Opusc. Zool. Budapest, 2009, 40 (2): 87–98

Zooplankton (Cladocera, Copepoda) dynamics in the River Danube upstream and downstream of Budapest, Hungary

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Abstract. The spatial distribution and seasonal dynamics of zooplankton (Cladocera, Copepoda) were studied in the River Danube near Budapest, Hungary. The investigated river section was relatively poor in plankton, nauplii dominated. A total of 36 species was recorded of which *Acanthocyclops robustus, Thermocyclops crassus, Bosmina longirostris* were the most abundant. There was a downstream increase in copepod densities, however, no other remarkable differences could be observed between the profiles upstream and downstream of the capital. Generally, the streamline was characterized by lower densities and lower number of taxa as compared to the river bank; nevertheless, there were differences between the left and the right banks both upstream or downstream as well. Seasonal dynamics was defined by a marked late winter–spring aspect and abundance peaks were found to be characteristic for Danube with high densities in May–June and August–September. Examining the relationship between zooplankton density and the hydrological regime, it can be concluded that zooplankton production in the main channel is of minor importance, rather floodplain areas and adjacent water bodies seem to be important sources of plankton biomass.

River Danube, as being the most species rich river in the Palaearctic (Naidenow, 1998), is entitled to great interest, so the research of its plankton means a crucial challenge. The first investigations on the zooplankton of the Hungarian section of the River Danube started in the 1910s with crustaceans (Kottász, 1913; Jungmayer, 1914; Unger, 1916) and continued in the middle of the century (Woynárovich, 1944; Éber, 1955; Ponyi, 1962) mainly with descriptive works. Nevertheless, these studies served as a basis for further research. Dudich (1967) gave detailed information about the fauna of the river Danube. Bothár has broken new ground in the studies of riverine plankton since the 1960s. With research among others on the sampling strategies (Bothár, 1996), on the long-term status of planktonic crustaceans at the area of Göd (Bothár, 1968, 1972, 1988a, 1994, 1996) and on the crustacean plankton near Budapest (Bothár, 1978, 1988b), she has made a major contribution to our better understanding of zooplankton in the River Danube.

In the 1970s and particularly in the 1980s crustacean abundance increased notably, which was best professed by the abundance peaks in summer. The change in species composition and individual numbers implied eutrophication in Danube. However, the hydrological regime has changed as well, which may influence zooplankton assemblages both qualitatively and quantitatively (Bothár, 1985). Towards the estuary, crustacean density increased by 25 fold within the 417 km long Hungarian river section (Bothár, 1988 a). The third period of the Danube plankton research began in the 1990s with the studies of Gulyás (1994, 1995, 1997, 2002) who has extended the research to rotifers. Rotifers dominated the plankton, only copepodites and nauplii were represented in similar abundance.

The most frequent species were characteristic of eutrophicated stagnant waters and rivers of low current velocity (Gulyás, 1994, 1995, 2002). Large abundance of some species and the downstream increase of zooplankton abundance implied increasing eutrophication in the river (Gulyás, 1995). Biomass values measured upstream and downstream of Budapest (near Budapest) were similar, then increased southwards (Gulyás, 1997).

Although numerous studies have been conducted on the zooplankton in the River Danube, relatively little emphasis was put on the transversal distribution of plankton (Bothár, 1978, 1985; Naidenow, 1971, 1979). On the other hand, de-

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tailed surveys have been performed on the horizontal distribution of zooplankton along the river (Bothár, 1973, 1982, 1988 a; Gulyás, 2002; Pujin 1990; Naidenow & Schewzowa, 1990, 1991).

The objectives of this study were (1) to get a comprehensive picture of the crustacean plankton near Budapest, (2) to describe the community structure both from qualitative and quantitative points of view, (3) to present the spatial and temporal changes of microcrustacean plankton considering the hydrological regime as a possible driving force.

MATERIALS AND METHODS

Study sites

River Danube is the second longest river in Europe, it is more than 2800 km long with a catchment area of 817,000 km^2. The Hungarian section occupies 417 km. The middle section is 377 km long and has a relatively balanced hydrological regime, which is controlled by the water discharge of the upper section. In the middle section, current velocity ranges between 0.8–1.2 m sec^{-1} in the upper layers, which can reach the values of 2–2.5 m sec^{-1} during flooding events. The water level fluctuation takes 5–8 m, discharge values range from 500 (low water period) to 6000–8000 (flood) m^3 s^{-1}. The shoreline is mostly regulated, rip-rap is characteristic of this section.

The present study was conducted in the main channel of the River Danube at two profiles upstream and downstream of Budapest (Újpest–-Békásmegyer, 1657 rkm and Tököl–Százhalombatta, 1623 rkm) (Fig. 1). The general characteristics of the two profiles are similar, but the sampling site of Tököl–Százhalombatta is characterized by gravel banks interrupted occasionally with rip-rap, whereas in the profile of Újpest–Békásmegyer rip-rap is the main component. There was no macrovegetation either at the upstrem or at the downstream profile throughout the years. The sampling point of Békásmegyer is situated in the downstream section of the Danube arm of Szentendre, near to the estuary into the main channel.

The study sites were designated on the basis of our objectives, i.e. possibilities for transversal sampling (ferry), and sampling profiles upstream and downstream of Budapest.

Sampling and data analysis

Samples were collected at biweekly intervals from October 2006 to September 2008 at two sampling profiles each containing three sampling sites (stream line, left bank and right bank). Samples taken at the river bank were performed at water depth of some 1–2 metres. During the winter period (between December and February) zooplankton was sampled monthly. 100 litres of water were taken from the surface water layer (upper 50 cm water column) and filtered through a plankton net (50 μm mesh size). The material collected was preserved *in situ* in 4% formaldehyde solution. A total of 270 samples were collected and analysed. Nauplii were counted in 5 ml subsamples in special counting chambers after homogenization. For the taxonomic determination of the animals identification keys by Gulyás and Forró (1999, 2001), Einsle (1993), Amoros (1984) and Dussart (1969) were used. Copepods and cladocerans were identified to species level, however, copepods belonging to the suborder Harpacticoida and ostracods were only counted.

