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Long-term changes in cladoceran assemblages in the Danube floodplain area (Slovak–Hungarian stretch)

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Abstract

In this paper, the distribution of Cladocera species in the different sampling sites: *the main channel/old river bed, parapotamal type side arms* and *plesiopotamal side arms*, is described. The structure of cladoceran assemblages in the by-passed Danube section and in the adjacent floodplain water bodies has changed since the Gabčíkovo hydropower plant was put into operation. Great changes have been observed in the previous parapotamal side arm situated between river km 1840 and 1820, artificially fed with water from the head-race canal. The dominance of tychoplanktonic (benthic and phytophilous) species has increased, while the typical euplanktonic species have disappeared. Three characteristic groups of cladoceran assemblages were recorded when a different type of habitat was taken into consideration. Euplanktonic cladocerans prevailed on all sampling sites before damming. In periods after damming, littoral species, and later also a euplanktonic forms, dominated on the main channel sampling sites. In parapotamal and plesiopotamal side arms with rich littoral macrovegetation during periods after damming, phytophilous cladoceran species were the ones with the highest occurrence. The samplings from the first time period were rather homogenous. The samplings from the second and third period were more similar when considering the sample site than regarding the time period. In total, 64 cladoceran species were recorded in the course of 13 years (from 1991 to 2004). The increase in number of Cladocera species from 1991 to 2004 was significant. *Chydorus sphaericus* was found to be the most widely distributed species in the study area. The finding of *Disparalona hamata* is the first faunistic record from the central part of the Danubian watersheds.

Keywords: Crustacea; Cladoceran assemblages; Inundation; Habitat requirements; Gabčíkovo

Introduction

In 1992 the Gabčíkovo hydroelectric power plant was put into operation. After the Danube River being dammed at Čuňovo (river km 1851.7) an active connection between the abandoned Danube stretch and the side-arm system in the floodplain was abolished. The water supply to the protected floodplain was realized through an artificial water recharge system. As a result of a barrage system implementation at Gabčíkovo – Holčík, Bastl, Ertl, & Vranovský (1981) predicted a number of ecological changes occurring in aquatic communities in the affected area.

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Investigation of Cladocera in the Danube floodplain has a long tradition. The first list of species living in the water bodies of Žitnỳ ostrov Island presented Vranovskỳ and Ertl (1958). The most important data on zooplankton of the Danube River and adjacent water bodies are included in the papers of Ertl (1966) and Vranovskỳ (1969, 1972, 1974, 1985, 1991, 1995), but did not aim to provide the analysis of the cladoceran fauna. Later, Illyová & Némethová (2002) studied the relationship between cladoceran and copepod communities and the different types of macrovegetation in the Danube floodplain area. The crustacean assemblages on the right side of this section (the Szigetköz floodplain area in Hungary) had been investigated for a long time by Bothár (1973, 1979), Bothár & Ráth (1994) and Gulyás (1994).

Intensive hydrobiological investigation in the region started in 1990 and has continued up to now in order to monitor environmental impacts of the river regulation. First changes in planktonic crustacean assemblages as a result of intensive water engineering activities were observed as early as in the first years after damming (Illyová, 1996; Vranovskỳ, 1997). On the right side of the Danube (Szigetköz) Bothár (1994) and Kiss (2004) also observed long-term changes in crustacean assemblages.

The aim of this paper is (i) to resume the 13-year-long monitoring of the species composition and relative abundance of cladoceran assemblages (Ctenopoda, Anomopoda, Onychopoda and Haplopoda) in the Danube River and adjacent water bodies on the left-bank of the floodplain (r. km 1840.5–1804); (ii) to detect long-term changes in the composition of these assemblages.

Study area

The study section is situated in the Danubian lowland area in Slovakia (Fig. 1). Svobodová (1994), Illyová (1996) and Vranovskỳ (1997) have already published a comprehensive characteristic of these sampling localities. The sites were selected because they represent a basic type of the local aquatic environment, influenced by the operation of the Gabčíkovo hydropower plant. The classification of water bodies proposed by Ward, Trockner, Arscortt, & Claret (2002) was used. The general characteristics of the six habitat types investigated are as follows:

Site 1, Dobrohošt (D) – the main river channel/old river bed at Dobrohošt Village (r. km 1840.5); after damming the decrease in water level was significant. **Site 2, Gabčíkovo (G)** – the main river channel/old river bed at Gabčíkovo Village (r. km 1819.5). The mean depth in the km 1820 profile was 4.5–5.0 at a discharge equal to the long-term mean discharge; after damming, it decreased to 2.0–2.5 m (Vranovskỳ, 1997). **Site 3, Bodíky**

