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AQUATIC BEETLE AND BUG ASSEMBLAGES OF STANDING WATERS WITH DIFFERENT SUCCESSIONAL STAGES IN THE FLOODPLAIN OF DRAVA

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VÍZIBOGÁR ÉS VÍZIPOLOSKA EGYÜTTESEK A DRÁVAMENTI-SÍK KÜLÖNBÖZŐ SZUKCESSZIÓS STÁDIUMÚ ÁLLÓVIZEIBEN

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ABSTRACT: Water bodies of floodplains are harbouring significant biodiversity even after water regulation. They represent different types as stages of natural and anthropogenically modified routes of terrrestrializational succession, which are traditionally described by botanical approach. In our study we examined whether aquatic Heteroptera and Coleoptera fauna is connected to these water body types in 30 backwaters of floodplain of River Drava at the southern border of Hungary. Results of redundancy analysis (RDA) of binary data proved that the above-mentioned types are well distinguishable by their vegetation in this area. Aquatic Coleoptera and Heteroptera species also show significant correlations with water body types. Oxbows used as fishponds, temporary waters and, in a lesser extent, diverse middle-succession stages on the protected part were separated. Vegetation-based habitats and flooded or protected part position do not have significant correlation with studied aquatic macroinvertebrate groups. Higher diversity of middle stages of succession compared to that of beginning and end stages is also proved by all studied organisms. Anthropogenic degradation of fishponds was indicated by vegetation and Coleoptera fauna, but not by Heteroptera. Temporary waters have diverse vegetation and beetle and bug fauna too.

Key words: oxbow lakes, diversity, habitats, vegetation, Coleoptera, Heteroptera, RDA

KIVONAT: Az ártereken a folyószabályozás után is visszamaradó vizek jelentős biodiverzitást hordoznak. A feltöltődési szukcesszió természetes és módosított útjainak különböző stádiumait képviselik, melyek botanikai megközelítéssel, növényfajok és Á-NÉR élőhelyek segítségével jól leírhatók. Kutatásunk során azt vizsgáltuk, hogy a vízibogár és –poloskafauna mennyiben kötődik a fenti szukcessziós típusokhoz a Drávamenti-sík 30 holt- és mellékágában és időszakos vizeiben. Bináris adatokon végzett redundancia-analízis (RDA) eredményei szerint a fenti típusok növényzetük szerint vizsgálati területünkön egyértelműen elkülönülnek. A típusok szignifikáns korrelációt mutattak bogár- és poloskafajokkal. Jól elváltak a horgásztóként használt holtágak, az időszakos vizek és – kisebb mértékben – a mentett oldal természetközeli holtágai. Az Á-NÉR élőhelyek és a hullámtéri vagy mentett oldalai helyzet nem mutatott szignifikáns korrelációt a vizsgát rovarcsoportokkal. A szukcesszió köztes stadiumainak a kezdeti- és végállapothoz képest magasabb diverzitása az ártéri és mentett oldali szukcessziós utak esetében egyaránt beigazolódott. A horgásztavak degradáltsága megmutatkozott a növényzetben és a bogárfaunában, a poloskákat azonban nem zavarta. Az időszakos és újkeletű vizek vegetációja és faunája egyaránt igen gazdagnak mutatkozott.

Kulcsszavak: holtmedrek, diverzitás, élőhelyek, növényzet, Coleoptera, Heteroptera, redundancia analízis

Introduction

River floodplains with numerous wetland ecosystems are diversity hotspots (SKERN et al. 2010, ORTMANN-AJKAI and HORVÁTH 2010a). High diversity of ecosystems, habitats and biota is due to geomorphologic (river dynamics) and ecological (succession) processes (NAKAMURA et al. 2008, BORNETTE et al.1998). There is a kind of dynamic equilibrium: oxbow lakes disappearing by sedimentation are replaced by new ones cutting off of the main channel. Flood regulation stops meandering and oxbow creation and flood protection dams separate floodplains into flooded and protected parts. In the flooded areas – due to confinement –water bodies are connected directly to the main channel of the river. Floods are dynamic, regular in every year, flooding is high and long-lasting (can be measured in weeks or even in month). Characteristic water body types are long side-arms, usually flooded by the river in every year. Strong spring floods sweep out most of the biota. There are some cut-off arms too, in different stages of terrestrialization.

River regulation basically changes this process (MARSTON et al. 1995, THOMS et al. 2005). Floodplain floods are almost disappeared from the protected part, but water levels of water bodies have a distinct seasonal pattern due mostly to groundwater level changes. Some of the oxbows may be connected to the main channel through drainage channels, but water flows are regulated unnaturally, according to aims of water regulation. Characteristic water body types are oxbows sometimes terrestrialized and developed into forest stage. Due to stagnant waters in the summer some of them show more or less mire characteristics. Via ecological succession they evolve towards some of few climax vegetation types, so the overall riverine landscape diversity deteriorates (MARSTON et al. 1995, GEERLING et al. 2008). Patterns of landscape elements created by succession are „frozen in": numerous important habitats are present, but as remnants of a formerly dynamic system.

Present successional routes in the Drava floodplain, presented in Fig.1, are adaptations of Kevey's (2008) general scheme to our area. In the side arms of flooded areas water vegetation is missing because of strong floods (Type 1 in Fig.1.). Their banks are steep due to incision (GYENIZSE and LOVÁSZ 2002); they offer no growing sites for riparian vegetation. When side-arms are cut off due to incision, their flooding becomes irregular (not in every year and in every part). Slower floods allow more sedimentation, which lowers the water level, giving opportunity for arising of types of mineralogenic succession (Type 2 in Fig.1.; KOVÁCS and KÁRPÁTI 1973, KEVEY 2007, 2008, KEVEY et al. 2008) leading to species-arm, closed woody vegetation (Type 3 in Fig.1.).

Succession series of protected areas also starts from side-arms, dated form the time before regulation. After (artificial) cut-off of oxbows, in the more or less stagnant waters organogenic succession can be assumed (DÉNES and ORTMANN-AJKAI 1999, 2006, ORTMANN-AJKAI 2004, KEVEY 2008) creating the successional route of mire euhydrophytic communities, mire reedbeds, tussocky sedge stands, willow mires and swamps, alder-ash mire and swamp woodlands (Type 4-6 in Fig.1.). In the studied part of the floodplain of Drava this natural process now can be observed only very fragmentally (ORTMANN-AJKAI and HORVÁTH 2010b) for various reasons. Water of oxbows is not stagnant in most cases, because drainage channels are lead into them (and through them to the Drava). Diffuse organic pollution coming from neighbouring agricultural areas raises nutrient levels. In most oxbows fish are introduced in great quantities (sometimes alien species, e.g. *Ameiurus melas*, *Carassius auratus gibelio*, *Ctenopharyngodon idella*, *Hypophthalmicthys* sp.). Some of them are intensively used as fishponds for hobby fishing (Type 5 in Fig.1). Their open waters are maintained by frequent removal of vegetation, so slowing down sedimentation, and sometimes by direct mechanical sediment removal; introduced fish extirpate most of the vegetation. Some oxbows protected since 40 years are in advanced stage of terrestrialization and succession [dense, species-arm willow bushes (Type 6 in Fig.1.) similar to last stage in flooded areas]. A further type, not easily includable into this scheme is newly created or in this extremely wet year temporarily flooded areas (Type 7).

