Spatio-temporal patterns of zooplankton densities according to water chemical characteristics and hydrological events in a river floodplain system at the Danube (rkm 1498-1469)

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

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1 Introduction

The spatial and temporal variability and complexity of the river floodplain systems induces a high biodiversity that makes investigations of lotic ecosystems extremely difficult. After the introduction the Flood Pulse Concept (Junk et al. 1989) and the Riverine Ecosystem Synthesis (Thorp et al. 2006) an increased interest was devoted to the dynamically changing connection between large rivers and floodplains (Hein et al. 1999, Baranyi et al. 2002, Berczik & Buzetzky 2006). The applied hydro-ecological research projects about large rivers and floodplains often focused on fish and benthic invertebrate assemblages, neglecting the great importance of the zooplankton in lotic food-webs and their suitability for biomonitoring.

Growth and density of lotic zooplankton depend on the area of retentive inshore habitats and the connection between the main channel and its adjacent floodplain water bodies (Reckendorfer et al. 1999, Baranyi et al. 2002, Zimmermann-Timm et al. 2007). The zooplankton assemblages of the floodplains are affected by abiotic (water age, physical and chemical parameters) and biotic characteristics (food-web, competition, predation) of each side channel (Dinka et al. 2006). Most of these parameters are defined by the overall discharge of the main arm, which varies over time (Lair 2005). Some studies have focused on zooplankton density and diversity patterns and the regulation of abiotic and biotic factors in large rivers, but the role of the hydrological regime in this process on natural floodplains is still unclear (Schöll 2009, Elosegi et al. 2010).

The aim of our study is to clarify the effects of flooding in different types of floodplain water bodies on hydrobiological processes during rising, standing and sinking water level. Our hypothesis based on previous field observations was that during high flood water chemistry changes along a gradient from the main arm to remote water bodies. Suspended matter and nutrient concentration would decrease, while the amount of chlorophyll-a would increase in the direction to eupotamal-parapotamal-plesiopotamal-conjunctive water bodies. We expected highest zooplankton densities in the plesiopotamal and lowest densities in the main arm.

2 Material and methods

The floodplain Gemenc (Duna-Dráva National Park) is situated between rkm 1498 and 1469, on the right bank of the Danube. It covers 180 km^2, which makes it the only notable floodplain of the Middle Danube today. It is also one of the largest floodplains in Europe, with unique natural value (Zinke 1996). As it is completely within the dam system, the characteristic hydrological processes of the river floodplain system are not disturbed. We can observe every characteristic “functional unit” (eu-, para-, plesio- and paleopotamal) of an ecological succession, providing a great opportunity to compare them simultaneously (Roux 1982; Guti 2001).

[1] Hungarian Danube Research Institute of the H.A.S. Vácrátót, H-2163, Alkotmány str. 2-4. Hungary. e-mail: scholl.karoly@gmail.com

The floodplain is 30 km long and 5-10 km wide. In this reach of the Danube the mean annual discharge is 2400 m^3s^{-1}, with a minimum of 618 m^3s^{-1} and a maximum of 7940 m^3s^{-1} (mean values). The water level fluctuation is monitored by the gauge at Baja (rkm 1479) and the maximum amplitude is 9 m. The slope is about 5 cm km^{-1} in the main arm, with a flow velocity of 0.8-1.2 m s^{-1} at mean water level. The river starts to overflow into the floodplain after it reaches a water level of 500 cm at Baja.

Three dates (23 May, 11 and 25 September 2007) with different hydrological regime (Fig. 2) and 19 sampling sites in the main arm (D1489), the parapotamal Rezéti-Holt-Duna (RDU) and Vén-Duna (VDU), and the plesiopotamal Grébeci-Holt-Duna (GDU) were chosen to clarify the effects of flood on zooplankton densities and water chemistry (Fig. 1 and Tab. 1).