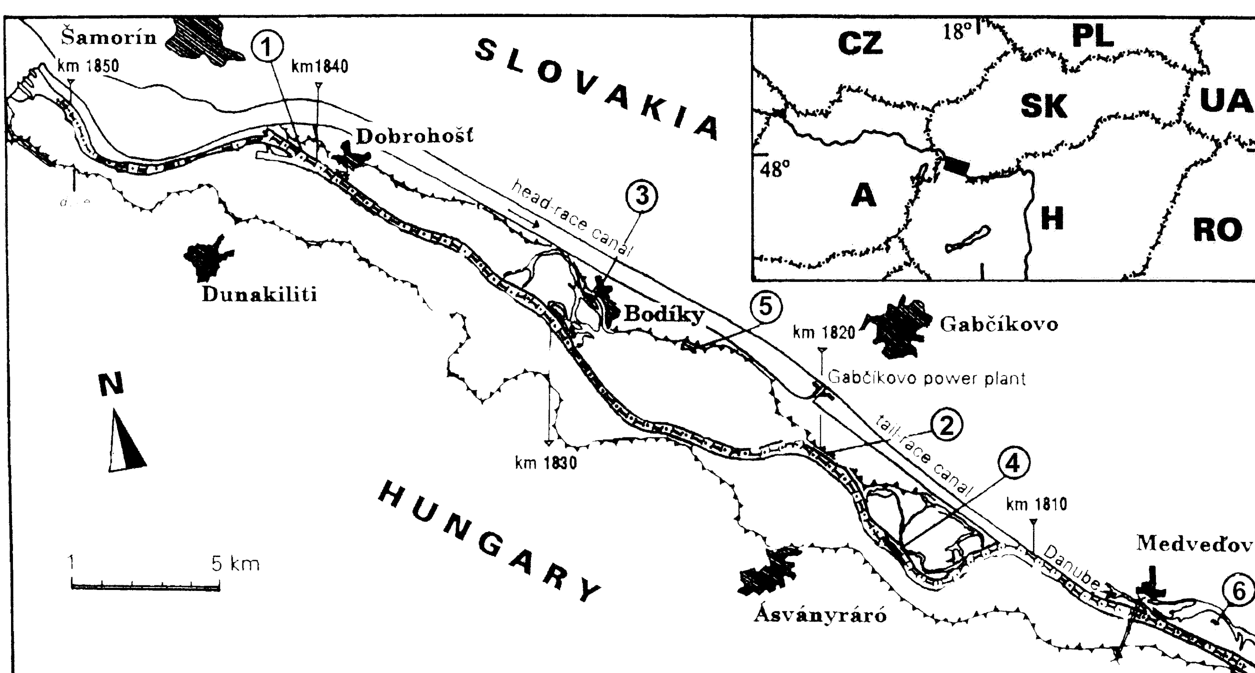

Fig. 1. Location of sampling sites in the Danube delta downstream from Bratislava (river km 1841–1804). (1) Dobrohošs main channel/old river bed et? Danube; (2) Gabčíkovo, main channel/old river bed; (3) Bodíky, side arm; (4) Istragov, side arm; (5) Král'ovská lúka, side arm; (6) Sporná sihot', side arm.

(B) – the Bodícke side arm at the village of Bodíky (r. km 1830). The side arm of a parapotamal type is situated in the upper part of the by-passed region. Due to artificial feeding after damming, the arm is permanently flowing, but current velocities are rather low (Vranovskỳ, 1997). From 1995 onwards, macrophytes have increased significantly in its littoral zone. The bottom sediment is formed of gravel. **Site 4, Istragov (I)** – the Istragovské side arm is situated at **Gabčíkovo** Village (r. km 1815.5). A parapotamal type of the side arm; it is non-permanently flowing at present. The bottom sediment is formed of gravel and sand. Poor aquatic littoral macrophytes have been developing since 2000. **Site 5, Král'ovská lúka (K)** – the side arm near Trstená na Ostrove Village (r. km 1825). This plesiopotamal type of a water body is a remainder of an originally flowing arm. At present it is mostly a stagnant river arm, which is acquiring a paleopotamal character. About 60% of the side arm area is overgrown with macrophytes. The bottom sediment is formed of gravel, mud and clay. **Site 6, Sporná sihot' (S)** – a side arm near Kl'účovec Village (r. km 1804) is the mostly stagnant river arm. Prior to the damming it was a side arm of a plesiopotamal type, at present it is filled with shallow water. About 80% of its water level is overgrown with macrovegetation. It is not directly affected by the Gabčíkovo hydropower plant structures. It has a muddy bottom and rich macrophytic vegetation.