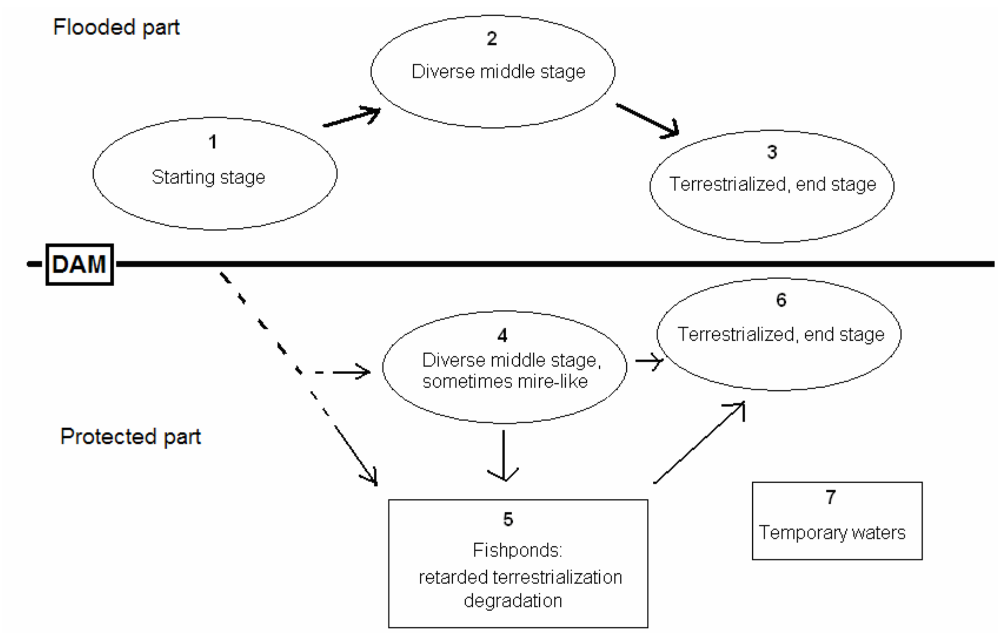

Fig. 1. Hypothetical successional routes and water body types in Drava floodplain.

Hydrological connectivity, and frequency and intensity of floods are considered as key factors determining aquatic macroinvertebrate communities of wetland ecosystems (OBOLEWSKI 2011). These two factors are the main distinguishers of the above-mentioned two successional routes, so the system of stages presented in Fig.1. seems to be an appropriate framework for studying aquatic macroinvertebrate communities.

Successional stages differ in many aspects, e.g. in hydrology, flood dynamics, geomorphology, chemical, (nutrients, pollution), vegetation (food, shelter). They offer different conditions for aquatic organisms, which is the reason for high biodiversity in floodplains. Because floodplains are continually changing for natural and anthropogenic reasons, water body types are continually disappearing or appearing. Disappearance of a certain water body types implies losing those species which require the specific conditions provided by this type. As rare and protected species may be bound to certain types, for conservation it is crucial to predict the possibility of medium- or long-term survival of these types in the changing system. Understanding of background processes of these changes can greatly improve evaluation of threatening anthropogenic activities (e.g. changes of water supply, sediment and vegetation removal, pollution) and conservation measures (passive conservation, side-arm revitalization, providing more water for oxbows, etc).

Our study aimed to 1. test the above-mentioned succession scheme on Drava floodplain on a majority of small water bodies (mostly oxbows and temporarily cut-off side-arms) of the floodplain of Drava in Baranya county; 2. to examine whether these water types have characteristic aquatic Coleoptera and Heteroptera assemblages.

Material and methods

Study area

The left-side floodplain of river Drava in Baranya country is cca 70 km long and up to ten kilometres wide. Flood protection dam (at the same time border of Duna-Dráva National Park in most places) divides it into flooded and protected parts. Flooded part is covered mostly with near-natural willow and poplar forests (*Salix alba, Populus alba*). Protected areas are mostly arable fields. Wetland habitats, survivors of formerly rich floodplain ecosystems are found in cut-off meanders, in oxbow lakes and their surroundings. Floodplain of Drava were studied from many aspects, e.g. in hydrology, flood dynamics, geomorphology (GYENIZSE and LOVÁSZ 2002), water quality of oxbows (MAJER et al. 1998, ORTMANN-AJKAI et al. 2002), etc. Biodiversity of the Drava floodplain was intensively studied in the last decades, due to the creation of Danube-Drava National Park (1996), as a preferred area of National Biodiversity Monitoring Program (NBMR) and in frames of a Hungarian-Croatian INTERECO Project, whose results are published in four different volumes (UHERKOVICH 1995, 1998, ÁBRAHÁM 2005, PURGER 2008). Its vegetation is well known due to many botanical studies. The latest synthesis with a full list of references is ORTMANN-AJKAI and HORVÁTH 2010b, based on a landscape-level vegetation survey was made in 2003-2004 during the MÉTA project (MOLNÁR et al. 2007). Oxbows are intensively studied since the end of 1990's (DÉNES and ORTMANN-AJKAI 1999, 2006, ORTMANN-AJKAI 2004). Faunistical studies cover a large diversity of groups. Two of the above-mentioned volumes (UHERKOVICH 1995, 1998) are fully zoological, and there are many recent results in the other two ones. More references for aquatic Coleoptera and Heteroptera are to be found in KÁLMÁN et al. (2011).

Field survey

In summer 2010 (August and early September) 30 small water bodies (mostly oxbows and temporarily cut-off side-arms) were surveyed. Selection of the sites was based on literature data, authors' and national park managers personal knowledge and satellite images (GoogleEarth). Names, GPS coordinates, and types of sites are listed in Table 1.

Table 1. List of sites with GPS coordinates, types and codes.

