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Microcrustacean (Cladocera, Copepoda, Ostracoda) Diversity in Three Side Arms in the Gemenc Floodplain (Danube River, Hungary) in Different Hydrological Situations

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Abstract: The microcrustacean assemblages, from different functional units of the Gemenc Floodplain (Danube River), were studied in various hydrological situations between 2002 and 2009. Sixty-three microcrustacean taxa were recorded from which 38 belonged to Cladocera, 18 to Copepoda and seven to Ostracoda. Among them there were some rare for the Middle Danube Region species, such as *Dunhevedia crassa* King, 1853, *Holopedium gibberum* Zaddach, 1855, *Monospilus dispar* (Sars, 1862). Significant differences were found between the different functional units of the floodplain focusing on the examined parameters of the microcrustacean assemblages. The most important factors influencing the species richness, as well as the density and diversity patterns of the assemblages, were the occurrence of flow, the connectivity with the main arm and the hydrological distance from the main arm. Most of these environmental factors are determined by the water level fluctuations of the Danube River which showed a negative correlation with all the examined parameters of the zooplankton assemblages. The density of the communities in both side arms correlated positively with the chlorophyll-a concentration. Moreover, the microcrustacean abundance showed an inverse relationship with the temperature but not in all of the side arms.

Keywords: Cladocera, Copepoda, Ostracoda, diversity, floodplains, connectivity

Introduction

Floodplains along large rivers are heterogeneous systems, wherein the water regime of the main arm influences the degree of lateral connectivity and has a main role in the maintaining of the riverine wetlands (Junk *et al.* 1989). The degree of connection between a river and its floodplain depends on the water level and the floodplain morphology. Hydrological connectivity is an important factor for the structure and productivity of planktonic communities in floodplain water bodies (Baranyi *et al.* 2002). Zooplankton assemblages of floodplains are affected by abiotic (*e.g.* water age, physical and chemical parameters) and biotic characteristics (*e.g.* food availability, predation, exploitative and interference competition) of the side channels and backwaters (Lair 2006).

The Gemenc Floodplain is one of the largest in Europe with unique natural value and containing various characteristic side arms and backwaters. The Gemenc Research Project organized by the Danube Research Institute started in 2002. The aim of the study was to understand the ecological and hydrobiological functions of the Gemenc floodplain. The main objectives of the zooplankton studies were to investigate the assemblages of the different "functional units" (eu-, para-, plesio- and paleopotamal) in the studied floodplain. In this paper the characteristics of microcrustacean communities are described for a five-year period in the eu-, para- and plesiopotamal functional units of the floodplain and in different hydrological situations.

Material and Methods

The Gemenc floodplain is situated between rkm 1498 and 1469, on the right bank of the Danube River. The floodplain is 30 km long and 5-10 km wide, with an area of 180 km^2. The mean annual discharge is 2400 m^{3}s^{-1} (minimum: 618 m^3 s^{-1}, maximum 7940 m^3 s^{-1}) and the amplitude of water level fluctuations reaches 9 m. The Danube River starts to flow into the floodplain after it reaches a water level of 500 cm at Baja. Sampling was carried out during five years, on 24 sampling occasions altogether (2002: 5 (n=46), 2003: 4 (n=34), 2004: 5 (n=43), 2007: 6 (n=42), 2009: 4 (n=56). The samples were collected usually from April to October from 17 sampling sites. Our study area in the floodplain included the main arm of the Danube River (D1489) and the parapotamal 15 km long Rezéti-Holt-Duna (RDU, 7 sites), the parapotamal 5 km long Vén-Duna (VDU, 4 sites) and the plesiopotamal 7 km long Grébeci-Holt-Duna (GDU, 6 sites) side arms (Fig.1). The sites GDU 6, RDU 6, 7, 8, 9 and VDU 5 are conjunctive water bodies and namely small channels, branching out from the side arms and hydrologically interconnecting them to the floodplain (Roux *et al.* 1982).

Microcrustacean samples were collected by filtering of 100 L of water through plankton net with mesh size of 70µm. The faunal material was preserved in 4% formalin. The Cladocera, Copepoda and Ostracoda taxa were identified to species level and enumerated by using inverted microscopy. Microcrustacean density, including copepodites, was evaluated by enumerating the individuals of the whole sample.

Water temperature, pH, conductivity, dissolved oxygen content were recorded *in situ* with a WTW Multiline-P4 field device. The amount of suspended matter and chlorophyll-a content were determined using standard analytical methods (Golterman *et al.* 1978).

