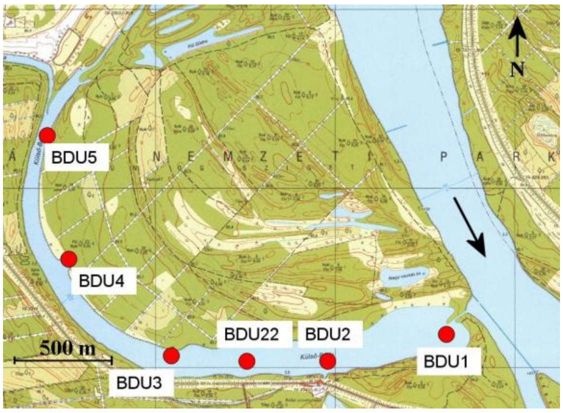

Figure 1. *Sampling sites at Külső-Béda (BDU) and at Danube (rkm D 1447)*

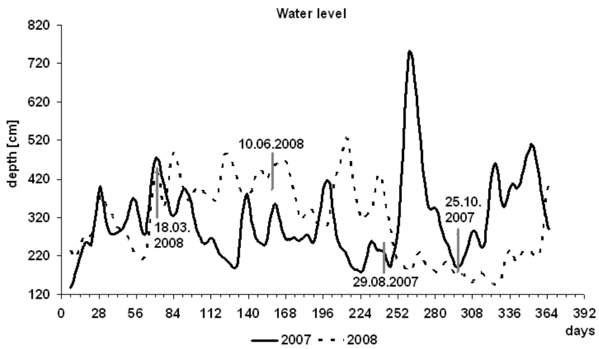

Figure 2. *Water level fluctuations at Mohács (Danube rkm 1447) and sampling dates*

Zooplankton

Planktonic rotifer and microcrustacean species (Cladocera, Ostracoda, Copepoda) were sampled separately: 10 l of water were filtered through a mesh of 40 µm for the rotifer and 50 l through a mesh of 70 µm for the microcrustacean species. Samples were preserved in 4% formaldehyde solution. Nikon SMZ stereo microscope and Olympus light microscope were used for identification and counting individuals. Juvenile stages of copepods (copepodids) were incorporated in the total number of copepods.

Data were analysed by hierarchical cluster (HC) and principal component (PCA) analyses by using the Past (Hammer et al. 2001) and Statistica program packages.

3 Results and Discussion

The changes in water level of the Danube (rkm 1447) during the investigated periods of two consecutive years: 2007 and 2008 is presented in Figure 2.

Water chemistry

Remarkable differences were found between chemical parameters of the main and side arms (BDU) and among the sampling sites of the side arm, which were caused by the water regime of the main arm inducing seasonal changes in the biotic and abiotic parameters.

The pH, conductivity, sodium, magnesium, calcium and sulphate concentrations in most of the cases were higher in the side than in the main arm (Tab. 1).

Table 1. *The main physico-chemical parameters in the Külső-Béda (BDU) and in the Danube at rkm 1447*

Site		pH	T	Cond.	O_2	Na^+	K^+	Mg^{2+}	Ca^{2+}	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}
			C°	μScm^{-1}	%	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}
BDU	**min.**	**7.6**	**8.4**	**300.0**	**83.0**	**9.4**	**2.4**	**11.6**	**26.1**	**78.6**	**0.0**	**13.9**	**25.7**
	max.	**8.8**	**26.8**	**752.0**	**169.5**	**34.3**	**3.5**	**24.0**	**100.7**	**347.3**	**49.3**	**31.7**	**59.2**
Danube	**min.**	**7.3**	**9.7**	**340.0**	**96.6**	**9.8**	**2.1**	**8.5**	**38.8**	**135.5**	**0.0**	**21.6**	**22.2**
	max.	**8.3**	**24.8**	**454.0**	**129.0**	**17.0**	**5.9**	**15.1**	**61.9**	**203.3**	**38.8**	**24.6**	**36.5**