Name of sampling sites	Code	Type	Lat. (N)	Lon. (E)
Füzesi oxbow (Vejti)	Ve	1	45°47'39,23"	17°58'04,62"
Kenderáztató (Drávapalkonya)	Ke	1	45°47'13.39"	18°10'45.22"
Boros-Dráva (Old)	Bo	2	45°45'00.24"	18°20.27.56"
Dázsonyi oxbow lake (Drávaszabolcs)	Dá	2	45°47'06.84"	18°13'27.46"
Felső-Lóka (Drávakeresztúr)	FL	2	45°49'25,97"	17°46'54,44"
Felsőszentmárton branch (Felsőszentmárton)	FSzMe	2	45°50'13,63"	17°42'22,97"
Gyöngyszigeti oxbow (Kemse)	GySz	2	45°47'44,27"	17°55'06,02"
Oxbow near Támasós (Tésenfa)	TáG	2	45°47'33,04"	18°07'28,52"
Kiserdei oxbow (Drávakeresztúr)	KisE	2	45°49'34,64"	17°44'54,96"
Mrtvica, branch (Felsőszentmárton)	Mhu	2	45°50'32,71"	17°42'35,03"
Roza oxbow (Tésenfa)	Ro	2	45°47'31,06"	18°08'37,28"
Támasós oxbow (Tésenfa)	Tá	2	45°47'21,91"	18°07'18,19"
Zokogai oxbow (Drávakeresztúr)	Zo	2	45°49'05,95"	17°46'36,12"
Borjanci oxbow (Felsőszentmárton)	Bor	3	45°50'19.68"	17°40'03.51"
Alder swamp near the dam (Kisszentmárton)	KA	4	45°48'33,59"	17°48'12,67"
Alder swamp near the village (Kisszentmárton)	KÉ	4	45°49'21,18"	18°01'10,02"
Oxbow1 (Kisszentmárton)	Kat	4	45°48'42,59"	18°02'19,43"
Oxbow2 (Kisszentmárton)	KK	4	45°48'40,68"	18°02'13,34"
Mailáthpusztai oxbow lake (Kisszentmárton)	MH	4	45°46'50,45"	18°03'41,65"
Hótedra oxbow lake (Gordisa)	Hó	5	45°46'12.99"	18°15'17.95"
Kisinci oxbow lake, Cún-Szaporcai Ó-Dráva (Szaporca)	KisI	5	45°46'51,49"	18°06'08,75"
Külső-Hobogy, Cún-Szaporcai Ó-Dráva (Szaporca)	KH	5	45°48'02,99"	18°05'33,32"
Piskói oxbow lake (Piskó)	Pi	5	45°47'44,23"	17°55'52,61"
Recska oxbow lake (Alsószentmárton)	Re	5	45°47'00.39"	18°18'55.98"
Vájási oxbow lake (Drávasztára)	Vá	5	45°48'21,17"	17°50'20,36"
Belső-Hobogy oxbow lake, Cún-Szaporcai Ó-Dráva (Szaporca)	BH	6	45°47'57,16"	18°05'25,44"
Szilháti oxbow, Cún-Szaporcai Ó-Dráva (Szaporca)	SzH	6	45°48'02,74"	18°05'17,52"
playground flooded by inland water (Kovácshida)	KHJ	7	45°50'02.86"	18°10'57.38"
Small pond (Cún)	Cú	7	45°47'56,26"	18°04'21,36"
Inland water by the dam (Drávakeresztúr)	OgG	7	45°50'04,06"	17°44'22,88"

Botanical data collecting included compiling lists of plant species, plant communities (BORHIDI 2003), and habitats (BÖLÖNI et al. 2007) of the sites. Sampling of aquatic macroinvertebrates: During the collecting period (2010 summer and autumn) aquatic macroinvertebrates were captured by sweeping with a long handled (1,5 m) pond net (mesh size: 0,5 mm) on water surface, and among the submerged or emergent vegetation. Captured specimens were preserved in 70% ethyl-alcohol.

In the present study we were using the data of Coleoptera and Heteroptera. Coleoptera were identified by Z. Csabai, Z. Kálmán and A. Kálmán; Heteroptera by N. Soós, using keys of ANGUS (1992), BENEDEK (1969), CSABAI (2000, 2003), CSABAI et al. (2002), JANSSON (1986), SAVAGE (1989) and SOÓS (1963).

Data analysis

Sites were grouped empirically into types. Species and habitats lists of types were compiled by summarizing data of sites belonging to each type. Types were compared by species and habitat numbers and composition. Interdependence of water body types, topographic position (flooded/protected part), habitats and biota were analysed by multivariate methods. After linearity of data was tested (LEPS and SMILAUER 2003) redundancy analysis (RDA) and hierarchical classification of sites and species (presence-absence data) were performed using CANOCO for Windows version 4.5 (TER BRAAK and SMILAUER 2002) and Past version 1.99 (HAMMER et al. 2001). RDAs were executed only with species occurring at least at two sites

Results

Faunistical data

A total of 73 Coleoptera Haliplidae 7; Dytiscidae 38; Noteridae 2; Spercheidae 1; Hydrochidae 4; Helophoridae 2; Hydrophillidae 18; Dryopidae 1) and 25 Heteroptera species (Nepidae 2; Corixidae 7; Naucoridea 1; Notonectidea 3; Pleidae 1; Mesoveliidae 2; Hydrometridea 2; Hebridae 1; Veliidae 2; Gerridae 4) were found. Most important species is *Graphoderus bilineatus*, an endangered, disappearing, listed in many Red Lists (Bern Convention, Annex of Habitat Directive, and IUCN) strictly protected species in Hungary and in most European countries. It formerly as catched in site oxbow lake, Támasós (Tésenfa); it is new for Drava floodplain, formerly it was known only from northeast Hungary. Other notable species: Coleoptera: *Hydrochus megaphallus*, *Rhantus exoletus*; Heteroptera: *Notonecta lutea* and *Mesovelia thermalis.* More information and a full list of faunistical records can be found in KÁLMÁN et al. (2011).

Characteristic habitats and occurrence of types

Side arms (Type 1) with frequent and strong flooding and steep banks are poor in habitats: mostly small-sized floating plant communities (A1) mostly of *Lemna minor*. In more terrestrialized Type 2 sedimentation produces a mosaic of sites with different shallow water levels, where diverse aquatic and riparian vegetation can develop, with large-sized floating and rooting plants (A23 – with *Nymphaea alba, Nuphar lutea, Stratiotes aloides, Utricularia vulgaris*), different types of low riparian vegetation (B2, B3 – *C.pseudocypeus, Myosotis palustris, Butomus umbellatus, Alisma spp*), sedges B5 (mostly *Carex gracilis)* and reedbeds (B1a), develops with species. At the end stage of flooded-area series the oxbow is filled up, dominated by dense *Salix cinerea* bush (J1a), but many other habitats of the former stage are preserved in small fragments. In Type 4 – diverse middle-stage in protected area –

all habitats can be found except shallow-bank riparian ones (B2, B3, and B5), often mire types too: oligotrophic reed and sometimes floating *Typha angustifolia* beds (B1b), A23, alder mires and swamps (J2). Fishponds (Type 5) represent an anthropogenic deviation from the natural successional series, with most of the habitats still present, but in a fragmented and degraded state (which cannot be seen in our presence-absence data). Because of many plant-eating fishes large-sized floating plants dominate (A3a, A23: *Nymphaea alba, Nuphar lutea, Nymphoides peltata*). End stage of succession (Type 6) is similar to that of Type 3 (J1a, *Salix cinerea* bush). Newly created and temporary water bodies are surprisingly rich in vegetation (and fauna also) with aquatic (A1, A23) and riparian habitats (B1a, B2, B3). Habitat occurrences in types are summarized in Table 2.

Table 2. Á-NÉR habitats in types.