Water temperature was measured *in situ* whereas conductivity was measured in laboratory. Water discharge and water level data (1645.5 rkm) were obtained from the Environmental and Water Research Institute („VITUKI”). Water residence time was calculated with the formula:

$$R = 0.08A_d^{0.6}/Q^{0.1}$$

where R is the residence time at the sampling site (days), A_d watershed area upstream of the sampling site (km^2), and Q river discharge (m^3 s^{-1}) (Soballe & Kimmel, 1987). We used the discharge data measured at Budapest (1646.5 rkm). In order to explore the temporal patterns, cluster analysis and non-metric multidimensional scaling (NMDS) using the Euclidean distance were performed (with standardized data).

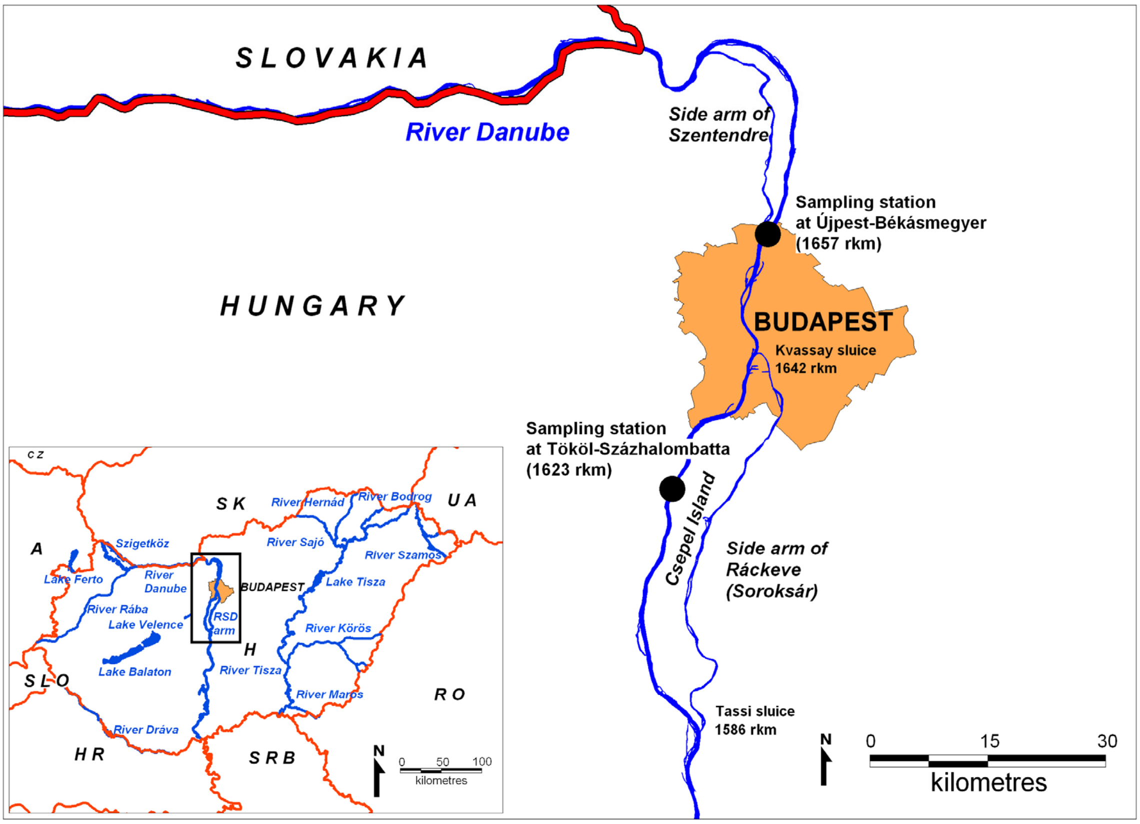
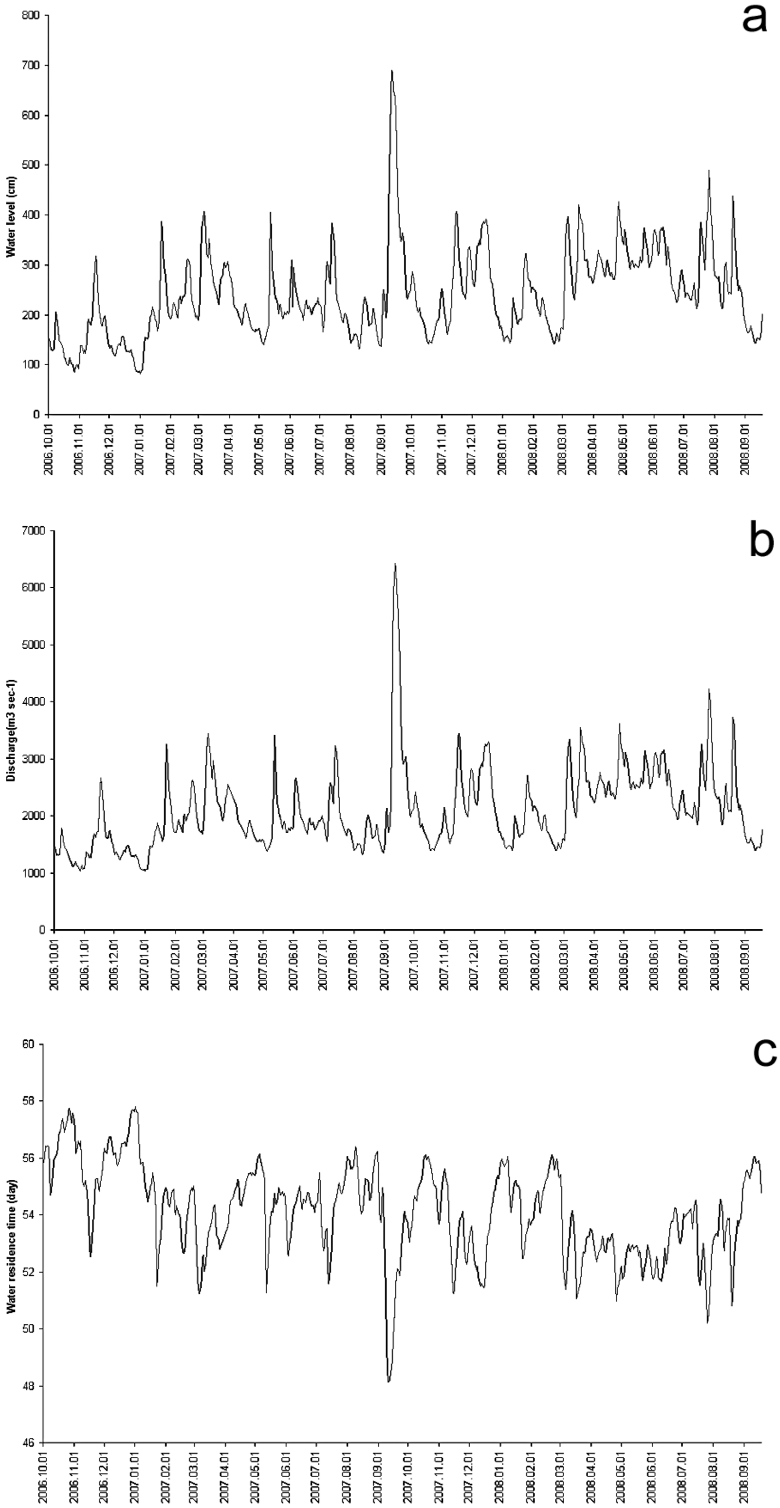