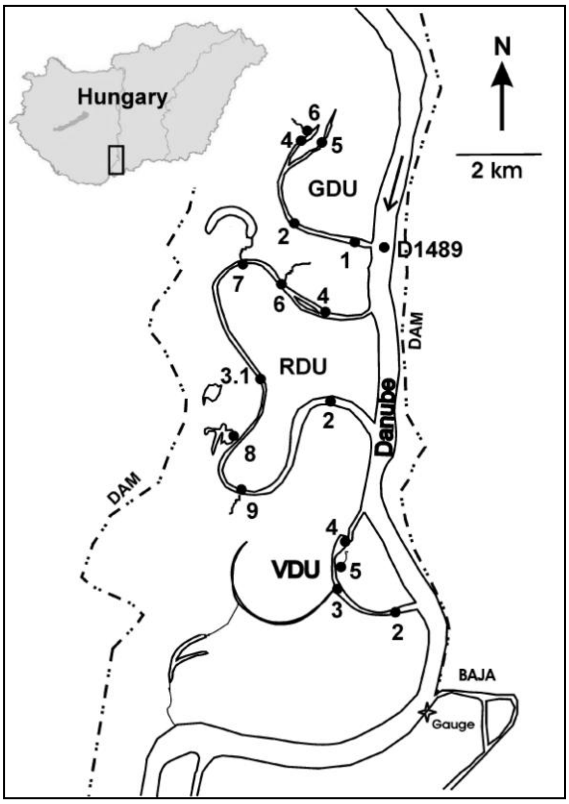

Figure 1. *The investigated area and the sampling sites*

The mean values and standard deviations of the water level during seven consecutive days prior to the sampling were taken into consideration to characterize the hydrological regime.

Table 1. *Characteristics and position of sampling sites*

	Site	GPS coordinates		Hydrological character
Eupotamal	*D1489*	N46º16.403’	E18º54.547’	the main arm, constant flow
Parapotamal	*RDU5*	N46º15.599’	E18º53.623’	15 km long side arm, mostly flowing
	RDU4	N46º16.015’	E18º53.645’	15 km long side arm, mostly flowing
	RDU3.1	N46º14.767’	E18º52.541’	15 km long side arm, mostly flowing
	RDU2	N46º14.224’	E18º53.192’	15 km long side arm, mostly flowing
	VDU4	N46º12.754’	E18º53.940’	5 km long side arm, constant flow
	VDU3	N46º12.118’	E18º53.843’	5 km long side arm, constant flow

	VDU2	N46º11.880’	E18º55.177’	5 km long side arm, constant flow
Plesiopotamal	*GDU1*	N46º16.495’	E18º54.104’	7 km long side arm, mostly stagnant water
	GDU2	N46º17.202’	E18º52.921’	7 km long side arm, mostly stagnant water
	GDU3	N46º17.451’	E18º55.610’	7 km long side arm, mostly stagnant water
	GDU4	N46º17.638’	E18º53.162’	7 km long side arm, mostly stagnant water
	GDU5	N46º17.641’	E18º53.261’	7 km long side arm, mostly stagnant water
Conjunctive water bodies	*VDU5*	N46º12.346’	E18º53.732’	small periodical inflow from the floodplain
	GDU6	N46º17.682’	E18º53.210’	small periodical inflow from the floodplain
	RDU6	N46º16.208’	E18º52.671’	small periodical inflow from the floodplain
	RDU7	N46º16.237’	E18º52.373’	small periodical inflow from the floodplain
	RDU8	N46º13.950’	E18º51.918’	stagnant, periodical floodplain water body
	RDU9	N46º13,412’	E18º51,967’	small periodical inflow from the floodplain

Water temperature (ºC), conductivity (μS cm^{-1}), pH, dissolved oxygen (mg l^{-1}) and oxygen saturation (%) were measured *in situ* with WTW Multi 340i or Hydrolog 2100 instruments (Grabner, Wien). Water samples were analyzed for NH_4-N, NO_3-N and PO_4-P with a Dionex DX-120 ion-chromatograph after filtration (Chromafil filter, 0.2 μm pore size). Clorophyll-a and suspended matter (SM) were determined by standard analytical methods (Golterman et al. 1978).