Type No.	Type	Á-NÉR habitats
1	Side arms	A1 standing water communities, with Lemna, Trapa, Salvinia and *Ceratophyllum* B1a Eu- and mesotrophic reed and *Typha* beds B5 Non-tussock beds of large sedges
2	Flooded part, diverse middle stage	A1 standing water communities, with *Lemna, Trapa, Salvinia* and *Ceratophyllum* A23 Euhydrophyte communities with *Nymphaea, Nuphar, Utricularia* and *Stratiotes* B1a Eu- and mesotrophic reed and *Typha* beds B2 *Glyceria, Sparganium* and *Schoenoplectus* beds B3 Water-fringing helophyte beds with *Butomus, Eleocharis* and *Alisma* B5 Non-tussock beds of large sedges J1a Willow mire shrubs
3	Flooded part, terrestrialized end stage	A1 standing water communities, with *Lemna, Trapa, Salvinia* and *Ceratophyllum* A23 Euhydrophyte communities with *Nymphaea, Nuphar, Utricularia* and *Stratiotes* B1a Eu- and mesotrophic reed and *Typha* beds B2 *Glyceria, Sparganium* and *Schoenoplectus* beds B3 Water-fringing helophyte beds with *Butomus, Eleocharis* and *Alisma* B5 Non-tussock beds of large sedges J1a Willow mire shrubs
4	Protected part, diverse middle stage	A1 standing water communities, with *Lemna, Trapa, Salvinia* and *Ceratophyllum* A23 Euhydrophyte communities with *Nymphaea, Nuphar, Utricularia* and *Stratiotes* A3a Communities of slowly running waters with *Potamogeton* and *Nymphoides* B1a Eu- and mesotrophic reed and *Typha* beds B1b Oligotrophic reed and *Typha* beds of fens, floating fens J1a Willow mire shrubs J2 Alder and ash swamp woodlands
5	Fishponds	A1 standing water communities, with *Lemna, Trapa, Salvinia* and *Ceratophyllum* A23 Euhydrophyte communities with *Nymphaea, Nuphar, Utricularia* and *Stratiotes* A3a Communities of slowly running waters with *Potamogeton* and *Nymphoides* B1a Eu- and mesotrophic reed and *Typha* beds J1a Willow mire shrubs J2 Alder and ash swamp woodlands
6	Flooded part, terrestrialized end stage	A1 standing water communities, with *Lemna, Trapa, Salvinia* and *Ceratophyllum* B1a Eu- and mesotrophic reed and *Typha* beds J1a Willow mire shrubs
7	Temporary waters	A1 standing water communities, with *Lemna, Trapa, Salvinia* and *Ceratophyllum* A23 Euhydrophyte communities with *Nymphaea, Nuphar, Utricularia* and *Stratiotes* B1a Eu- and mesotrophic reed and *Typha* beds B2 *Glyceria, Sparganium* and *Schoenoplectus* beds B3 Water-fringing helophyte beds with *Butomus, Eleocharis* and *Alisma*

Diversity patterns of successional series

Diversity of types was compared using a very simple diversity measure, number of habitats or species of a type as a percent of all occurring in all studied types. Results are presented in Fig.2. Succession usually begins with assemblages poor in species; diversity increases for a while then decreases again. Our results prove this for all studied biotic objects (habitats, plant, Coleoptera and Heteroptera species) but in a different degree. In flooded area successional series (Types 1 – 2 - 3) number of plant, Coleoptera and Heteroptera species are all much higher in the middle stage than in beginning and end stage. In the series of protected part (1- 4,5 – 6) this diversity „bow" also can be seen but the decrease at the end stage is less marked. Type 4 and 5 (near-natural oxbows and oxbows used as fishponds) differ in degree of anthropogenic disturbation. This makes only a slight difference for plant species and habitats (according to these presence-absence data); there are far less water beetle species in fishponds (19/39), almost as low as in the end stage (17), but more water bug species (10/7). Temporary and newly created water bodies (Type 7) show a surprisingly high diversity, almost as high as middle stages for plants and habitats, and the same and even higher for water beetles and bugs.

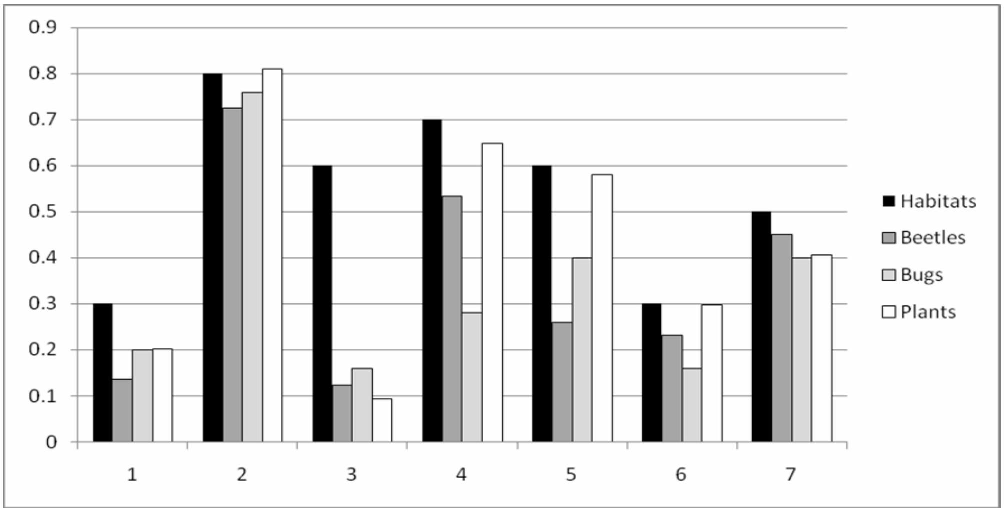

Fig. 2. Habitats and species numbers of types (as a percent of all occurring in all studied types).

Results of multivariate analyses

Results of RDAs are summarized in Table 3.

Habitats and plants: Habitat and plant species composition of water bodies are strongly determined by topography (flooded or protected part of the floodplain) and successional type. Flooded water bodies (T1, T2, T3) are characterized by dense *Lemna* cover (A1) and rich riparian vegetation of shallow banks (B2, B3, B5). On the protected side (T4, T5, T6) there are big-leaved water plants of open-water lakes (A2, A3a), reedbeds (B1a, B1b) and woody end-stages (*Salix cinerea* bushes J1a, *Alnus* mire forests J2). Fig.3.

Table 3. Results of RDA. All species data are without species occurring only in one site. Variance explained by first/all canonical axes: p1=significance of first canonical axe; p1/p all=significance of first canonical axis/all canonical axes; values significant at p<0.05 are highlighted in **bold**.

	Flooded/protected		**Types**		**Habitats**	
	Variance explained	**p1**	**Variance explained**	**p1/p all**	**Variance explained**	**p1/p all**
Habitats	9	**0.002**	11/19/25	0.06/**0.003**		
Plant species	8,5	**0,001**	10/16/20	**0.002/0.006**	11/17/22	**0.007/0.03**
Beetle species	4	0,2	9/15/19	**0.01/0.01**	9/16/23	0.13/**0.02**
Bug species	3	0,53	11/13/13	**0.01/0.005**	10/17/23	0.38/0.38