Figure 1. The study area and the sampling sites (●)

Correspondence analysis was applied to demonstrate the relationship between species and sampling sites, that is certain species seem to be more abundant at a definite sampling site. Diversity t-test is a useful tool to compare the diversities of the sampling sites by calculating the Shannon diversity of each sampling site and comparing the diversities statistically. Linear correlation was used to detect any significant association between some environmental variables and zooplankton community. When necessary, data were transformed (log, square root) to obtain the normal distribution. Significant differences were identified at $p < 0.05$. All data analyses were performed using the PAST program (Hammer *et al.*, 2001).

RESULTS

During the study period, water level varied between 83 and 689 cm-s, maxima were recorded in September of 2007. This marked peak was two times higher than other peaks. Low water level occurred in the year of 2006, whereas relatively high water level persisted in spring and summer of 2008. Discharge values (ranged between 1030 and 6420 m^3 sec^{-1}) strongly followed this pattern. Despite some deviations, the annual discharge pattern typical of river systems in the temperate region was observed with low water period in autumn and winter, and discharge peaks in early and late spring. Water residence time ranged between 48 and 58 days (Figs. 2 a–d). Water



Figures 2 a–c. Hydrological parameters recorded during the study period. a = water level, b = discharge, c = water residence time

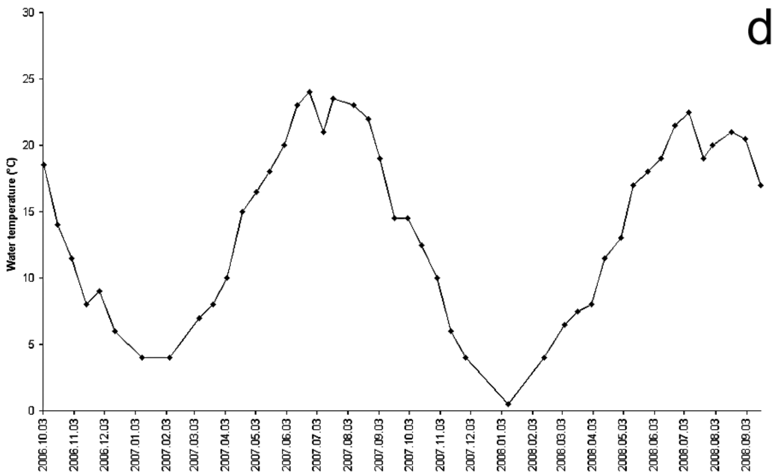


Figure 2 d. Water temperature recorded during the study period

temperatures showed typical annual cycle, maximum values were observed in June–August (23–24°C) and minimum in January (0.5 °C). There was a negative relationship between water level and conductivity both upstream ($r = 0.40$; $p = 0.0073$) and downstream ($r = 0.38$; $p = 0.0118$) of Budapest over the study period.

A total of 36 species were observed of which 11 belonged to copepods and 25 to cladocerans (Table 1). *Diacyclops crassicaudis* was recorded for the first time in the Hungarian section of the River Danube. The occurrence of *Diaphanosoma mongolianum* in the main channel of the Danube is new, as it was only reported from the Szigetköz backwaters and few water bodies respectively (Gulyás & Forró, 1999). Frequent species included *Acanthocyclops robustus, Thermocyclops crassus, Bosmina longirostris, Alona rectangula, Chydorus sphaericus*, moreover harpacticoid copepods were also determining. The species number in the streamline was similar upstream and downstream (17–16 species), 10 common species were recorded. The distribution of the species number within the sampling profile was more dispersed downstream with a maximum of 30 species detected at Tököl. The relative abundance of nauplii was mostly greater than that of other zooplankton groups, whereas adult copepods and copepodites were represented in similar abundances. Cladocerans contributed up to 19.5% of the total density upstream of Budapest and 18.1% downstream, respectively.

The percentage compositions of the zooplankton community upstrem and downstream of the capital are presented in Figs. 3–4. There is evidence of a remarkable downstream increase in copepod densities meaning that adult copepod densities became doubled and copepodit densities increased by 18%. This phenomenon is mainly due to the fact that the relative contribution of *Thermocyclops crassus* increased considerably at the downstream profile, although calanoid densities increased as well. Such notable longitudinal differences cannot be seen either in cladoceran community composition, or in nauplii.

Generally, the streamline was characterized by lower individual numbers and lower number of taxa in comparison with the river bank (Table 2), however, there were also differences between the left and the right banks both upstream or downstream of Budapest. Average densities ranged between 5.08 and 12.96 ind./100 litres, whereas maximum density reached 87 ind./100 litres at Békásmegyer. Note that nauplii densities are included as well, these results suggest that the river is poor in planktonic crustaceans. Regarding diversities it seemed to be essential to present the

Table 1. Zooplankton taxa recorded in the River Danube (October 2006 to September 2008) and their codes. Abbreviations: B: Békásmegyer (right bank); UBS: Újpest–Békásmegyer streamline; U: Újpest (left bank); Sz: Százhalombatta (right bank); TSzS: Tököl–Százhalombatta streamline; T: Tököl (left bank)