Methods

From 1991 to 2004 (except of 1998) samples of cladoceran assemblages from six sampling sites were collected and analyzed three times a year (spring, summer and autumn). The samples of cladocerans were collected from the medial, open-water zone of the side-arms and of the main channel. Samples were taken either from a boat by vertical tows or from the bank by tows from the bottom to surface. The samples were filtered through a 90-μm mesh net. Samples of littoral plankton were also obtained. The samples were preserved in 4% formaldehyde. A total of 107 samples was collected and analyzed. Qualitative analyses and dominance determination were performed on preserved material.

Data from field observations on the six sampling sites that lasted for 13 years were divided into three periods: first period (1991 and 1992) before damming of the Danube River (D1, G1, B1, I1, K1 and S1); second period (1993–1997) includes the first 5 years after damming (D2, G2, B2, I2, K2 and S2); and third period (1999–2004) includes the last 6 years after damming (D3, G3, B3, I3, K3 and S3). The average values of these three periods are marked in Table 1. The relative abundance of Cladocera species from the six sampling sites and three periods were transformed to six categories based on proportion of total fauna collected (1: <1%; 2: 1–3%; 3: 3–10%; 5: 10–20%; 7: 20–40%; 9: 40–100%; by Vranovskỳ, 1997).

Linear regression was used to confirm the increase of species richness (number of species) during the 14-year period on each of the six sampling sites. Species richness was logarithmically transformed before entering linear regression to ensure the normal distribution.

The principal component analysis (PCA) was performed to assess the relationship among cladocerans and sampling sites using the program Canoco (Ter Braak & Šmilauer, 1998). The taxa by sites matrix included 64 cladoceran species and 18 objects. The analysis was based on the transposed relative abundances of individual taxa (Table 1).

Results

Cladocerans taxa and their habitat requirements

A total of 64 taxa of cladocerans were encountered during this study, of which 17 were euplanktonic and 47 were littoral species (Table 1). The increase in number of Cladocera species from 1991 to 2004 was significant (Table 2).

Disparalona hamata was recorded for the first time in the Danube area. Eight invaders: *Daphnia ambigua, Daphnia parvula, Bosmina coregoni, Bosmina longispina, Diaphanosoma mongolianum, Moina weismanni, Disparalona hamata* and *Pleuroxus denticulatus* were recorded after 1995. The species *Alona guttata* var. *tuberculata, Alonella exiqua, Anchistropus emarginatus, Camptocercus rectirostris, Ceriodaphnia laticaudata, C. rotunda, C. setosa, Daphnia pulicaria, Chydorus ovalis* and *Monospilus dispar* were found only once and were proved to be rare species in the Slovak Danube floodplain area. On the contrary, *Chydorus sphaericus* was found to be the most widely distributed species in the study area, with high occurrence frequency (92%). *Bosmina longirostris* and *Simocephalus vetulus* were present in more than 60% of samples followed by chydorids *Alona affinis, A. rectangula, Disparalona rostrata* and *Pleuroxus aduncus* (in more than 40%). In the first 2 years *Moina brachiata* was widely distributed as well, but after damming it has disappeared.

The ordination diagram of PCA confirmed the presence of different cladoceran community groups corresponding to 3 habitats types (Fig. 2).

Group I includes the main channel and parapotamal side arms before damming (D1, G1, B1 and I1), habitats without macrovegetation. The most typical cladocerans were *Bosmina longirostris, Diaphanosoma brachyurum,*

Table 1. Species composition and average dominance of Cladocera in the monitored sites of the Danube floodplain area in 1991–2004