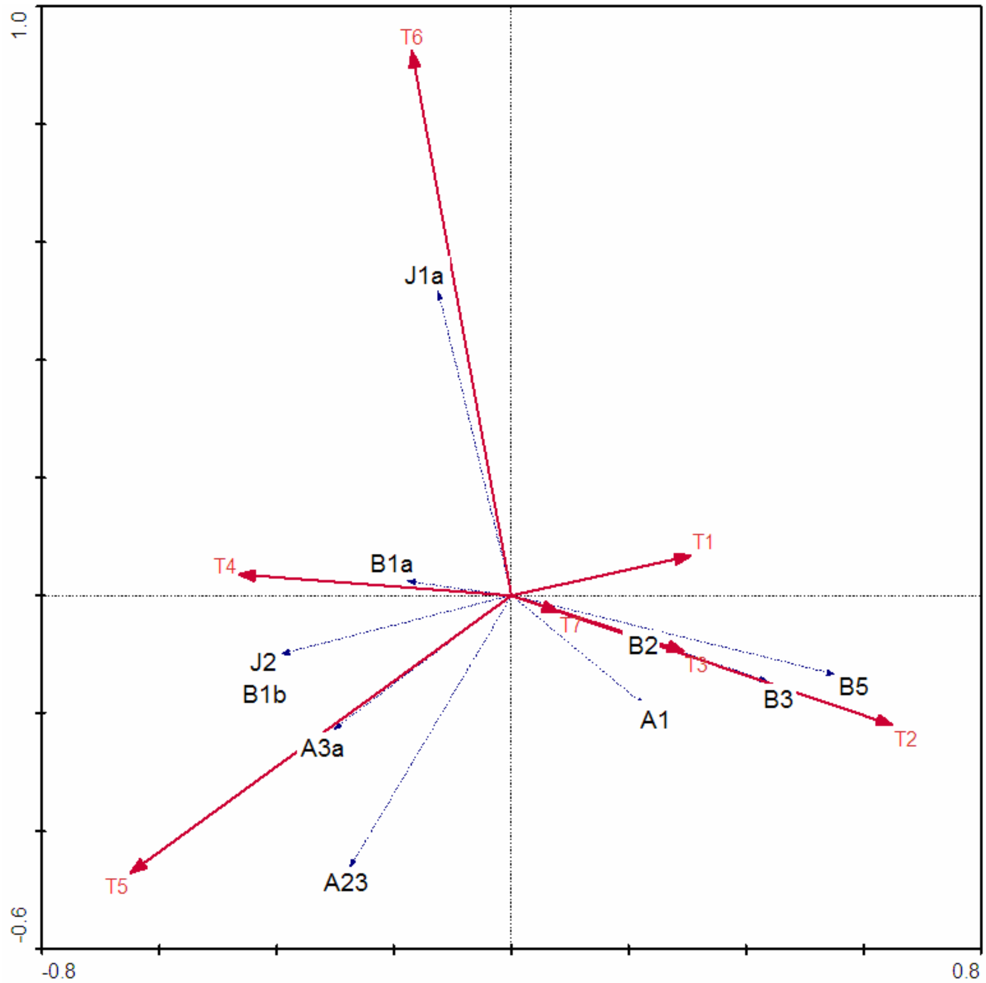

Fig.3. RDA plot with habitat data. T1-T7: types (see Fig.1.), A1-J2: habitats (see text and Table 2.).

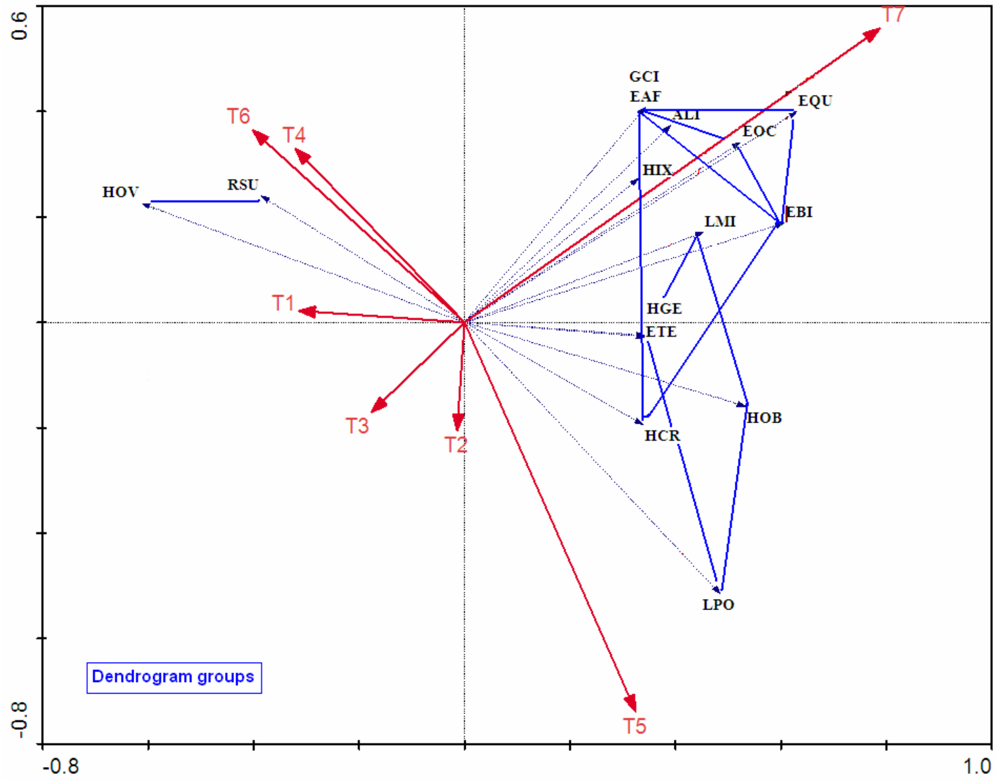

Fig.4. RDA plot with beetle species data. [T1-T7: types (see Fig.1.). Coleoptera species codes for Fig. 4. and Fig. 5.: ACA=*Acilius canaliculatus* Nicolai, 1822; ALI=*Anacaena limbata* Fabricius, 1792; ASU=*Acilius sulcatus* Linnaeus, 1758; AUN=*Agabus undulatus* Schrank, 1776; CFU=*Colymbetes fuscus* Linnaeus, 1758; CLA=*Cybister lateralimarginalis* De Geer, 1774; CMA=*Cymbiodyta marginella* Fabricius, 1792; COR=*Coelostoma orbiculare* Fabricius, 1775; EAF=*Enochrus affinis* Thunberg, 1794; EBI=*Enochrus bicolor* Fabricius, 1792; ECO=*Enochrus coarctatus* Gredler, 1863; EME=*Enochrus melanocephalus* Olivier, 1792; EOC=*Enochrus ochropterus* Marsham, 1802; EQU=*Enochrus quadripunctatus* Herbst, 1797; ETE=*Enochrus testaceus* Fabricius, 1801; GAU=*Graphoderus austriacus* Sturm, 1834; GCI=*Graphoderus cinereus* Linnaeus, 1758; GPI=*Graptodytes pictus* Fabricius, 1787; HAN=*Hydroporus angustatus* Sturm, 1835; HAT=*Hydrophilus aterrimus* Eschscholtz, 1822; HCA=*Hydrochara caraboides* Linnaeus, 1758; HCR=*Hydrochus crenatus* Fabricius, 1792; HFL=*Haliplus fluviatilis* Aubé, 1836; HFX=*Hydrochara flavipes* Steven, 1808; HGE=*Hydroglyphus geminus* Fabricius, 1792; HGR=*Hydaticus grammicus* Germar, 1830; HIM=*Haliplus immaculatus* Gerhardt, 1877; HIX=*Hygrotus impressopunctatus* Schaller, 1783; HIN=*Hygrotus inaequalis* (Fabricius, 1776); HOB=*Haliplus obliquus* Fabricius, 1787; HOX=*Helochares obscurus* O.F.Müller, 1776; HOV=Hyphydrus ovatus Linnaeus, 1761; HPA=*Hydroporus palustris* Linnaeus, 1761; HRU=*Haliplus ruficollis* De Geer, 1774; HSE=*Hydaticus seminiger* De Geer, 1774; HTR=*Hydaticus transversalis* Pontoppidan, 1763; HVE=*Hygrotus versicolor* Schaller, 1783; LHA=*Liopterus haemorrhoidalis* Fabricius, 1787; LHY=*Laccophilus hyalinus* De Geer, 1774; LMI=*Laccophilus minutus* Linnaeus, 1758; LMX=*Laccobius minutus* Linnaeus, 1758; LNI=*Limnoxenus niger* Zschach, 1788; LPO=*Laccophilus poecilus* Klug, 1834; NCL=*Noterus clavicornis* De Geer, 1774; NCR=Noterus crassicornis O.F.Müller, 1776; PCA=Peltodytes caesus Duftschmid, 1805; PLI=Porhydrus lineatus Fabricius, 1775; RBI=Rhantus bistriatus Bergsträsser, 1778; RSU=Rhantus suturalis MacLeay, 1825; SDO=Suphrodytes dorsalis Fabricius, 1787].