Pearson product moment correlation analyses and Mann-Whitney test were performed by using the PAST software (Hammer *et al.* 2001). The Danube River water level data were obtained from http://www.hydroinfo.hu for the official gauge station of Baja (rkm 1479; 46^{0}10'41"N, 18^{0}55'29"E).

Results and Discussion

Species composition, density and diversity patterns in the different potamal types

During the five-year sampling period 63 microcrustacean species were detected, and namely 38 Cladocera, 18 Copepoda and seven Ostracoda. Fifteen species occurred in all water bodies while some rare for the Middle Danube Region species were also detected, such as *Dunhevedia crassa* King, 1853, *Holopedium gibberum* Zaddach, 1855, *Monospilus dispar* (Sars, 1862) (Table 1). Focusing on the examined parameters of the microcrustacean assemblages there were some significant differences between the different functional units of the floodplain (Table 3).

In the eupotamal (D1489) 23 taxa were recorded and 34.8% of the species occurred only once. The most frequent species were *Bosmina longirostris* (O.

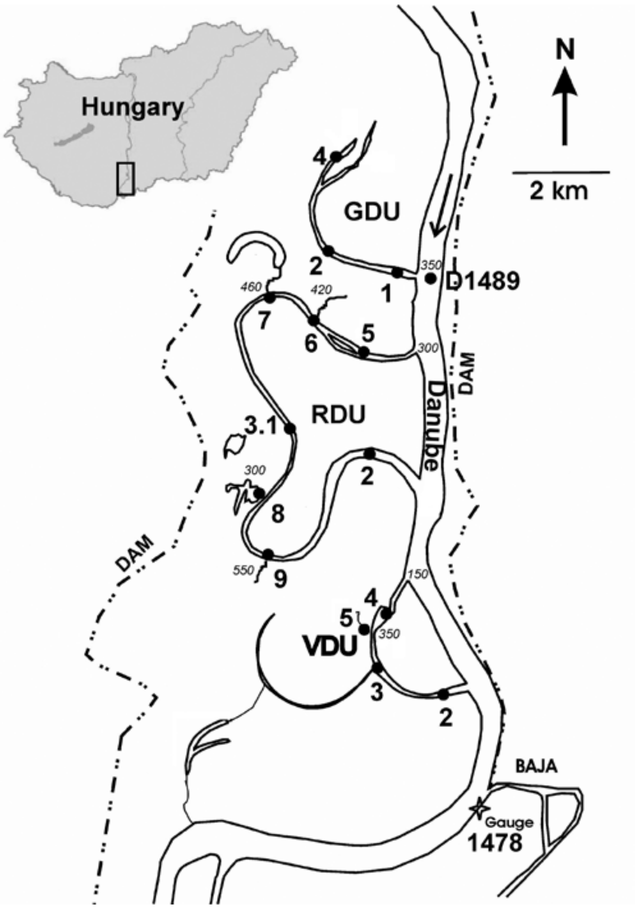

Fig. 1. Sampling sites in the main arm of the Danube River (D1489) and the three side arms (Grébeci-Holt-Duna (GDU); Rezéti-Holt-Duna (RDU); Vén-Duna (VDU)

F. Müller, 1785) and *Thermocyclops oithonoides* (Sars, 1863) (Table 1). The mean and maximum density and species richness of the assemblages there were significantly lower than the ones for the other potamal types (p<0.01). The rare *Paracyclops fimbriatus* (Fischer, 1853) and *Pleuroxus denticulatus* Birge, 1879 have also been detected in the main arm. *Pleuroxus denticulatus* is a relatively new invader in the Danube River (Hudec, Illyová 1998) and has been recorded in 2003 in the Hungarian part of the Danube River (Kiss 2006).

A total of 59 species were recorded in the parapotamal side arms (VDU: 40, RDU: 46) and 28 species were common for both parapotamal side arms. The average and maximum values of the Shannon diversity index were the highest in the parapotamal side arms; however the species richness and the density values were between the values we registered for the eu- and plesiopotamal. The portion of copepodites (20 and 37%) was the highest in this potamon type. The most frequent species were *Chydorus sphaericus* (O. F. Müller, 1776), *Moina brachiata* (Jurine, 1820), *Acanthocyclops robustus* (Sars, 1863), *Thermocyclops crassus* (Fischer, 1853) and with maximum density was *Thermocyclops oithonoides*.