Taxon/sampling sites	Sampling sites	Dominance																	
		Site 1 (D)			Site 2 (G)			Site 3 (B)			Site 4 (I)			Site 5 (K)			Site 6 (S)		
	Code/period	D1	D2	D3	G1	G2	G3	B1	B2	B3	I1	I2	I3	K1	K2	K3	S1	S2	S3
Acroparus harpae (Baird)[t]				+			2		1	1			1			1	1	2	2
Acroperus neglectus (Lilljeborg)[t]							1			+			+			3		1	3
Alona affinis (Leydig)[t]	ALOAFF	3	5	7	5	2	3	2	2	3	+	3	1	+	+	1			1
Alona costata Sars[t]									+	2				2		1			
Alona guttata Sars[t]	ALOGUTT			1			1		3	1				+	2	2	2	1	1
Alona guttata var. tuberculata Kurz[t]										1						+			
Alona protzi Hartwig[t]				1			3			+									
Alona quadrangularis (O.F.M.)[t]	ALOQUA	7	3	1		3	1	2	2	+		+						1	1
Alona rectangula Sars[t]	ALOREC		2	3		3	3	1	3	3	3	2	1	3	3	3	2	1	1
Alonella excisa (Fischer)[t]	ALOEXS							2		1						1	1	2	1
Alonella exiqua (Lilljeborg)[t]																1			
Alonella nana (Baird)[t]	ALONAN								2	1			1			3			1
Anchistropus emarginatus Sars[t]																1			
Bosmina longispina Leydig	BOSLNS			1			1												
Bosmina coregoni Baird	BOSCOR		2	1			3		1	3		+							
Bosmina longirostris (O.F.M.)	BOSLON	9	5	5	9	5	7	9	5	3	7	7	9	5	5	9	9	3	5
Camptocercus rectirostris Schoedler[t]															1				
Ceriodaphnia laticaudata (P.E.M)[t]																+			1
Ceriodaphnia megops Sars[t]	CERMEG								1	+					1	+		2	1
Ceriodaphnia pulchella Sars[t]	CERPULL							2				+	2		2	2		2	3
Ceriodaphnia quadrangula (O.F.M)[t]																+		2	
Ceriodaphnia reticulata Sars[t]	CERRET														+	+		2	3
Ceriodaphnia rotunda Sars[t]																1			
Ceriodaphnia setosa Matile[t]																+			
Daphnia ambigua Scourfield													1		1				1
Daphnia cucullata Sars	DAPCUC		3	1	3	3	3	5	2		5	3	1						1
Daphnia galeata Sars	DAPGAL		3	5			3			1			1			1		1	1
Daphnia longispina (O.F.M)	DAPLON	5		2	3	2	1	3			3			2		1		3	1
Daphnia parvula Fordyce, 1901													1						
Daphnia pulicaria (Forbes)				1															
Diaphanosoma brachyurum (Liévin)	DIABRA				3	2		2			7			7	2	1	1	1	1
Diaphanosoma mongolianum (Ueno)													+						1
Diaphanosoma orghidani (Negrea)	DIAORG		2	2		5	5		3	1		3	3		2	1			1
Disparalona hamata Birge[t]													1						
Disparalona rostrata (Koch)[t]	DISROS		2	3	1	3	2		3	3		2	2		2	1			
Eurycercus lamellatus (O.F.M.)[t]	EURLAM		+	1						1		+	1			+		3	1
Graptoleberis testudinaria (Fischer)[t]	GRATES			+			2		+	3			1		3	1		1	1
Chydorus ovalis Kurz[t]										+									

Table 1. (*continued*)

Taxon/sampling sites	Sampling sites	Dominance																	
		Site 1 (D)			Site 2 (G)			Site 3 (B)			Site 4 (I)			Site 5 (K)			Site 6 (S)		
	Code/period	D1	D2	D3	G1	G2	G3	B1	B2	B3	I1	I2	I3	K1	K2	K3	S1	S2	S3
Chydorus sphaericus (O.F.M.)[t]	CHYDSPH		3	3		3	3	2	7	7	+	3	5	3	7	5	5	7	7
Ilyocryptus agilis Kurz[t]							1			1			1			+			1
Ilyocryptus sordidus (Liévin)[t]	ILYSOR		2	+		2			1			2	1			+		1	
Lathonura rectirostris (O.F.M.)[t]																1			
Leptodora kindtii (Focke)						2	1					1	1		2				
Leydigia leydigii (Schoedler)[t]	LEYLEY		2	2			1					3							
Macrothrix hirsuticornis N.et Brady[t]	MACHIR		7	5		3	2			1		5	2					1	1
Macrothrix laticornis (Fischer)[t]	MACLAT			1			1	1	5	1		2	1						1
Moina brachiata (Jurine)	MOIBRA				2			2			5			2			2		
Moina micrura Kurz			3		2	2	3	1	1	1	2	2	5	3	3	1	3	2	1
Moina weismanni Ishikawa			2																
Monospilus dispar Sars[t]				1															
Pleuroxus aduncus (Jurine)[t]	PLEADU		3	+					2	3		+	1	+	3	1	2	2	3
Pleuroxus denticulatus Birge[t]	PLEDEN			+					2	2		2	1		+	3		1	1
Pleuroxus laevis Sars[t]	PLELAE								+	+						1			
Pleuroxus truncatus (O.F.M.)[t]	PLETRU								2	3		+	+			1		1	1
Pleuroxus uncinatus Baird[t]	PLEUNC		2	2				2		1		+	1						
Polyphemus pediculus (Linné)																+	1	1	
Pseudochydorus globosus (Baird)[t]	PSEGLO								+	+			+			+			1
Scapholeberis mucronata (O.F.M.)[t]	SCAMUC		1	+				2	2	2	1	+	2		3	1	5	2	2
Scapholeberis rammneri D et P[t]																1			1
Sida crystallina (O.F.M)[t]	SIDCRY		2	1			2		2	3		+	3	2	3	1	1	2	1
Simocephalus congener Schoedler[t]	SIMCON												1		+			1	1
Simocephalus exspinosus (Koch)[t]															1			2	
Simocephalus serrulatus (Koch)[t]	SIMSER			+					+	+		1	1		3	3		1	1
Simocephalus vetulus (O.F.M.)[t]	SIMVET	3	2	1	2		1		2	2	+	2	1		3	3	3	7	5
Number of species																			