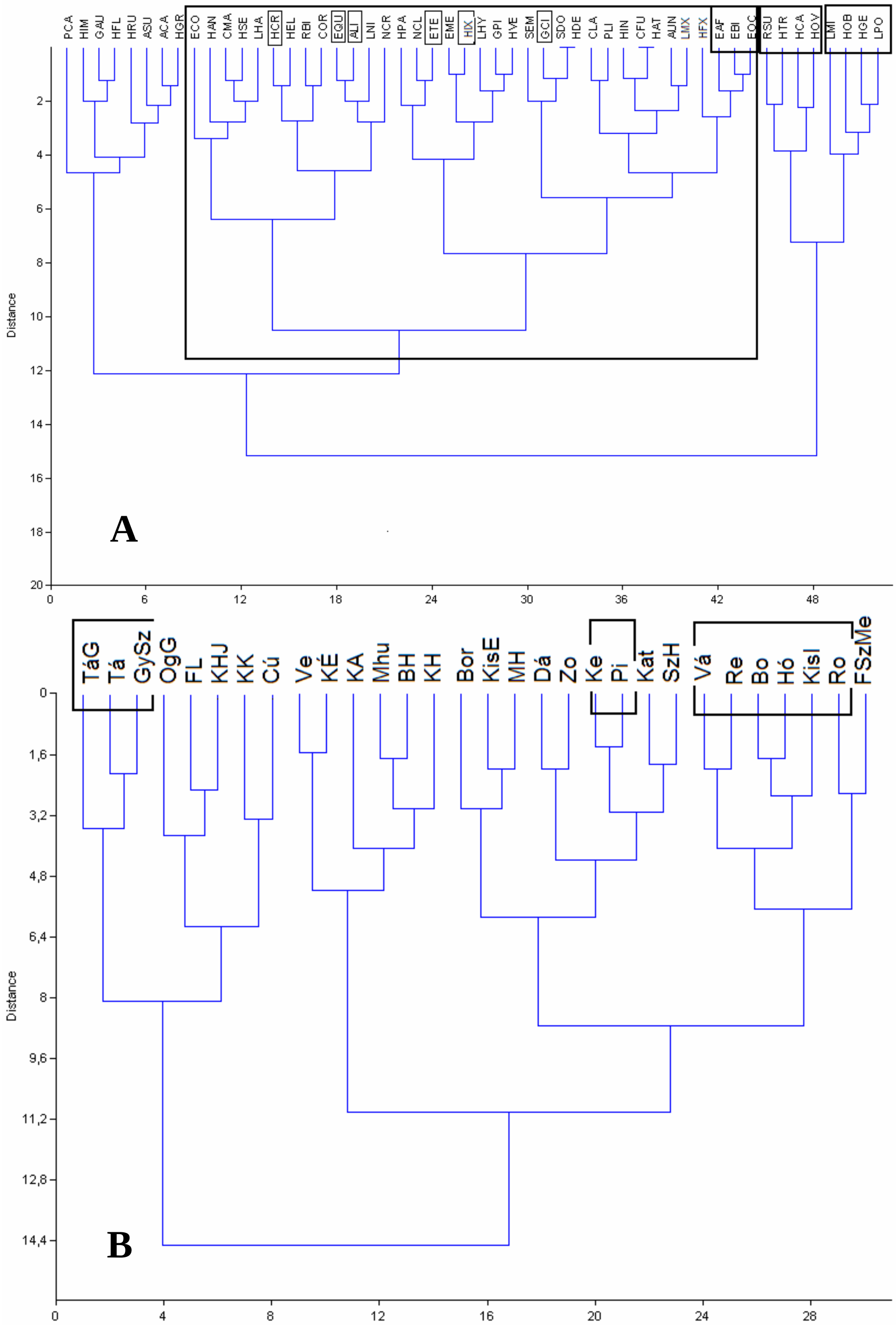

Fig. 5. Dendrogram of beetle species (A) and site (B) data (Euclidean distance, Ward's clustering; site codes are according to Table 1; species codes see in the title of Fig. 4.).

Water beetles: RDA was executed only with species occurring at least at two sites. Ordination plots for Coleoptera (Fig.4) displays two distinct species groups, with few characteristic species (variance explained over 30%: *Hyphydrus ovatus*) on the shady and more on the open side (variance explained over 30%: *Enochrus quadripunctatus*, *Enochrus bicolor*, above 25%: *Haliplus obliquus*, *Enochrus ochropterus*, over 20%: *Laccophilus poecilus*, *Laccophilus minutus*). On the dendrogram of Ward's clustering (Fig.5a) the first separating group consists of species *Laccophilus poecilus*, *Laccophilus minutus*, *Haliplus obliquus*, *Hydroglyphus geminus, Hyphydrus ovatus, Rhantus suturalis*, which show strongest separation (largest explained variances) also in RDA, but in different sides of the scattergram. Next separating group consist of species with low explained variance (not displayed in Fig 5a). The remaining big group is situated on the „open" (T5, T7 types) side of the RDA scattergram, but without further differentiation.

Water bugs: For Heteroptera species, RDA ordination plots (Fig. 6) and dendrogram (Fig. 7a) show more similar groups. On RDA plot, many species are over average explained variance limit (11%), but only three are above 15% (*Plea minutissima, Microvelia buenoi, Gerris lacustris*) and none above 20%, and their connection with habitats or types are not clear. Three of four groups separated in the dendrogram are distinguished clearly, and the fourth partly on RDA plot too. *Plea minutissima*, *Microvelia reticulata,* and *Notonecta glauca* seems to be associated to more or less terrestrialized types of the floodplain (T2, T3); *Microvelia buenoi* and *Gerris lacustris* to non-floodplain end stage (T6). NEPA, SST, and SFA associate to open lakes (T4, T5) on the protected part. The fourth, more undetermined group seems to be more, but not exclusively on the flooded part.

Discussion

Our results support that stages of mineralogenic and organogenic succession on floodplains and anthropogenic effects produces distinct water body types both on flooded and protected parts of the floodplain of river Drava. These stages can be well characterized with vegetation-based (Á-NÉR) habitats.