The highest was the number of the rare for the Middle Danube Region species in the parapotamal side arms. *Bosmina coregoni* Baird, 1857, *Bosmina longispina* Leydig, 1860, *Dunhevedia crassa*, *Holopedium gibberum*, *Monospilus dispar* and *Pleuroxus uncinatus* var. *balatonicus* Daday, 1885 were detected only in the parapotamal side arms (Table 1).The main characteristics of the assemblages differed in the sampling sites of the two side arms. Between the sampling sites within the longer and hydromorphologically diverse Rezéti-Duna side arm there were significant differences in the examined parameters of the assemblages. On the other hand, the species number, density and diversity values of the microcrustaceans from the sampling sites within the shorter Vén-Duna side arm, which is with relatively uniform hydrological features, were nearly similar in the whole side arm. The species richness and Shannon diversity were higher in the conjunctive water bodies connected to the parapotamal side arms (*e.g.* VDU 5, RDU 6, 7, 8, 9) than in the other side arm sites (Schöll *et al.* 2012).

The mean and maximum density, as well as the average taxon richness were the highest in the slower flowing plesiopotamal Grébeci-Duna side arm, while the Shannon diversity was significantly lower than the one in the parapotamal side arms (p<0.01). From the 63 taxa, 38 taxa were found in this side arm with the most frequent species being *Bosmina longirostris*, *Cyclops vicinus* Uljanin, 1875 and *Thermocyclops crassus*. The rare *Alona intermedia* Sars, 1862, as well as *Ceriodaphnia reticulata* (Jurine, 1820), *Thermocyclops dybowski* (Lande, 1890) and the phytophilous *Graptoleberis testudinaria* (Fischer, 1848) were recorded only in this side arm. There were significant spatial differences in the mean abundance values: the average density increased from the main arm to the outermost part of the side arm (p<0.01). Similarly to the parapotamal sampling sites, the highest mean diversity values were observed in the conjunctive water bodies (*e.g.* GDU 6).

Environmental parameters

Among the examined parameters, the water level of the main arm was the most important parameter to the microcrustacean communities but the degree of correlation differed in the various potamal types (Table 2). There was no correlation between the water level and the main arm assemblages. In the case of the conjunctive water bodies the species richness and density negatively correlated with the water level of the main arm. Negative relationship occurred between the density and water level in all side arms, while negative relationship between the species richness and water level was found only in the plesiopotamal side arm. The Shannon diversity of the microcrustacean assemblages did not show any correlation with water level, but examining separately the sampling sites, in the outermost sites of the parapotamal Vén-Duna side arm and the plesiopotamal Grébeci-Duna side arm, the diversity was found to correlate negatively with water level (VDU4: r=-0.57, p=0.007, N=21; GDU4: r=-0.55, p=0.04, N=14).

The examined parameters of the microcrustacean communities varied in the different hydrological situations (Table 3). At low water levels, between 0 and 300 cm (measured at Baja), when the lateral connectivity decreased, the density and the species richness of the assemblages in the side arms were highest and the composition of the assemblages in the main arm and in the side arms was significantly

Table 1. List of species and relative frequency of taxa in the main arm (D1489) and the three side arms (Vén-Duna (VDU), Rezéti-Holt-Duna (RDU), Grébeci-Holt-Duna (GDU)