Taxa: Taxa marked with [t] are tychoplanktonic taxa.
Code: Abbreviation of corresponding taxa (for Fig. 2 of PCA analysis)
Sites: 1 = Dobrohošt', 2 = Gabčíkovo, 3 = Bodíky, 4 = Istragov, 5 = Král'ovská lúka, 6 = Sporná sihot'
D1, G1, B1, I1, K1, S1 = 1st - period of year 1991–1992;
D2, G2, B2, I2, K2, S2 = 2nd - period of year 1993–1997;
D3, G3, B3, I3, K3, S3 = 3rd - period of year 1999–2004.
Dominance (occurence): 1 means <1%; 2 = 1–3%; 3 = 4–10%; 5 = 11–20%; 7 = 21–40%; 9 = 41–100%
+ Species only in qualitative samples.

Table 2. Results of the linear regression analysis. Independent variable (*x*–year) was coded as follows: 1991–1, 1992–2,…, 2004–14

Sampling sites	Regression equation	Significance level	r^2	p
Site 1	$y = 0.807 + 0.023x$	$p = 0.032$	0.355	*
Site 2	$y = 0.771 + 0.022x$	$p = 0.023$	0.388	*
Site 3	$y = 0.960 + 0.014x$	$p = 0.153$	0.177	ns
Site 4	$y = 0.744 + 0.033x$	$p = 0.009$	0.480	**
Site 5	$y = 0.820 + 0.033x$	$p < 0.001$	0.705	***
Site 6	$y = 0.944 + 0.025x$	$p = 0.004$	0.540	**

Dependent variable (y) in all equations species richness. *$p<0.05$, **$p<0.01$, ***$p<0.001$, ns – not significant.

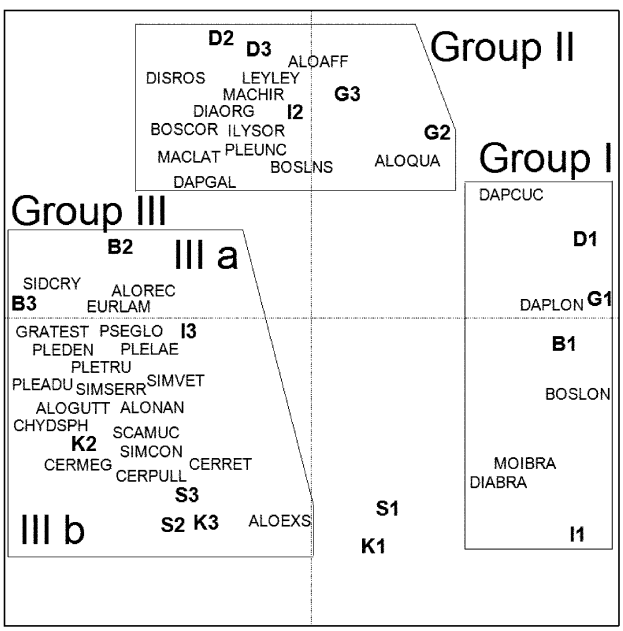

Fig. 2. First two axes of PCA as a biplot of Cladoceran species and sampling sites. The first two ordination axes ($\lambda_1 = 0.298$ and $\lambda_2 = 0.190$) accounted for 48.8% of the total variance of the species data. From the 64 taxa in the analysis included (see Table 1 for codes of species) only taxa with best fit shown.

Moina brachiata and *Daphnia cucullata* (Fig. 2) that are regular members of plankton in backwater and slow watercourses.