Our main hypothesis, that these types have different aquatic Coleoptera and Heteroptera assemblages, is supported by the fact that occurrence of at least some species is determined by habitats or other characteristics of the types (e.g. position on flooded or protected part, shallow or steep banks).

Species numbers of different groups correspond well with conventional successional schemes and habitat numbers. Middle stages both on flooded and protected sides have remarkably higher species numbers than those of beginning and end stages. More diverse habitat and vegetation structure means more diverse microhabitats, shelter and food opportunities for most aquatic macroinvertebrate groups.

As for near-natural and strongly anthropogenic types of diverse middle stages of protected side – near-natural oxbows and those used as fishponds -- the two macroinvertebrate groups behaves differently. Aquatic beetle fauna of fishponds is impoverished compared to that of near-natural oxbows, but bug species number is higher in fishponds that in near-natural oxbows.

Results of multivariate analysis also show different patterns for the two macroinvertebrate groups, not always interpretable with studied variables. Significant correlations were found between water types and both aquatic Coleoptera ($p=0.01$ both for first and all canonical axes) and Heteroptera species ($p=0.01$ for first, $p=0.005$ for all canonical axes). These results prove that these types, determined by hydrogeomorphic conditions (water regime, flooding) differing by topographical position (flooded or protected side), are real functional elements of floodplains. Variances explained by first RDA axes are 9% for beetles and 11% of bugs, and 43% and 37% accordingly for the first three RDA axes. These values, although low compared to studies of direct environmental variables (e.g. OBOLEWSKI 2010, SKERN et al. 2010), are acceptable for cases of indirect, complex environmental variables as habitats or geomorphologic or other empirical types (LEPS and SMILAUER 2003).

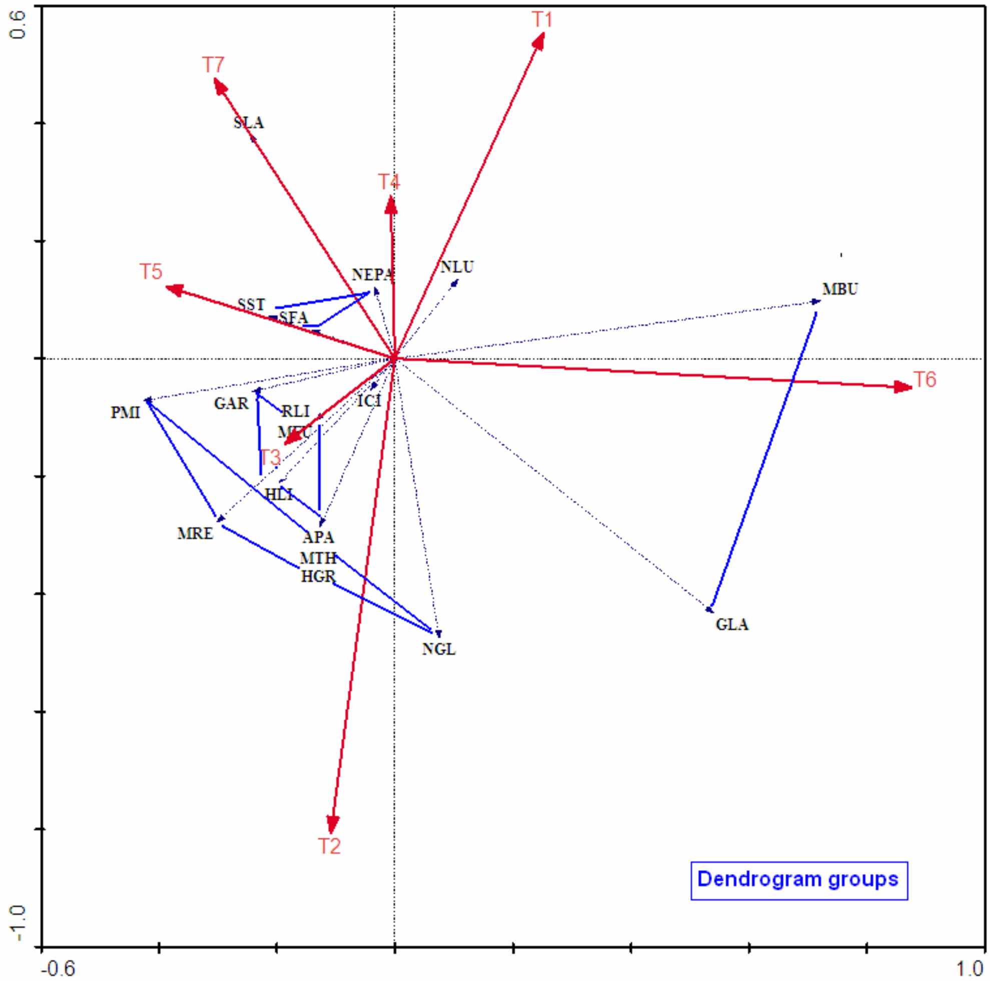

Fig. 6. RDA plot for bug and type data. [T1-T7: types see Fig.1. ; Heteroptera species codes for Figs 6. and 7.: APA=*Aquarius paludum* Fabricius, 1794; GAR=*Gerris argentatus* Schummel, 1832; GLA=*Gerris lacustris* Linnaeus, 1758; HGR=*Hydrometra gracilenta* Horváth, 1899; HLI=*Hesperocorixa linnaei* Fieber, 1848; ICI=*Ilyocoris cimicoides* Linnaeus, 1758; MBU=*Microvelia buenoi* Drake, 1920; MFU=*Mesovelia furcata* Mulsant et Rey, 1852; MTH=*Mesovelia thermalis* Horváth, 1915; NEPA=*Nepa cinerea* Linnaeus, 1758; NGL=*Notonecta glauca* Linnaeus, 1758; NLU=*Notonecta lutea* Müller, 1776; PMI=*Plea minutissima* Leach, 1817; RLI=*Ranatra linearis* Linnaeus, 1758; SFA=*Sigara falleni* Fieber, 1848; SLA=*Sigara lateralis* Leach, 1818; SST=*Sigara striata* Linnaeus, 1758].