	D1489	**VDU**	**RDU**	**GDU**
CLADOCERA				
Alona affinis (Leydig, 1860)			<0.01	
Alona costata Sars, 1862	<0.01	<0.01	<0.01	<0.01
Alona guttata Sars, 1862			<0.01	<0.01
Alona intermedia Sars, 1862				<0.01
Alona quadrangularis (O. F. Müller, 1785)	<0.01	<0.01	<0.01	
Alonella nana (Baird, 1850)		<0.01	<0.01	
Bosmina coregoni Baird, 1857		<0.01	<0.01	<0.01
Bosmina longirostris (O. F. Müller, 1785)	0.46	0.10	0.08	0.20
Bosmina longispina Leydig, 1860		<0.01		
Ceriodaphnia laticaudata P. E. Müller, 1867	<0.01			
Ceriodaphnia pulchella Sars, 1862			<0.01	
Ceriodaphnia quadrangula (O.F.Müller, 1785)	<0.01	<0.01		<0.01
Ceriodaphnia reticulata (Jurine, 1820)				<0.01
Chydorus sphaericus (O. F. Müller, 1776)	0.03	0.03	0.01	0.01
Daphnia cucullata Sars, 1862	<0.01	<0.01	<0.01	<0.01
Daphnia hyalina Leydig, 1860		<0.01		
Daphnia longispina O. F. Müller, 1785	<0.01		<0.01	<0.01
Diaphanosoma brachyurum (Liévin, 1848)	<0.01	<0.01	0.03	<0.01
Diaphanosoma mongolianum Uéno, 1938			0.01	
Disparalona rostrata (Koch, 1841)	<0.01	0.01	<0.01	<0.01
Dunhevedia crassa King, 1853			<0.01	
Graptoleberis testudinaria (Fischer, 1848)				<0.01
Holopedium gibberum Zaddach, 1855			<0.01	
Iliocryptus agilis Kurz, 1878		<0.01	<0.01	<0.01
Iliocryptus sordidus (Liévin, 1848)		<0.01		
Leydigia leydigi (Schoedler, 1863)		<0.01		
Macrothrix hirsuticornis Norman et Brady, 1867		<0.01	<0.01	<0.01
Macrothrix laticornis (Fischer, 1848)		<0.01	<0.01	
Moina brachiata (Jurine, 1820)	0.01	0.05	0.09	<0.01
Monospilus dispar (Sars, 1862)		<0.01		
Pleuroxus aduncus (Jurine, 1820)	<0.01	<0.01	<0.01	<0.01
Pleuroxus denticulatus Birge, 1879	<0.01	<0.01		
Pleuroxus truncatus (O. F. Müller, 1785)		<0.01	<0.01	<0.01
Pleuroxus uncinatus var. balatonicus Daday, 1885			<0.01	
Scapholeberis mucronata (O. F. Müller, 1785)	<0.01	<0.01	<0.01	<0.01
Scapholeberis ramneri Dumont et Pensaert, 1983			<0.01	
Sida crystallina (O. F. Müller, 1776)		<0.01	<0.01	
Simocephalus vetulus (O. F. Müller, 1776)		<0.01	<0.01	<0.01
COPEPODA				
Acanthocyclops robustus (Sars, 1863)	<0.01	0.06	0.07	<0.01
Canthocamptus staphylinus (Jurine, 1820)			<0.01	<0.01
Cyclops insignis Claus, 1857			<0.01	<0.01
Cyclops strenuus Fischer, 1851		<0.01	<0.01	<0.01
Cyclops vicinus Uljanin, 1875	<0.01	<0.01	<0.01	0.20

	D1489	**VDU**	**RDU**	**GDU**
Diacyclops bicuspidatus (Claus, 1857)		<0.01		<0.01
Ectocyclops phaleratus (Koch, 1838)			<0.01	
Eucyclops macrurus (Sars, 1863)		<0.01		<0.01
Eucyclops serrulatus (Fischer, 1851)	0.01	0.02	<0.01	0.03
Eudiaptomus gracilis (Sars, 1863)		<0.01	<0.01	<0.01
Eudiaptomus vulgaris (Schmeil, 1896)			<0.01	
Eurytemora velox (Lilljeborg, 1853)	<0.01	<0.01	<0.01	<0.01
Megacyclops viridis (Jurine, 1820)		<0.01		<0.01
Mesocyclops leuckarti (Claus, 1857)	0.02	0.03	<0.01	<0.01
Paracyclops fimbriatus (Fischer, 1853)	<0.01		<0.01	
Thermocyclops dybowski (Lande, 1890)				<0.01
Thermocyclops crassus (Fischer, 1853)	0.05	0.02	0.08	0.40
Thermocyclops oithonoides (Sars, 1863)	0.12	0.20	0.40	<0.01
Copepodites	0.18	0.37	0.20	0.08
OSTRACODA				
Cyclocypris laevis (O. F. Müller, 1776)			<0.01	
Cyclocypris ovum (Jurine, 1820)		<0.01	<0.01	
Cypridopsis vidua (O. F. Müller, 1776)		0.02		<0.01
Cypris pubera (O. F. Müller, 1776)			<0.01	<0.01
Limnocythere inopinata (Baird, 1843)			<0.01	
Notodromas monacha (O. F. Müller, 1776)	<0.01			
Physocypria kraepelini G. W. Müller, 1903			<0.01	<0.01
Number of micrucrustacean taxa	23	40	46	38

different. The number of the tychoplanktonic species and the large-bodied cladoceran species increased, especially in the outermost part of the side arms where sometimes stagnant water conditions evolved and submerged macrophyte stands occurred, which likely enhanced microcrustacean diversity and density. At mean water levels the density, diversity and species richness were highest in the main arm and the maximum Shannon diversity values of the microcrustaceans were also maximum in all potamon types. The constant flow in the side arms generated optimal ecological disturbances, which maximized local species diversity (Intermediate Disturbance Hypothesis, Connell 1978). At high water levels (>600 cm) the zooplankton communities were similar in the main arm and in the side arms. The species richness, diversity and density differences decreased in accordance with the increasing lateral connectivity and water flow, as well as with the homogenization effects of flood (Thomaz *et al*. 2007).