The N concentrations were lower in BDU than in the main channel (D rkm 1447) (Tab. 2), the nitrate concentrations by 2-100%, the ammonium by 23-96% (except from 25.10.2007) and the TDN by 12-81%. Also lower P concentrations (SRP and DTP) were measured in the side arm. The lower nutrient concentrations in the BDU demonstrate the role of floodplain waters in nutrient retention e.g. denitrification and sedimentation, which are higher in the floodplain than in the main channel (Venterink et al. 2003). The nitrate concentration decreased with distance from the main arm and this was associated by an increase in the concentration of HCO_3^-, which suggests that the intensity of denitrification processes, mediated by the microbial oxidation of organic carbon (Kim et al. 2009) also increase with distance from the main arm. This process is essential for N removal and water purification.

Contrary to the N and P concentrations, the C concentrations at BDU in most of the cases exceeded those in the main arm (the DTC by 3-37%, the DOC by 0.4-47% and the DIC by 2-39%) and increased with distance from the main arm. From among the measured C forms the DOC is one of the most important components of the aquatic food webs (Guéguen et al. 2006).

The chlorophyll-a concentrations varied between 8.0-129.9 $\mu g\ l^{-1}$ (Tab. 2); higher chlorophyll-a concentrations were measured in the side arm. The high chlorophyll-a values might have been the reason for an algal bloom and suggest the contribution of phytoplankton to the DOC of autochthon origin (Guéguen et al. 2006). The chlorophyll-a concentrations in most of the cases positively correlated with the examined nutrient concentrations.

Table 2. *The nutrient, chlorophyll-a and suspended matter concentrations of the water in the Külső-Béda*

Site		Susp.m	Chl-a	NO_2^-N	NO_3^-N	NH_4^+N	DTN	SRP	DTP	DIC	DOC	DTC
		mgl^{-1}	μgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}	μgl^{-1}	μgl^{-1}	mgl^{-1}	mgl^{-1}	mgl^{-1}
BDU	**min.**	**2.0**	**8.0**	**0.00**	**0.00**	**0.00**	**0.86**	**0.07**	**14.07**	**22.05**	**4.67**	**31.12**
	max.	**50.8**	**129.9**	**0.12**	**2.83**	**0.49**	**2.02**	**32.22**	**42.62**	**63.40**	**26.08**	**81.48**
Danube	**min.**	**10.4**	**4.9**	**0.00**	**0.90**	**0.00**	**1.76**	**0.16**	**47.04**	**26.77**	**5.09**	**31.86**
	max.	**24.4**	**36.4**	**0.03**	**2.88**	**0.14**	**2.59**	**61.79**	**50.89**	**38.80**	**12.23**	**51.03**

Classification of the sampling sites based on the chemical parameters of the water

The relationship between the sampling sites and the chemical parameters of the water were determined by hierarchical cluster and principal component analyses on each sampling time (Fig. 3).

The farthest sampling site from the main arm, BDU5 represented the first similarity group on 29.8.2007 and 18.3.2008 and its separation was mainly determined by the electrical conductivity, DTC, DIC at both sampling times. The second similarity group involved two further sub-groups: when the water level was low (239 cm at Mohács, on 29.8.2007) BDU1, BDU2, BDU4 and BDU22, BDU3 were separated from the main arm (DU), but when the water level was high (453 cm on 18.3.2008) the sampling sites situated close to the main arm (BDU1, BDU2, BDU22) were in the same group with the main arm (DU) and were separated from the sampling sites distant from the main arm (BDU3, BDU4). On 25.10.2007 and 10.6.2008 the first similarity group was represented by the sampling sites situated in the side arm and the second group by the main arm (DU). At low water level (207 cm on 25.10.2007, after a flood event) the sampling site BDU5 was separated from the other sites of the side arm, while at high water level (487 cm on 10.6.2008) it was in the same group with the sampling sites close to the main arm: BDU22, BDU2, BDU1 (Fig. 3).