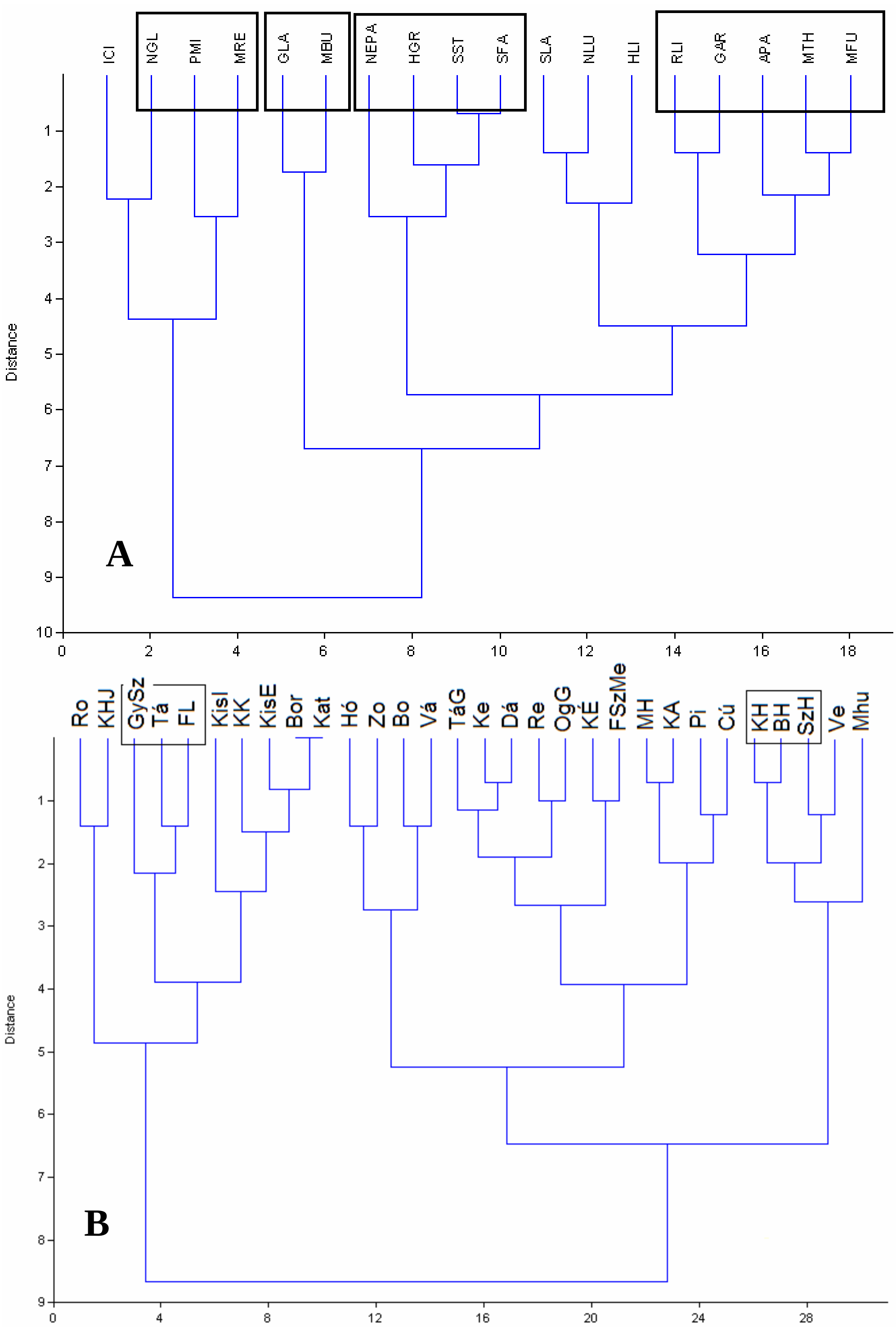

Fig. 7. Dendrogram of bug species (A) and site (B) data (Euclidean distance, Ward's clustering; site codes are according to Table 1; species codes see in the title of Fig. 6.).

No significant relationships were found between aquatic beetle and bug species and habitats and flooded or protected-part position, contradicting some studies (e.g. OBOLEWSKI 2010).

Characteristics patterns emerged from multivariate analysis are: separation and richness of temporal waters (T7), of fishponds (T5) and – in a lesser extent – separation of flooded-side diverse type (T2).

Temporary and newly created water bodies (Type 7) show a surprisingly high diversity. Their diversity is almost as high as middle stages for plants and habitats, and the same and even higher for water beetles and bugs (Fig.4) These water bodies also separate well especially by beetle data (Fig. 5, 6b). In the slightly sloping riparian zone of these waters B2 and B3 habitats – missing from larger protected-part lakes (T4, T5) – appear, thus compensating for missing broad-leaved (A3a) and woody (J1a, J2) plant communities. No habitat type is characteristic to only to this type (Fig.4). Beetles and bugs may prefer these shallow, quickly warming waters because of plenty of food, especially of Diptera larvae). At the end of summer many individuals of well-flying bugs and beetles emerged in static waters disperse to these waters and find their favourable conditions. *Enochrus* species (*E. quadripunctatus*, *E bicolor*, *E. ochropterus*, *E. affinis*) associated to T7 on RDA plot (Fig.4) with relatively high explained variances (above 30% for the first two ones) are good flyers and characteristic to temporal, shallow-shore waters.

Other consequently separating type is fishponds (T5). According to Fig.4., their habitat structure and vegetation is rich, but presence-absence data hide the fact that they are degraded, many habitat types occur only in fragments, as it is proved by fairly recent vegetation maps (DÉNES and ORTMANN-AJKAI 2006). Diversity of their Heteroptera fauna is highest in the protected part (Fig.2) but beetles are far less than in the more natural T4 type. This may be explained with the presence of many fish in fishponds. Large-sized introduced plant-eating fish (and also anglers, clearing their stands and boatways) destroy most of aquatic vegetation, except large, broad-leaved rooting plants as *Nymphaea alba*, *Nuphar lutea*, *Nymphoides peltata*. Steep banks of these oxbows also effects negatively vegetation development. Missing of aquatic macrophytes means a serious loss of microhabitats (food, shelter) for all aquatic macroinvertebrates. It is well expressed in remarkably less Coleoptera species, and separation of T4 and T5 types on Coleoptera RDA plot (Fig.4) contrasting to habitat and Heteroptera RDA plots (Fig.3, Fig.6). A floodplain-side fishpond (Boros-Dráva) – characterized as T2 empirically – even associates strongly to fishponds on dendrogram based on Coleoptera (Fig. 6b). As for Heteroptera, there are many species living on the water surface (open surface: Gerrideae, more floating plants: Microvelidae, Mesovelidae, Hydrometridae), eating small organisms falling from air, so they are not so much sensible to the loss of aquatic vegetation.

Some sites of T2 type tend to be close together (e.g. Gyöngysziget and Támasós both on Fig.5b, Fig.7b) and this type seems to be important for bugs (Fig.6), but not for beetle (Fig.4). Sites of protected-site diverse type (T4) and fishponds (T5) – similar successional stage and diversity, but different degree of anthropogenic effects – are similar regarding habitats and bugs, but very different for beetles, as explained above.

Our results prove that these water body types – defined by succession stages and anthropogenic effects – can be well characterized by habitat types. Aquatic Coleoptera and Heteroptera assemblages show significant correlations with the types, but these correlations can not be unambiguously explained with habitats or flooded or protected position (determining e.g. water regime and flood conditions).

Temporary waters harbour a rich array of many types of biota, so they represent a remarkable part of floodplain biodiversity and indicate a quick regeneration potential for certain organisms.

Our study was a quick preliminary one aiming to formalize more exact questions about how biodiversity of floodplain water bodies are determined by hydrological (flooded or protected-part position) and successional factors. We discovered some interesting patterns which call for more intensive studies: more quantitative sampling at least in some characteristic sites, a more detailed investigation of hydrological factors (flooding, connectedness of sites) and measurement of some physical parameters. Deepening our knowledge on linkages between hydrologic, plant and animal components of complex floodplain ecosystems may seriously improve decision-making in floodplain management, which is key for sustainable floodplain management for nature conservation and also for fulfilling requirements of Water Framework Directive.

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