Taxa	**Code**	**B**			**UBS**			**U**			**Sz**			**TSzS**			**T**		
		06	07	08	06	07	08	06	07	08	06	07	08	06	07	08	06	07	08
CLADOCERA																			
Alona affinis (Leydig, 1860)	Aaff			+						+						+			+
Alona guttata Sars, 1862	Agut		+															+	
Alona intermedia Sars, 1862	Aint		+																
Alona quadrangularis (O. F. Müller, 1785)	Aqua	+	+			+			+	+		+	+					+	
Alona rectangula Sars, 1862	Arec	+	+	+	+	+			+			+	+	+		+		+	
Bosmina coregoni Baird, 1857	Bcor																		+
Bosmina longirostris (O. F. Müller, 1785)	Blon		+	+	+	+	+		+	+		+	+		+	+		+	+
Chydorus sphaericus (O. F. Müller, 1776)	Csph	+		+		+	+	+	+	+			+		+	+			+
Daphnia cucullata Sars, 1862	Dcuc		+			+	+		+	+		+	+		+	+	+	+	+
Daphnia longispina O. F. Müller, 1785	Dlon		+			+			+						+				+
Diaphanosoma brachyurum (Liévin, 1848)	Dbra		+						+										
Diaphanosoma mongolianum Uéno, 1938	Dmon												+						+
Disparalona rostrata (Koch, 1841)	Dros						+		+	+			+						+
Graptoleberis testudinaria (Fischer, 1848)	Gtes		+																
Iliocryptus sordidus (Liévin, 1848)	Isor			+						+		+	+		+				+
Leydigia acanthocercoides (Fischer, 1854)	Laca																	+	
Leydigia leydigi (Schoedler, 1863)	Lley								+			+							+
Macrothrix hirsuticornis Norman & Brady, 1867	Mhir			+					+	+		+	+			+			+
Macrothrix laticornis (Fischer, 1848)	Mlat								+									+	
Moina macrocopa (Straus, 1820)	Mmac		+						+										
Moina micrura Kurz, 1874	Mmic		+			+	+		+			+	+					+	+
Pleuroxus aduncus (Jurine, 1820)	Padu											+						+	
Scapholeberis mucronata (O. F. Müller, 1785)	Smuc		+				+			+						+			
Sida crystallina (O. F. Müller, 1776)	Scry																	+	
Simocephalus vetulus (O. F. Müller, 1776)	Svet		+																
COPEPODA																			
CALANOIDA																			
Eudiaptomus gracilis (Sars, 1863)	Egrac					+							+					+	+
Eurytemora velox (Lilljeborg, 1853)	Evel		+						+	+		+	+		+	+		+	+
CYCLOPOIDA																			
Acanthocyclops robustus (Sars, 1863)	Arob		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Acanthocyclops vernalis (Fischer, 1853)	Aver														+				
Cyclops strenuus Fischer, 1851	Cstr									+	+	+						+	+
Cyclops vicinus Uljanin, 1875	Cvic			+			+			+									+
Diacyclops crassicaudis (Sars 1863)	Dcra						+												
Eucyclops serrulatus (Fischer, 1851)	Eser		+	+		+	+			+		+	+			+		+	
Mesocyclops leuckarti (Claus, 1857)	Mleu		+																+
Paracyclops fimbriatus (Fischer, 1853)	Pfim		+				+		+	+								+	
Thermocyclops crassus (Fischer, 1853)	Tcra		+	+		+	+		+	+	+	+	+		+	+		+	+
HARPACTICOIDA	Har	+	+	+		+	+	+	+	+	+	+	+		+	+	+	+	+
OSTRACODA	Ost		+						+	+						+		+	

Table 2. Major ecological parameters of the zooplankton community (n = 44). Density data include nauplii as well. For the abbreviations of the sampling sites see Table 1

Sampling site	B	UBS	U	Sz	TSzS	T
Average density (ind./100L)	8,48	6,80	9,82	9,17	5,08	12,96
Maximum density (ind./100L)	87,00	49,00	43,00	46,00	22,00	60,00
Taxa S	26,00	17,00	25,00	19,00	16,00	30,00
Dominance D	0,23	0,13	0,08	0,11	0,13	0,14
Shannon H	2,21	2,31	2,83	2,52	2,32	2,48
Evenness e^H/S	0,35	0,59	0,68	0,66	0,64	0,40
Berger-Parker	0,45	0,26	0,16	0,19	0,21	0,25