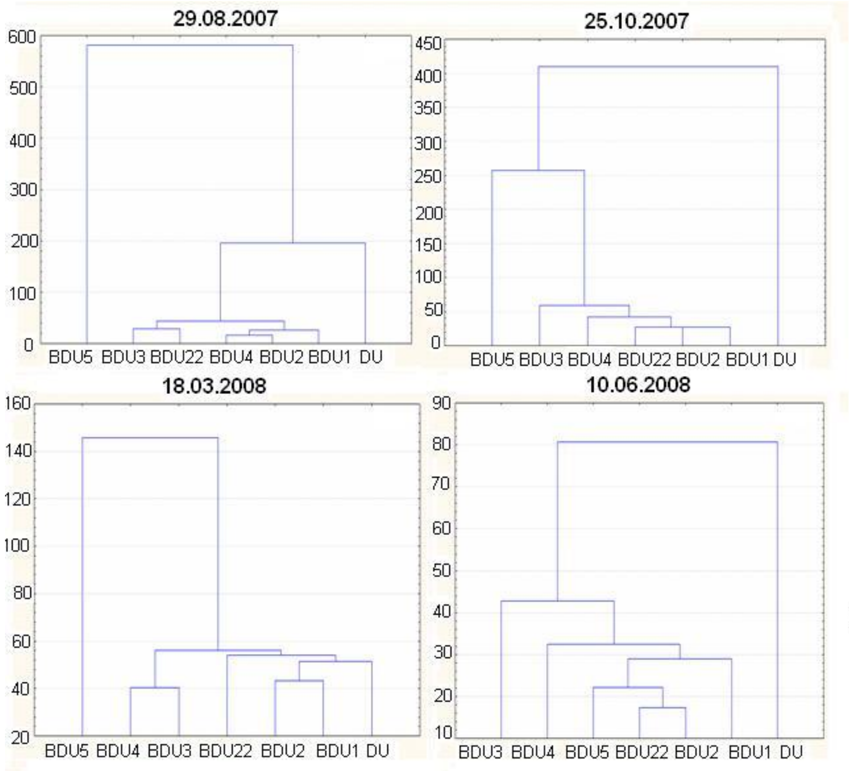

Figure 3. *Comparison of sampling sites based on the chemical characteristics of the water*

Zooplankton

24 Rotifer and 21 Crustacea taxa were found in the BDU during the investigation period. The rotifer abundance ranged from 160 to 560 ind. l^{-1} and the microcrustacean abundance from 0.04 to 450.2 ind. l^{-1}, while in the main arm the average number of rotifers and of the microcrustaceans was 38.5 ind l^{-1} and 1.7 ind l^{-1}, respectively.

Among the rotifer taxa Brachionus homoceros and B. forficula are rare in Hungary and in the last years have been reported only from the floodplain water of Gemenc by Schöll (2009). 13 Cladocera, 7 Copepoda and 1 Ostracoda taxa were identified and Copepoda (especially Thermocyclops oithonoides) clearly dominated by 82% in the main arm and 88% in the side arm. The zooplankton densities negatively correlated with the water level of the main arm.

Classification of the sampling based on rotifer densities

Remarkable differences were observed between the rotifer samples of the main and side arms except from 29.8.2007. Lower rotifer species number, diversity and density occurred in the main arm, caused by the characteristic high flow velocity, which inhibits rotifer reproduction and due to lower temperatures phytoplankton productivity, serving as a food source for rotifers. The temperature and hydrological regime play a major role in structuring the habitat conditions and biotic communities in the floodplain ecosystems (Tockner et al. 2000). The sampling sites of the side arm (BDU1-5) differed corresponding to their proximity; neighbouring sites were more similar (e.g. BDU4-5, BDU2-3, Fig. 4), independent of water levels of the main arm (18.3.2008: 453 cm, 10.6.2008: 487 cm). Site BDU1 situated close to the mouth of the side arm made an exception, as it was most likely affected by the main arm (backflow). On 29.8.2007 the similarity of sampling sites differed from the above described pattern, this was not significant as species and individual numbers were too small for HC and PCA analysis. The cause of the low species number and abundance is unknown; similar fluctuations in density and diversity occur from time to times most likely triggered by short generation time (7-9 days) of rotifers. Hydrological influence could be excluded as the water level of the main arm was low (201 cm) at this sampling time and in the previous week.