Group II includes the main channel (D2, G2, D3, G3) and a parapotamal side arm without macrovegetation (I2) during periods after damming. At these sites littoral species *Alona affinis, Macrothrix hirsuticornis* and the ''pelagic'' one *Diaphanosoma orghidani* were dominant. Also typical species for these habitats were *Bosmina coregoni, Bosmina longispina, Daphnia galeata* and from chydorids *Disparalona rostrata, Pleuroxus uncinatus* and *Leydigia leydigii* (Fig. 2).

Group III includes parapotamal and plesiopotamal side arms with rich littoral macrovegetation during the period after damming. For all these habitats the number of littoral (phytophilous and benthic) species was the highest one. This group was divided into two subcategories: **IIIa** group – former parapotamal side arms (B2, B3 and I3) with a gravel bottom and with vegetation only in the littoral, and **IIIb** group – former plesiopotamal side arms (K2, K3, S2 and S3) with a gravel and mud-clay bottom and with rich cover of macrovegetation both in the littoral and medial zone. Phytophilous species *Ceriodaphnia reticulata, C. pulchella, C. megops, Simocephalus congener, Alonella exscisa* and *A. nana* were associated with rich macrovegetation in former plesiopotamal side arms; whereas *Sida crystallina, Eurycercus lamellatus, Graptoleberis testudinaria* and *Pleuroxus* sp. were found mainly in former parapotamal side arms.

Two plesiopotamal arms K1 and S1 before damming are situated between Group I and II (Fig. 2). At these sites euplanktonic species *Bosmina longirostris* (K1) or *Diaphanosoma brachyurum* dominated.

The samplings from the first time period (before damming) are separated from the samplings taken after damming. The samplings from the second and third period are more similar when considering the sample site than regarding the time period (Fig. 2).

Cladoceran community changes in several sampling sites

Site 1 (Dobrohošt') – 31 species, 27 in an open water zone and 20 in a littoral zone were recorded. Before damming, *Bosmina longirostris, Alona quadrangularis* and *Daphnia longispina* were dominant species in an open water zone (Table 1). In 1993–1997 their relative abundance decreased. Littoral species appeared in plankton and their relative abundance increased significantly. The dominant species *M. hirsuticornis* usually occurred in March, often as the only representative of Cladocera (100%) being represented in the sample by ca. 9–30 individuals. In the third period (1999–2004) usually *Alona affinis* and species in the genus *Daphnia* and genus *Bosmina* are the major component of the cladoceran community (Table 1, Fig. 2).

Site 2 (Gabčíkovo) – 28 cladoceran taxa were recorded on this sampling site. In the first period (1991–1992) *Bosmina longirostris* predominated in the main channel. After damming, the increase of relative abundance of tychoplanktonic species in potamoplankton was observed. Among the pelagic species, *D. orghidani* appeared and maintained a higher relative abundance since 1994. In the third period, *Bosmina longirostris* predominated again; its high relative abundance (72–87%) was recorded particularly in spring of

2002 and 2003. After 1999, number of littoral species increased in plankton but they showed a low relative abundance (<1–6%; Table 1).

Site 3 (Bodíky) – 41 Cladocera species, 32 in the medial and 34 in the littoral zone were recorded on this sampling site. In 1991–1992, the euplanktonic species *Bosmina longirostris* and *Daphnia cucullata* predominated in this river arm. In the first years after damming, relative abundance of littoral species *Ch. sphaericus* and *M. hirsuticornis* increased. Almost all 23 species (except for *Diaphanosoma orghidani, Daphnia galeata* and *Bosmina coregoni*), which were found after 1993 were littoral species (Table 1). In the last 6 years (1999–2004), *Ch. sphaericus* proved the highest relative abundance and a strong trend in increase of relative abundance of tychoplanktonic species still continues (Table 1, Fig. 2).

Site 4 (Istragov) – 37 species, 29 in the medial and 31 in the littoral zone were recorded on this sampling site. Euplanktonic species showed higher relative abundance during all three periods. In the first and second period also the pelagic species *Diaphanosoma brachyurum* and *Daphnia cucullata* prevailed. In 1993–1997, *Diaphanosoma orghidani* and *M. micrura* appeared, but they occurred only in summer. Among littoral species *Macrothrix hirsuticornis* showed higher relative abundance in 1994–1996, and *Chydorus sphaericus* after 1997. *Disparalona hamata* occurred in the littoral zone in number of ca. 42 individuals per a sample in October 2003.