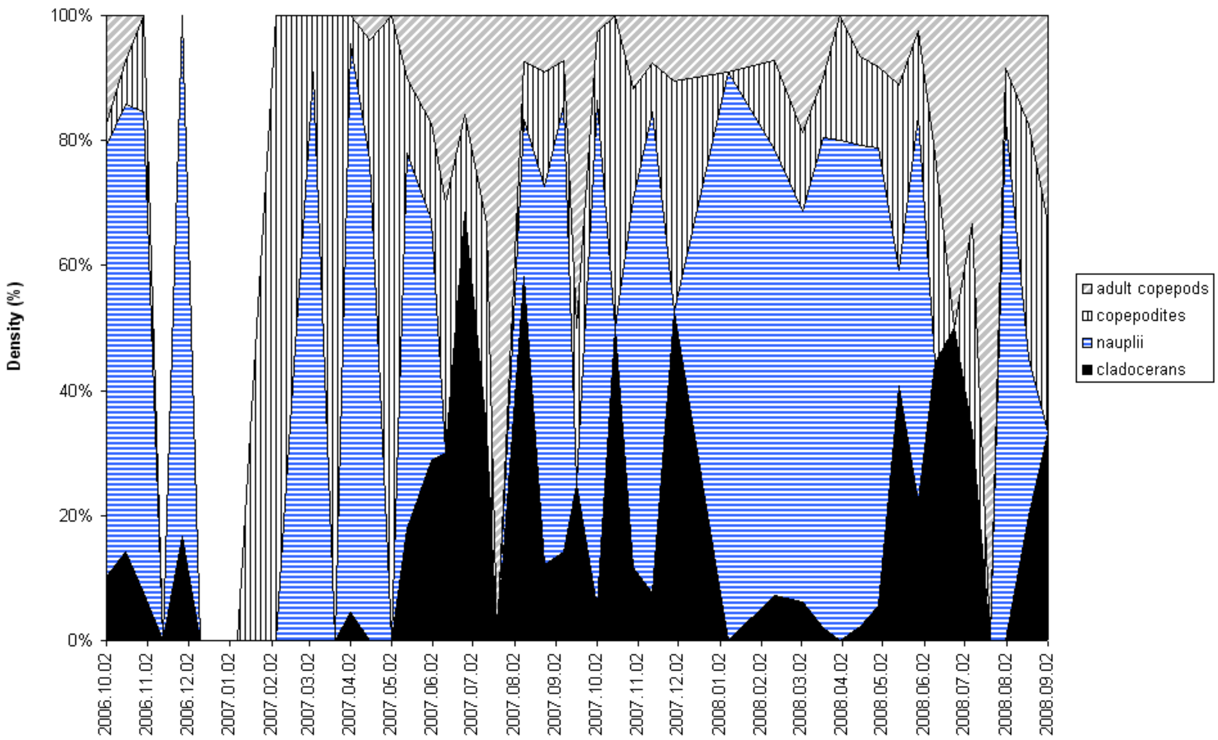


Figure 3. The percentage composition of the zooplankton community upstream Budapest. Results include data obtained from the streamline, left and right river banks (summed)

results of two different diversity indices. Shannon diversity values ranged within a relatively close interval (2.21–2.83), highest diversity and eveness values were measured at Újpest. Berger–Parker diversity peaked at Békásmegyer where the Shannon diversity was the lowest, which is due to the dominance of some species (dominance D = 0.23). Based on the diversity t-test, sampling station Újpest (U) differed significantly from the others (U-B: $t = 3.89$, $p<0.001$, U-UBS: $t = 3.77$, $p<0.001$, U-Sz: $t = 2.29$, $p = 0.02318$, U-TSzS: $t = 3.68$, $p<0.001$, U-T: $t = 2.54$, $p = 0.0156$). One more significant difference included Békásmegyer–Százhalombatta ($t = 2.32$, $p = 0.0214$).

The correspondence analysis (Fig. 5) suggests that the sampling site Békásmegyer, which is situated in the side arm of Szentendre, has specific features. The high individual numbers of *Moina micrura* and the presence of *Simocephalus vetulus, Alona guttata, Mesocyclops leuckarti, Graptoleberis testudinaria* are responsible for its separation. The sampling site Újpest (U) is also determined by the presence of several taxa. The sampling profile downstream of Budapest seems to form one group, although the sampling site Tököl (T) has some characteristic elements, e. g. *Bosmina coregoni, Sida crystallina* and it is dominated by *Thermocyclops crassus*.

Examining the temporal patterns of the zooplankton assemblage, no clear trajectory could be detected, however, there was a marked late winter-spring aspect (marked) with great similarities among samples. Samples taken in summer and autumn form a second group, but are far more dispersed (Fig. 6). Species number was low during the winter and increased in late spring, then remained relatively high during the summer months and decreased in autumn. Total abundance, however, peaked in spring of 2008 and in summer of 2007. The seasonal dynamics can be characterized by two population peaks within the year, the first in May–June, the second in August–September.

The seasonal patterns were similar between the upstream and downstream sections, with a positive correlation of the zooplankton community density between the two sampling profiles over the study period ($r = 0.58$; $p<0.001$). A strong positive correlation was detected between water temperature and zooplankton density at Tököl-Százhalombatta ($r = 0.35$; $p = 0.0178$), but not at Újpest-Békásmegyer, however, zooplankton density without nauplii was positively related to water temperature ($r = 0.42$; $p = 0.004$). Zooplankton density (without nauplii) was positively correlated with water level ($r = 0.32$; $p = 0.0303$) and discharge ($r = 0.32$; $p = 0.0307$) and negatively correlated with water residence time ($r = 0.32$; $p = 0.0305$) at the upstream section. However, these relationships were not significant at the downstream profile.

DISCUSSION

The time available for zooplankton to develop was esimated at 48–58 days (an estimate of the time the water has been in the river system) assuming that plankton drifts with the current passively. During this time 5 generations of cladocerans and 1 or 2 generations of copepods may develop (Naidenow, 1998). The growth is supposed to depend on the hydrological regime (increased residence time favours zooplankton, that is zooplankton benefits from low water velocity). This is not only due to the mechanical effect of the drift, but it is connected with the fact, that suspended matters have a negative impact on planktonic crustaceans (Zsuga *et al*., 2004; Gulyás, 2002;). However, we have found a negative relationship between water residence time and zooplankton density and a positive relationship between water discharge and zooplankton density, which strongly suggests that zooplankton production in the main channel is of minor importance, which is consistent with the findings of Reckendorfer *et al*. (1999). Floodplain areas and adjacent water bodies seem to be rather important sources of plankton biomass (Saunders & Lewis, 1989; Naidenow 1998; Schiemer *et al*. 2001; Zsuga *et al*., 2004). The positive correlation of zooplankton density with water level also seems to support this hypothesis. According to Reckendorfer *et al*. (1999), the physical interaction of flow regime and river margin morphology determines the availability of inshore storage zones and the rate at which plankton are added to the main river channel.

The dominant species that were found in the present study in the main channel (*Acanthocyclops robustus, Bosmina longirostris*) are consistent with the findings of Bothár (1985, 1988 b, 1994) and Gulyás (1994, 1995, 2002), however, the relatively large contributions of *Thermocyclops crassus* and Harpacticoida are new. Two thermophyl species, *Thermocyclops crassus* and *Moina micrura* are reported to become abundant in the River Danube since 1971 (Bothár, 1975), but they were regarded only as secondary species at Göd (rkm 1669) (Bothár, 1985). The relatively