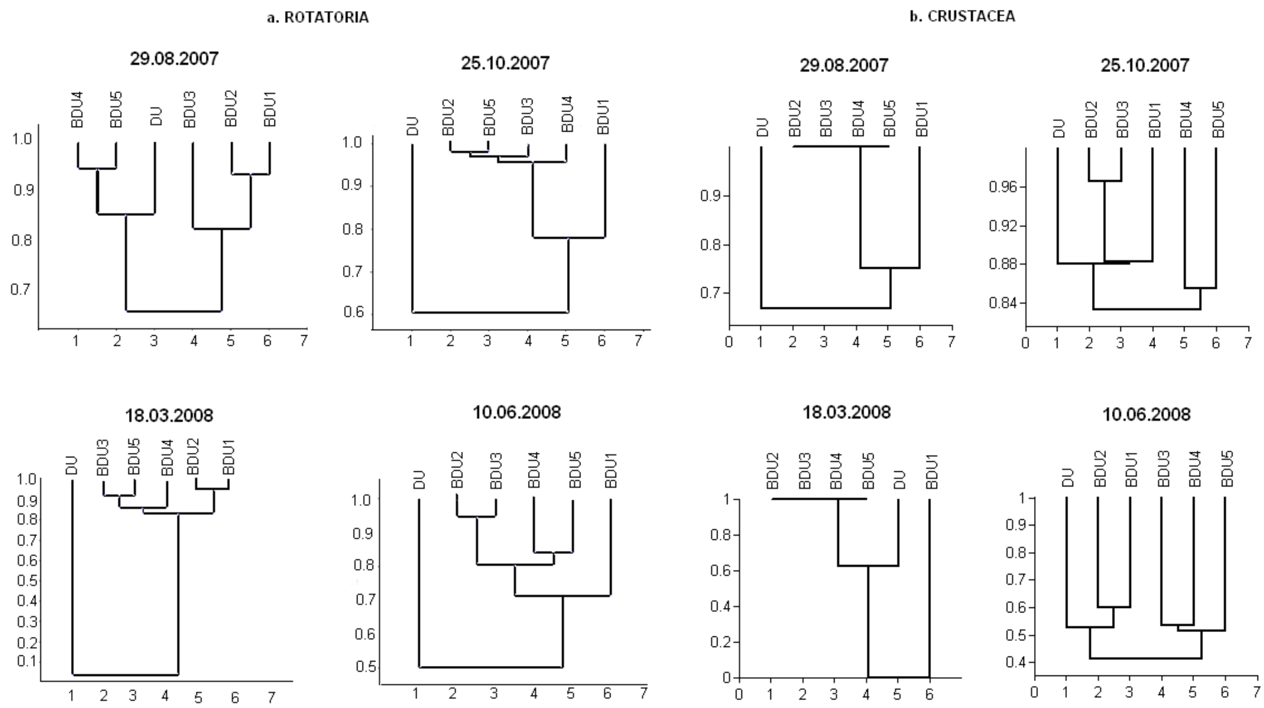

Figure 4. *Comparison of sampling sites based on rotifer and micro-crustacean densities*

Classification of the sampling sites based on microcrustacean densities

Similar to rotifers microcrustaceans showed different abundance in the main and side arm, especially in 2007 at low water period (Fig. 4). The crustacean assemblages of the side arm on 29.8.2007 and 18.3.2008 were very similar. In March 2008 the abundance was very low at all sites (especially in BDU1); because of the inhibitory effect of low temperature values (8.4-9.9 °C) mostly copepodids were present. In August 2007 (water level: 239 cm) the composition of assemblages were similar in the side arm, but copepod abundance increased significantly with distance from the main arm. On 25.10.2007 and 10.6.2008 the taxon number and diversity of assemblages were maximum at the farthest sites of the side arm (BDU4-5), presumably because of the slower water flow at the end of the side arm. These results showed that the temperature and the hydrological regime were the most important variables affecting the microcrustacean assemblages of the side arm.