Zooplankton samples were concentrated by filtering 20 L (Rotifers) or 50 L (Crustacea) of water collected from the water surface through 40 μm (Rotifers) or 70 μm (Crustacea) mesh sized nets. After collection the samples were instantly preserved in a 4 % formaldehyde solution.

3 Results

On 23 May the water level in the main arm was 256 cm (Fig.2). The mean value of the previous 7 days was 275 ± 39.1 cm, while the hydrological regime was slowly decreasing, near stagnating. On 11 September the water level was 697 cm (higher than anytime during the previous week). The mean value of the previous 7 days was 398 ± 174.1 cm; thus the hydrological regime was strongly increasing. On 25 September the water level was 426 cm, while the mean value of the previous 7 days was 510 ± 94.3 cm; consequently the hydrological regime was steadily decreasing (Fig. 2).

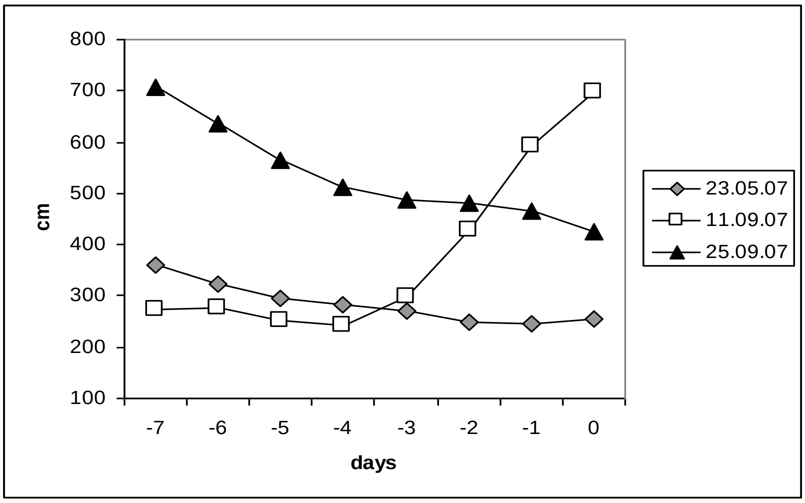

Figure 2. *Water level fluctuations in the main arm during seven days before the sampling date (zero)*

The patterns and differences in the physical-chemical characteristics and in the densities of the zooplankton assemblages depended on the hydrological regime.

On 23 May the temperature and ammonia and phosphate concentrations were lower in the main arm, while nitrate concentration was highest. Chlorophyll-a and SM concentrations were notably lower in the parapotamal side arms (Tab. 2). High differences occurred among the characteristics of sampling sites with identical hydrological character reflecting high habitat diversity. The densities of Rotifers and Cladocerans were highest in the parapotamal, while most Copepods occurred in the plesiopotamal. This can be explained by limiting low flow. In the eu- and parapotamal, where constant flow is typical, the zooplankton was dominated by Rotifers. In the plesiopotamal the longer water retention time favours biotic interactions among zooplankton groups leading to the dominance of Crustaceans (Schöll & Kiss 2008). At this time the conjunctive water bodies were dried out.

On 11 September, when water from the main arm flowed to the smaller water bodies of the floodplain, electric conductivity, oxygen concentration and pH were similar due to the short retention time (Tab. 2). However, the temperature increased, but the SM decreased with increasing distance from the main arm. The density of the three zooplankton groups was very low, with no notable differences between the sampling areas. The homogenizing effects of the flood reduce temporarily the habitat diversity and equalize the differences among zooplankton assemblages (Thomaz et al. 2007). In the whole floodplain the flowing water was more or less typically dominated by Rotifers, while Copepods and Cladocerans were virtually absent.

On 25 September the water flowed back from the floodplain to the direction of the side arms and the main arm. Water temperature and oxygen concentration were lowest, while conductivity was highest in the conjunctive water bodies, which can be caused by the longer retention time, which allows of getting on the local effects. The patterns of nutrient concentrations were mixed: maximum concentrations of ammonia and nitrate occurred in the main arm, maximum phosphate concentrations in the conjunctive water bodies. The chlorophyll-a concentrations were much higher in the plesiopotamal and conjunctive water bodies than in the eu- and parapotamal, while SM values were again highest in the main arm (Tab. 2). The densities of both Crustacean groups were highest in the conjunctive water bodies with longest retention time, but most Rotifers occurred in the plesiopotamal and dominated in all water bodies. The Copepoda/Cladocera ratio differed from the one observed during stagnant conditions on 23 May.