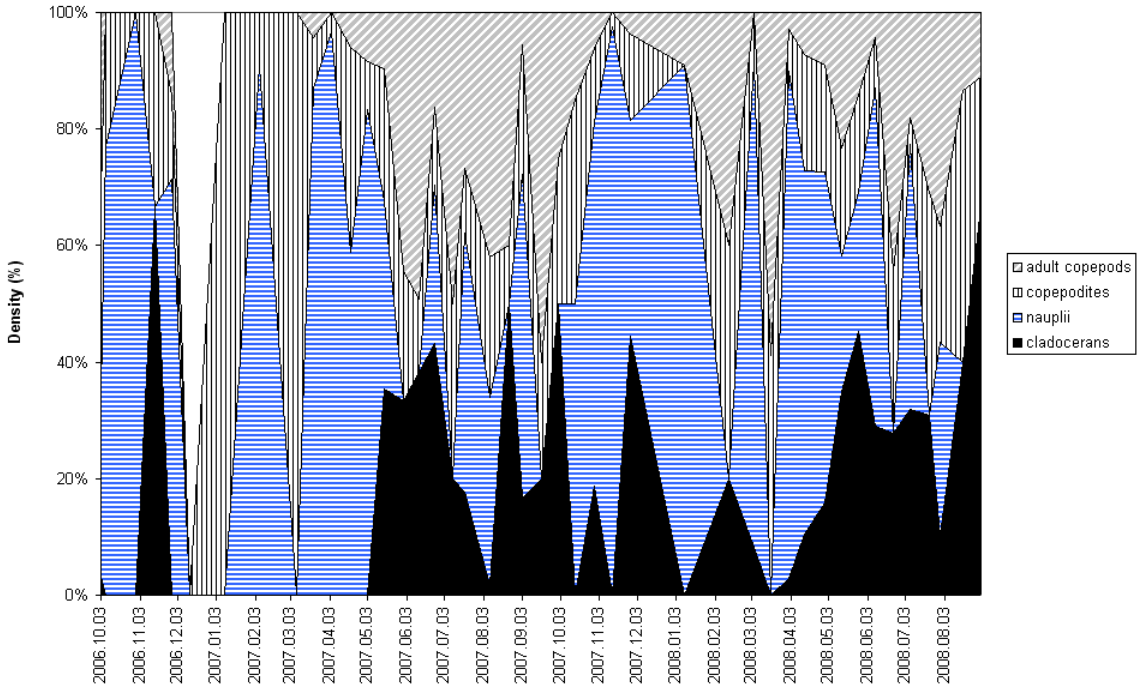


Figure 4. The percentage composition of the zooplankton community downstream Budapest. Results include data obtained from the streamline, left and right river banks (summed)

large frequency and abundance of *Thermocyclops crassus* may be related to the changing hydrological regime and increased temperature. Beyond the above-mentioned, there is no evidence of any significant long-term changes in species composition. The population peaks observed in the present study (May–June, August–September) are in line with the results of Bothár (1985, 1978), Bothár and Kiss (1990) and Gulyás (1995). Regarding densities, the examined river stretch was poor in plankton, the individual numbers were similar to the findings of Bothár *et al*. (1971) and Bothár (1978) at Újpest–Békásmegyer in the 1970s, at Adony (1598 rkm) in the 1980s (Bothár, 1988b), but not to that of Göd (Bothár, 1994). In quantitative aspect, contrasting my results to that of Gulyás (1994, 1995, 1997) is not meaningful since the author presented the overall densities (with rotifers).

There were no remarkable differences between the upstream and downstream sections, only copepod density increased downstream. This does not support the hypothesis that municipal and industrial wastewaters of the capital may create significant impact on zooplankton assemblages downstream Budapest. Bothár (1988) has observed lower maximum densities and different seasonal dynamics patterns downstream of Budapest. According to the author, these differences can be explained by the effects of wastewaters and changed stream conditions due to the regulated river bed and the side arm of Szentendre. Nevertheless, Gulyás (1997) has not found any remarkable differences between the upstream and downstream sections. Although the examined river stretch is poor in planktonic crustaceans, the recorded species and their contributions to the total density suggest that the river has a moderately rich fauna with several tichoplanktonic elements. The latter also implies for the significance of inshore storage zones.

The spatial distribution of zooplankton across the river was not equal, the streamline was characterized with lower densities and lower number

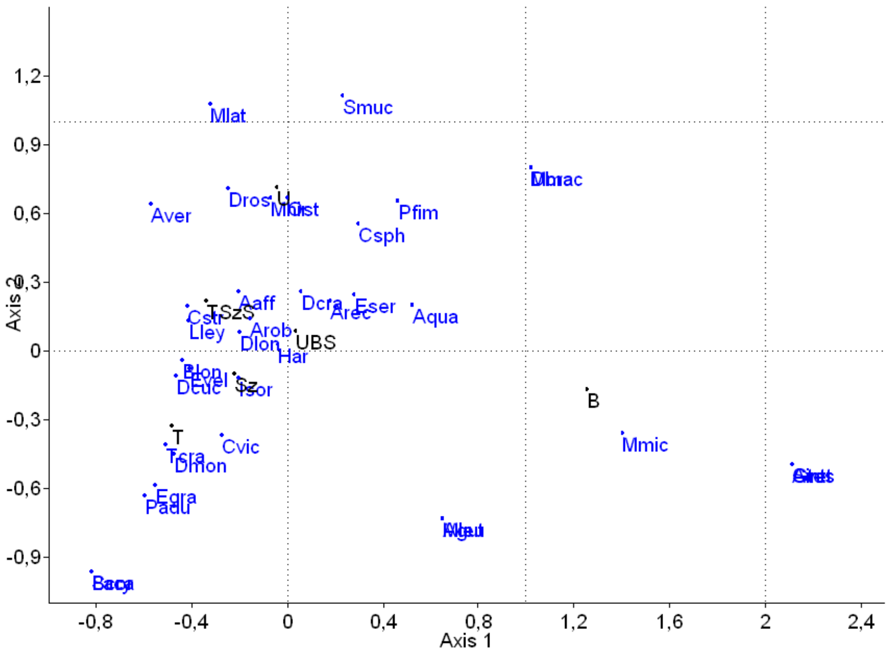


Figure 5. Biplot of the correspondence analysis. Codes of the taxa are presented in Table 1. Abbreviations of the sampling sites: B-Békásmegyer; UBS-Újpest-Békásmegyer streamline; U-Újpest; Sz-Százhalombatta; TSzS-Tököl-Százhalombatta streamline; T-Tököl