Site 5 (Král'ovská lúka) – 48 cladoceran species, 30 in the open water zone and 34 in the littoral zone were recorded. In 1991–1992 *Diaphanosoma brachyurum, Chydorus sphaericus* and *Bosmina longirostris* were typical representatives of the cladoceran fauna in the river arm. After damming, relative abundance of *D. brachyurum* and *B. longirostris* dropped strongly, but the littoral species *Ch. sphaericus* reached high dominance. Relative abundance of *B. longirostris* fluctuated during the third period: a new increase (86%) was recorded in 2000, but in the next years the number decreased again with the lowest value (1%) in 2003. In the second and third period, except for 2000, relative abundance of phytophilous species increased in the open water zone (Table 1). Rare species *Latonura rectirostris* occurred in the littoral zone of the river arm in summer (2003) in an unusually high number with more than 40 individuals.

Site 6 (Sporná sihot') – 41 cladoceran species were recorded on this sampling site. Before the Danube damming, *Bosmina longirostris* predominated there. In the second and third period relative abundance of littoral species increased. Five species of the genus *Ceriodaphnia* have appeared (Table 1, Fig. 2). High relative abundance was shown by *Chydorus sphaericus* and *Simocephalus vetulus*. After the Danube damming, a trend of strong predominance of littoral cladoceran species has continued.

Discussion

The number of Cladocera taxa (in total 64) found in Danubian localities was similar to those of Gulyás (1994) and Kiss (2004), who simultaneously monitored Cladocera on the Hungarian part of the Danube floodplain on Szigetköz Island. Gulyás (1994) recorded 58 species of Cladocera; similarly Kiss (2004) found 69 Cladocera among which 50 taxa corresponded with our results. It is remarkable that both authors did not found *Diaphanosoma orghidani*, which has been a common species on the Slovak side of the floodplain since 1994. On the other hand, the species *Moina brachiata* was widely distributed in Szigetköz, but in our investigated area this species has not been present since 1993. Equally, we did not found *Alona intermedia* which was frequently recorded in Szigetköz.

The most widely distributed and dominating species *Chydorus sphaericus* proved that species of the genus *Chydorus* are some of the most common cladocerans occurring in freshwater all over the world (Chengalath, 1982), likewise in the Danube and Morava floodplains (Illyová & Némethová, 2002). Very similar result was obtained during investigation of Kiss (2004), when *Ch. sphaericus* was also present in the whole monitored area during 1991–2002.

The number of species (64) was higher than it had been known (56 taxa) from Danube floodplain area up to 1991 (e.g. Vranovskỳ & Ertl, 1958; Vranovskỳ, 1981). The higher number of species produced by regular monitoring that has lasted for 13 years results from: (i) appearance of several invasion species detected to Slovakia (Hudec, 1998); (ii) long-term monitoring of sampling sites which allowed to record also the rare species; (iii) changes in the character of the Danube River and development of macrophytic littoral vegetation in almost all localities.

(i) In the last years, the cladoceran fauna of the Danube water basin has been enriched by eight species originally not occurring in Slovakia (Hudec, 1998). The faunistically most interesting finding is that of *Disparalona hamata* in the littoral zone of the Istragovské rameno Arm (site 4). It is the first record in Slovakia and the second record in Europe (Illyová & Hudec, 2004).

The species *Pleuroxus denticulatus* we found in a littoral zone of an arm fed artificially with water from the headrace canal in 1995. In the Danube floodplain, this species was recorded for the first time by Terek (1997) in 1992. On the Hungarian side, in the area of Szigetköz, its occurrence was given by Gulyás and Ferró (1999). Spreading of *P. denticulatus* was relatively intensive, as it also penetrated into other Danubian arms within a relatively short time (Illyová & Némethová, 2002) or into the left Danube tributary – the Morava River (Illyová & Kubíček, 2002). According to Hudec (1998) the species *Bosmina coregoni* and *Bosmina longispina* naturally invade from neighboring geographical regions (Alps, Bohemia Highland). Over a period of monitoring, both species appeared after the extensive floods: *Bosmina coregoni* in August 1997, while *Bosmina longispina* in October 2002. We confirmed the Hudec's thesis that spreading of both species in Slovakia differed (Hudec, 1998). While *Bosmina coregoni* has been distributed in the Danube area, according to Kiss (2004) as well; *Bosmina longispina* occurred sporadically and did not penetrate from the main channel into the arm system. Gulyás and Ferró (1999) also found *Bosmina longispina* in the main channel only.