The studied community parameters correlated with temperature and chlorophyll-a throughout the sampling period. An inverse relationship became obvious between the temperature and the density of communities in the Rezéti-Duna side arm (r=0.58, p=0.001, N=78) and in the outermost site of the plesiopotamal Grébeci-Duna (r=0.72, p<0.01, N=21). Like in other studies (*e.g.* Basu, Pick 1997) the microcrustacean abundance in all side arms correlated positively with the chlorophyll-a content but not in the main arm. In case of the other community parameters, the relationship with the chlorophyll-a content was less pronounced (species richness – GDU: (r=0.59, p=0.012, N=65, Shannon diversity – VDU: r=0.69, p=0.008, N=65).

Conclusions

The study, focusing on the main characteristics of microcrustacean communities in the Gemenc River floodplain system revealed differences between the different functional units of the floodplain. The most important factors influencing the species richness, as well as the density and diversity patterns of

Table 2. Pearson's correlation of the water level in the main arm (gauge of Baja) with the density, species richness and Shannon diversity of microcrustacean assemblages in the examined water bodies (cwb: conjunctive water bodies, r – correlation coefficient, p– two-tailed probability)

	Density					Species richness					Shannon diversity				
	D1489	VDU	RDU	GDU	cwb	D1489	VDU	RDU	GDU	cwb	D1489	VDU	RDU	GDU	cwb
r	-0.1	**-0.67**	**-0.59**	**-0.51**	**-0.53**	-0.29	-0.48	-0.38	**-0.53**	**-0.68**	0.03	-0.23	-0.18	-0.26	-0.20
p	0.67	**>0.01**	**>0.01**	**0.03**	**0.03**	0.23	>0.01	>0.01	**>0.01**	**>0.01**	0.91	0.06	0.1	0.04	0.35

Table 3. Mean, minimum and maximum values of the diversity, density and species richness of communities in the main arm and the side arms in different hydrological situations

		Shannon diversity			Density (ind. 100l^{-1})			Species richness		
	n	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**
Main arm (D1489)	18	0.81	0.00	1.36	83	1	470	4.00	1.00	8.00
low water (0-300 cm)		0.74			39			4.28		
medium water (300-600 cm)		0.83			149			4.37		
high water (above 600 cm)		0.61			10			2.33		
Vén-Duna (VDU)	65	0.94	0.00	1.86	108	2	1298	4.09	1.00	10.00
low water (0-300 cm)		1.02			220			5.05		
medium water (300-600 cm)		1.06			78			4.31		
high water (above 600 cm)		0.54			5			2.08		
Rezéti-Duna (RDU)	78	0.84	0.00	1.87	285	0	3650	4.17	0.00	12.00
low water (0-300 cm)		0.84			761			4.79		
medium water (300-600 cm)		0.93			191			4.75		
high water (above 600 cm)		0.58			9.63			2.31		
Grébeci-Duna (GDU)	60	0.70	0.00	1.64	556	2	6762	4.88	1.00	11.00
low water (0-300 cm)		0.70			1416			6.83		
medium water (300-600 cm)		0.82			1240			5.75		
high water (above 600 cm)		0.44			146			2.29		

the communities, were the occurrence of flow, the connectivity with the main arm and the hydrological distance from the main arm. Most of these factors are determined by the water level fluctuations in the main arm which showed negative correlation with all examined parameters of the assemblages. Moreover, in the main arm the assemblages were characterised by low density and diversity values because of the limiting effects of flow (heavily disturbed environment). Contrary to the main arm, high density and species richness were detected in the plesiopotamal side arm. The habitats of this side arm, with occasionally stagnant water conditions and the periodic presence of macrophytes, offer good life conditions for microcrustaceans. The highest diversity and the greatest number of rare species were recorded from the parapotamal side arms where the constant but moderate flow proved to be the intermediate ecological disturbance, which maximized local species diversity. All the examined community parameters were negatively correlated with the water level of the main arm and the composition of microcrustacean assemblages was less similar among habitats and potamon types during low water and more similar during high water levels and floods. The chlorophyll-a concentration positively correlated with the density of the assemblages in both side arms, while among the *in situ* measured environmental parameters only the temperature showed reverse relationship with the abundance. Our results support the efforts to understand the spatial dynamics of zooplankton in the dynamically changing river-floodplain system.

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