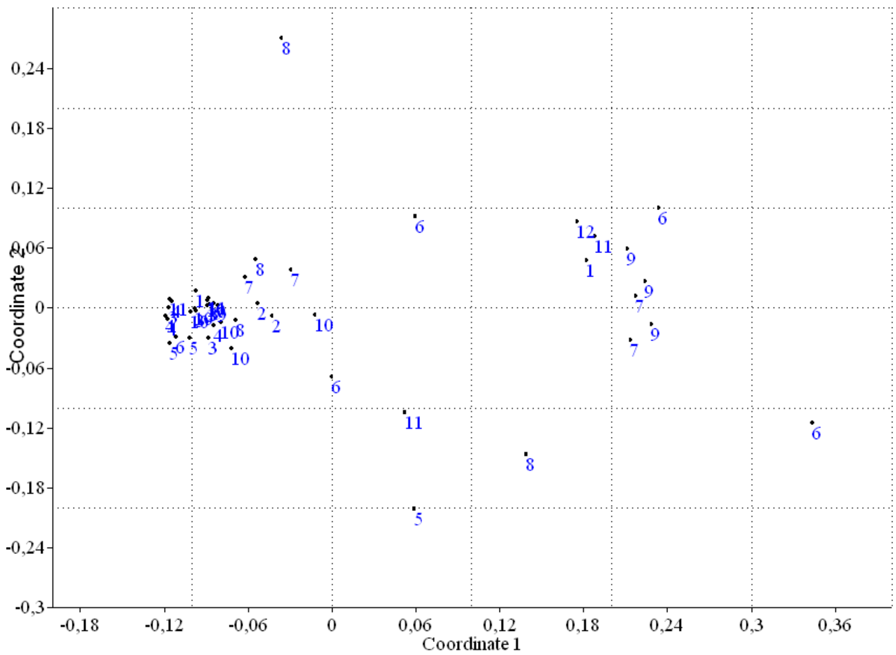


Figure 6. NMDS plot of the samples. Numbers represent the months: 1-January; 2-February etc.

of taxa. Similarly, densities were often found to be higher nearshore (Bothár, 1978, 1985; Thorp *et al*., 1994; Mitsuka & Henry, 2002).

In summary, my results pointed out the evidence of spatial heterogeneity across the river, however, save adult copepods no major difference was detected between the upstream and downstream sampling profiles. The author stresses the importance of adjacent lentic areas as sources of planktonic crustaceans.

Acknowledgements. I am indepted to Árpád Berczik, Katalin Bodolai, Mária Dinka, Levente Hufnagel, György Jablonszky and Katalin Zsuga for their help. I thank the crews of the ferries of Tököl–Százhalombatta and Újpest–Békásmegyer for their assistance in sampling. Finally, I am grateful for support of the Environmental and Water Research Institute (VITUKI).

REFERENCES

AMOROS, C. (1984): Crustacées cladocères. Introduction pratique à la systématique des organismes des eaux continentales françaises. *Bulletin Mensuel de la Société Linnéenne de Lyon*, 53: 1–63.

BOTHÁR, A. (1968): Untersuchungen des Donauplanktons an Entomostraca während der grossen Überschwemmung im Jahre 1965. Danubialia Hungarica XLVIII. *Annales Universitatis Scientiarum Budapestinensis Sectio Biologica*, 9-10: 87–98.

BOTHÁR, A. (1972): Hydrobiologische Untersuchungen im Nebenarm der Donau bei Göd. Danubialia Hungarica LXII. *Annales Universitatis Scientiarum Budapestinensis Sectio Biologica,* 13: 9–23.

BOTHÁR, A. (1973): Planktologische Ergebnisse einer Studienreise an der Donau zwischen Budapest und Turnu Severin. *16. Arbeitstagung der IAD, Bratislava, p. 9.*

BOTHÁR, A. (1975): Die Änderungen der Crustacea-Gemeinschaften des Planktons aufgrund der im Donauabschnitt von Göd (Stromkm 1669) durchgeführten Untersuchungen. Danubialia Hungarica LXXVIII. *Annales Universitatis Scientiarum Budapestinensis Sectio Biologica,* 17: 137–146.

BOTHÁR, A. (1978): Crustacea-Planktonuntersuchungen im Donauabschnitt zwischen Szob und Nagymaros (Stromkm 1707–1656). Danubialia Hungarica LXXXVIII. *Annales Universitatis Scientiarum Budapestinensis Sectio Biologica,* 20-21: 249–259.

BOTHÁR, A. (1982): Die Entwicklung des Zooplanktons und –benthos unter dem Einfluss des Abwassers. *Schweizerische Zeitschrift für Hydrologie*, 44 (2): 230-242.

BOTHÁR, A. (1985): Die qualitative und quantitative Verbreitung der planktonischen Crustaceen im ungarischen Donauabschnitt von 1965–1985. 25. Arbeitstagung der IAD, Bratislava, *Wissenschaftliche Kurzreferate*: 283–287.

BOTHÁR, A. (1988a): Results of long-term zooplankton investigations in the River Danube, Hungary. *Verhandlung Internationale Vereinigung Limnologie,* 23: 1340–1343.

BOTHÁR, A. (1988b): Quantitative und qualitative Zooplanktonuntersuchungen im Donauabschnitt oberhalb und unterhalb von Budapest I. J. 1987. 27. Arbeitstagung der IAD, Mamaia/Romania, *Wissenschaftliche Kurzreferate*: 179–182.

BOTHÁR, A. (1994): Qualitative und quantitative Planktonuntersuchungen in der Donau bei Göd/ Ungarn (1669 Stromkm) II. Zooplankton. 30. Arbeitstagung der IAD, Zuoz/Schweiz, *Wissenschaftliche Kurzreferate*: 41–44.

BOTHÁR, A. (1996): Die lang- und kurzfristigen Änderungen in der Gestaltung des Zooplanktons (Cladocera, Copepoda) der Donau – Probeentnahmestrategien. *Limnologische Berichte Donau* 1996. Band 1., 201–206.

BOTHÁR, A., DVIHALLY, ZS. T., KOZMA, E. V. (1971): Hydrobiologische Untersuchungen im Donauabschnitt zwischen Nagymaros und Megyer (Stromkm 1695–1656). Danubialia Hungarica, LVII. *Annales Universitatis Scientiarum Budapestinensis Sectio Biologica*, 3: 5–18.

BOTHÁR, A., KISS, K. T. (1990): Phytoplankton and Zooplankton (Cladocera, Copepoda) relationship in the eutrophicated river Danube. Danubialia Hungarica CXI. *Hydrobiologia*, 191: 165–171.

DUDICH, E. (1967): Systematisches Verzeichnis der Tierwelt der Donau mit einer zusammenfassenden Erläuterung. In: Liepolt, R. (ed.): Limnologie der Donau, 3: 4–69. *Stuttgart.*

DUSSART, B. (1969): *Les Copepodes des Eaux Continentales II: Cyclopoides et Biologie.* Ed. *N. Boubee & Cie, Paris*, pp. 292.