(ii) The long-term monitoring of selected water bodies of the Danube floodplain also enabled us to record a number of rare species. Faunistically the most interesting records are that of *Alona protzi* and *Lathonura rectirostris*. In Slovakia, *A. protzi* was recorded for the first time by Vranovskỳ (1971) in zooplankton of paddy fields; while in Hungary it was found by Gulyás and Ferró (1999) in the Balaton Lake. The holarctic species *L. rectirostris*, found in the littoral of the arm at Král'ovská lúka in an unusually large number (ca. 40 ind.), is very rare in Slovakia. It usually occurs only individually and can be easily overlooked.

(iii) The operation of the barrage altered the hydrological conditions in various water-bodies in the Danube floodplain area. After the main channel being diverted, water level decreased and the flow velocity slowed down from 2.0–3.5 to 1 $m\,s^{-1}$ (Vranovskỳ, 1997). Thus structural changes in the assemblages of Cladocera happened in 1991–2004. Before damming, *Bosmina longirostris* and *Alona quadrangularis*, or *A. rectangula* (Vranovskỳ, 1974, 1985) were the most abundant cladoceran species in the Danube River. The high population of *Bosmina longirostris* was typical also in parapotamal side arms before damming. In the first years after damming the decrease in dominance of *Bosmina longirostris* has been found (Illyová, 1996). That corresponds with those of Bothár (1994), who found out an abundant decrease of this species in the Danube main stream at river km 1669 and also explained this reduction as a consequence of damming. In the last 6 years of monitoring the dominance of daphnia has increased: particularly of *D. cucullata* a *D. galeata*, which are also characteristic for slow-running rivers (Dumont & Negrea, 1996), and other euplanktonic species (*Diaphanosoma orghidani*, *Bosmina* sp.) dominated as well. The species composition of cladocerans in an abandoned river bed in both profiles (Dobrohošt', Gabčíkovo) is similar, as it is demonstrated in PCA diagram.

Significant changes were recorded in the partially abandoned side arm **Bodíky** (site 3) between the river km 1840 and 1820. The number of euplanktonic species dropped, and the number of benthic and phytophilous littoral species, which are formed in annual average 60–100% of cladoceran assemblages increased. Similar changes were observed in the copepod taxocoenoses investigated simultaneously by Vranovskỳ (1997). This means, that copepods community, typical for these water bodies *before damming* were practically eliminated *after damming*, as a consequence of the artificial system. Since 1993, the main branches of the side arm system (between river km 1840–1820) has been fed from the bypassed canal by means of an intake structure built at Dobrohošt' (Fig. 1). Before damming, main branches of this system were flowing at discharge higher than about 2040 $m^3\,s^{-1}$ (average discharge in Bratislava), and were stagnant at lower discharge (Vranovskỳ, 1997). Now, due to artificial feeding they flow permanently. Additionally, a littoral zone was covered with rich macrovegetation, so the relative abundance of the macrophyte-associated species increased.

The parapotamal side arm **Istragov** (site 4), which is located between the villages of Gabčíkovo and Sap, is different. The arm is not artificially supplied with water and is situated 5 km upstream from the confluence of the tail-race canal with the old Danube (Fig. 1). The side arm Istragov is steadily becoming shallower after diverting of the Danube. Euplanktonic species predominated there during the whole period of monitoring. It is related to a lentic character of the habitat and its poor littoral macrovegetation.

Changes have also been recorded in plesiopotamal-type of side arms **Král'ovská lúka** (site 5) and **Sporná sihot'** (site 6). It can be stated, that a number of cladoceran species has been increasing with the increasing distance from the main channel, because the most diversified assemblages (48, 41) have formed in the plesiopotamal type of arms. Owing to the distance of the old channel and artificial flooded systems, respectively, these arms lose their periodical connection with adjacent arm-systems and the previous main channel. This situation has developed due to the decrease in its depth. Dense macrophyte vegetation has supported the increase in the phytophilous cladocerans. There were also the rare species that inhabit eutrophic shallow waters recorded: e.g. *Latonura rectirostris, Camptocercus rectirostris, Anchistropus emarginatus* and *Ceriodaphnia setosa*. Our findings corresponded with that of Gulyás (1994) who also found the rare species *Alona guttata* var. *tuberculata, Alonella exiqua, Kurtzia latissima, Camptocercus lilljeborgi* and others in water-bodies densely overgrown with stands of macrophytes. We assume, as Gulyás (1994) did, that these habitats play an important role in conservation of genetic diversity and therefore must be protected. However, prognoses of development of cladoceran assemblages in these water-bodies are difficult. At present the arms are exposed to a process of natural aggradations. Especially in the Sporná sihot' Arm the water depth is strongly decreasing during summer.

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