4 Conclusions

The nutrient concentrations (N and P forms) were lower, while the concentrations of the C forms were higher in the side arm as compared to the main arm, which demonstrated the nutrient retention function of the Külső–Béda plesiopotamal side arm. The zooplankton densities and diversities were higher in the side arm than in the main arm (these differences increased with the distance from the mouth of the side arm) and beside the seasonal variation, interacted with the changes in the water regime and habitat heterogeneity of the side arm. The monitoring of zooplankton groups provides quick information about the ecological changes of waters, because of their short life-cycle, high mobility and complex species composition.

Our results reflected that the habitat diversity based on the chemical heterogeneity of the water was interrelated with the hydrology and increased the zooplankton densities and diversities in the Külső-Béda side arm, which belongs to the active floodplain zone of the Béda-Karapancsa Landscape Protection Area of the Danube-Dráva National Park.

Acknowledgments

The authors express their cordial thanks to J. Bloesch for reviewing the manuscript. This work was supported by DBU 24050 project and by the Hungarian Academy of Sciences.

References

Baranyi, C., Hein, T., Holarek, C., Keckeis, S. & Schiemer, F. 2002. Zooplankton biomass and community structure in a Danube River floodplain system: effects of hydrology. Freshwater Biology 47. 1-10.

Cristofor S. A., Vadineanu, A. & Ignat, Gh. 1993: Importance of flood zones for N and P dynamics in the Danube-Delta. Hydrobiologia 251: 143-148.

Garnier, J. Billen, G., Hannon, E., Fonbonne, S., Videnina Y. & Soulie M. 2002. Modelling the Transfer and Retention of Nutrients in the Drainage Network of the Danube River. Estuarine, Coastal and Shelf Science 54/3: 285-308.

Goltermann, H. L., Clymo, R. S. & Ohnstad, M. A. M. (1978): Method for physical and chemical analysis of freshwaters. IBP Handbook No. 8, Blackwell Sci. Publ. p. 1-213.

Glińska-Lewczuk, K. 2009. Water quality dynamics of oxbow lakes in young glacial landscape of NE Poland in relation to their hydrological connectivity. Ecological Engineering. 35: 25-27.

Guéguen, C., Guo, L., Wang, D., Tanaka, N. & Hung, Ch. 2006. Chemical Characteristics and Origin of Dissolved Organic Matter in the Yukon River. Biogeochemistry. 77, 2 :139-155

Hammer, R., Harper, D. A. T. & Ryan, P. D. (2001): Past Paleontological statistics software package for education and data analysis. Paleontologia electronica 4/1: 9 pp.

Hein, T., Baranyi, C. & Schiemer, F. 2004. The impact of surface water exchange on the nutrient and particle dynamics in side-arms along the river Danube, Austria. Science of the Total Environment. 328/1-3: 207-218.

Junk, W. J., Bayley, P. B. & Sparks, R. E. (1989): The flood pulse concept in river floodplain systems pp. 110-127. in D. P. Dodge ed. Proceedings of the International Large River Symposium. Can Spec. Publ. Fish. Aquat. Sci. 106. 110-127.

Kim, K.-H., Yun, S.-T., Choi, B.-Y, Chae, G.-T., Yoo, Y., Kim, K. & Kim, H.-S. 2009. Hydrochemical and multivariate statistical interpretations of spatial controls of nitrate concentrations in a shallow alluvial aquifer around oxbow lakes (Osong area, central Korea). Journal of Contaminant Hydrology.

Mitsch, W. J.& Gosselink, G. J. 2007. Wetlands (Fourth Edition) Publ. by John Willey & Sons, Inc. pp. 582.

Schöll, K. 2009: Diversity of planktonic rotifer assemblages in the water bodies of Gemenc floodplain (Duna-Dráva National-Park, Hungary). Biologia 64/5: 951-958.

Tockner K., Malard F. & Ward J. V. 2000. An extension of the flood pulse concept. Hydrol. Process. 14: 2861-2883.

Vinterink, O. H., Wiegman F., Van der Lee, G. E. M. & Vermaat, J. E. 2003. Role of Active Floodplains for Nutrient Retention in River Rhine. J. Environ. Qual. 32: 1430-1435.