ÉBER, Z. (1955): Plankton of the rivers in the Carpathian Basin. (In Hungarian). *Hidrológiai Közlöny*, 35 (1-2): 66–72.

EINSLE, U. (1993): *Crustacea, Copepoda: Calanoida und Cyclopoida.* In: Schwoerbel, J & P. Zwick (eds): Süsswasserfauna von Mitteleuropa, Bd. 8, Heft 4, Teil 1, *Gustav Fischer Verlag, Stuttgart,* pp. 208.

GULYÁS, P. (1994): Studies on the rotatorian and crustacean plankton in the Hungarian section of the

Danube between 1848,4 and 1659,0 riv. km. In: Kinzelbach, R. (ed.): Biologie der Donau. *Gustav Fischer, Stuttgart*, pp. 49–61.

GULYÁS, P. (1995): Rotatoria and Crustacea plankton of the River Danube between Bratislava and Budapest. *Miscellanea Zoologica Hungarica*, 10: 7–19.

GULYÁS, P. (1997): Untersuchungen des Rotatoria- und Crustacea-Planktons an der Donaustrecke unterhalb Budapest sowie im Donauarm Ráckevei-Soroksári Duna (RSD). 32. Arbeitstagung der IAD, Wien/Österreich, *Wissenschaftliche Referate* 1: 265–270.

GULYÁS, P. (2002): Qualitative and quantitative investigations of Rotatoria and Crustacea plankton in the River Danube. (In Hungarian.) *Vízügyi Közlemények,* 84: 601–620.

GULYÁS, P., FORRÓ, L. (1999): Identification key for Cladocera (In Hungarian), 2nd edition. Vízi Természet- és Környezetvédelem, 9. kötet, *Környezetgazdálkodási Intézet*, pp. 237.

GULYÁS, P., FORRÓ, L. (2001): *Identification key for Copepoda (suborders Calanoida and Cyclopoida). (In Hungarian), 2nd edition..* Vízi Természet- és Környezetvédelem, 14. kötet, *Környezetgazdálkodási Intézet*, pp. 198.

HAMMER, O., HARPER, D. A. T., RYAN, P. D. (2001): PAST: Paleontological statistics software package for education and data analysis. *Paleontologia Electronica*, 4 (1): 1–9.

JUNGMAYER, M. (1914): Free living copepods of Budapest and its region. *Mathematikai–Természettudományi Közlemények*, 33: 1–156.

KOTTÁSZ, J. (1913): Cladocerans of the region of Budapest. *Állattani Közlemények*, 12 (2): 73–104.

MITSUKA, P. M., HENRY, R. (2002): The fate of copepod populations in the Paranapanema River (São Paulo, Brazil), downstream from the Jurumirim dam. *Brazilian Archives of Biology and Technology,* 45: 479–490.

NAIDENOW, W. (1971): Zustand und Perspektiven der Untersuchungen über das Zooplankton der Donau, ihrer Nebenflüsse und der stehenden Gewässer. *Schweizerische Zeitschrift für Hydrologie,* 33: 314–321.

NAIDENOW, W. (1979): Ein Beitrag zur Kenntnis des Zooplanktons der ungarischen Donau. *Hidrobiologiya,* 9: 38–43.

NAIDENOW, W. (1998): Das Zooplankton der Donau. In: Kusel-Fetzmann, E., Naidenow, W., Russev, B. (ed.): Plankton und Benthos der Donau, Ergebnisse der Donau-Forschung, *Wien*, Band 4, pp. 163–248.

NAIDENOW, W., SCHEWZOWA, L. (1990): Die Verteilung des Metazooplanktons der Donau von Str.-km 20 bis Str.-km 1928 im März 1988. Ergebnisse der Donauexpedition 1988. *Eigenverlag der IAD, Wien*, pp. 181–189.

NAIDENOW, W., SCHEWZOWA, L. (1991): Über die Verteilung des Metazoenplanktons der Donau zwischen Str. km 20 und 1928. *Hydrobiology* (Sofia), 37: 15-23.

PONYI, E. (1962): Beiträge zur Kenntnis des Crustaceen-Planktons der ungarischen Donau. Danubialia Hungarica XIV. *Opuscula Zoologica Budapest,* 4 (2-4): 127–132.

PUJIN, V. (1990): Zur Kenntnis des Donauplanktons aufgrund der Untersuchung bei der Internationalen Donauexpedition 1988. Ergebnisse der Donauexpedition 1988, *Eigenverlag der IAD, Wien*, pp. 199–201.

RECKENDORFER, W., KECKEIS, H., WINKLER, G., SCHIEMER, F. (1999): Zooplankton abundance in the River Danube, Austria: the significance of inshore retention. *Freshwater Biology,* 41: 583–591.

SAUNDERS, J. F., LEWIS, W. M. (1989): Zooplankton abundance in the lower Orinoco River, Venezuela. *Limnology and Oceanography*, 34: 397–409.

SCHIEMER, F., KECKEIS, H., RECKENDORFER, W., WINKLER, G. (2001): The „inshore retention concept"and its significance for large rivers. *Large Rivers*, 12: 509–516.

SOBALLE, D. M., KIMMEL, B. L. (1987): A large-scale comparison of factors influencing phytoplankton abundance in rivers, lakes, and impoundments. *Ecology*, 68: 1943–1954.

THORP, J. H., BLACK, A. R., HAAG, K. H., WEHR, J. D. (1994): Zooplankton assemblages in the Ohio River: seasonal, tributary, and navigation dam effects. *Canadian Journal of Fisheries and Aquatic Sciences*, 51: 1634-1643.

UNGER, E. (1916): Data to the knowledge of the fauna and ecology of the River Danube. *Állattani Közlemények*, 15 (3-4): 262–281.

WOYNÁROVICH, E. (1944): Hydrobiological surveys around the „Albrecht kir. Herceg" Research Station of the Hungarian National Museum. *Albertina*, 1: 34–64.

ZSUGA, K., TÓTH, A., PEKLI, J., UDVARI, ZS. (2004): Zooplankton development of the Tisza river basin since the 1950s. *Hidrológiai Közlöny,* 84: 175–178.