Table 2. *Physical-chemical characteristics and zooplankton densities in the different types of water bodies (SM-suspended matter, Cop-Copepoda, Clad-Cladocera, Rot-Rotifera)*

		T	Cond.	pH	O_2	Chl-a	SM	NH_4-N	NO_3-N	PO_4-P	Cop	Clad	Rot
		ºC	µScm^{-1}		mg l^{-1}	µg l^{-1}	mg l^{-1}	µg l^{-1}	mg l^{-1}	µg l^{-1}	ind/50L	ind/50L	ind/50L
23.05.07. 256 cm	Eupot.	21.0	379	8.3	13.6	91.0	33.4	60.3	1.14	0	22	2	3625
	Parapot.	25.1	359	8.5	14.3	53.0	17.7	78.2	0.65	2.86	18	201	30915
	Plesiopot.	25.1	463	8.0	13.1	95.0	31.1	317.7	0.26	16.0	710	56	1500
	Conj. w.	-	-	-	-	-	-	-	-	-	-	-	-
11.09.07. 697 cm	Eupot.	14.7	340	7.6	8.6	2.0	116.4	66.0	0.80	28.6	1	7	500
	Parapot.	15.1	349	7.5	8.4	4.5	72.4	58.8	0.72	32.2	1	3	730
	Plesiopot.	15.5	364	7.5	8.0	2.0	20.1	68.0	0.83	35.2	0.5	1	875
	Conj. w.	15.6	355	7.6	7.8	3.0	6.0	43.0	0.70	47.0	1	1	375
25.09.07. 426 cm	Eupot.	15.7	386	7.7	9.3	5.0	34.4	60.0	0.90	27.9	2	7	525
	Parapot.	16.2	391	7.5	9.2	8.8	15.5	51.6	0.97	27.8	7	21	3540
	Plesiopot.	16.0	397	8.0	10.4	55.0	11.7	8.0	0.17	5.0	4	65	8585
	Conj. w.	15.0	409	7.6	8.0	33.0	14.5	16.0	0.23	39.0	15	84	2750

4 Conclusions and outlook

The effects of the hydrological regime represent the fourth dimension (time) in lotic ecosystems, especially in a river-floodplain system (Ward 1989).

The physical-chemical characteristics of the floodplain water bodies are influenced by local effects (e.g. flow, connectivity with the main arm, nutrient release from sediments, autochthonous primary production), by the seasonal/meteorological effects (temperature, duration and intensity of sunlight, precipitation) and by the direct effects of the hydrological regime. During stagnant water levels the intensity of local effects is dictated by the hydrological connectivity (as a hydrological distance from the main arm). The patterns of zooplankton assemblages depended more or less on the local characteristics. During higher floods, the direct effects of the hydrological regime became significant. The homogenizing effect of flood temporarily eliminates the physical and chemical gradients and sweeps out the local zooplankton assemblages. After the flood local effects begin to dominate again. According to our hypothesis the water chemical characteristics changes more or less along a gradient from the main arm to the plesiopotamal, but the characteristics of conjunctive water bodies are more diverse. The suspended matter and nutrient concentrations are the highest in the main arm and the lowest in the plesiopotamal/remote water bodies. After the flood event the densities of zooplankton groups are lowest in the main arm and highest in the plesiopotamal/conjunctive water bodies, but in the stagnating period the more dense assemblages occurred in the parapotamal.

Research about the effects of high floods on floodplain water bodies and their biota calls for further, more detailed investigations (e.g. the detailed nutrient cycle of the river-floodplain system; the influence of hydrological connectivity on the spatial and temporal biodiversity patterns; the role of the floodplains as a source of biota for the main arm) as it addresses an important aspect of the river-floodplain system in terms of conservation, water use and water quality.

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