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Aquatic macrophytes as bioindicators of water chemistry in nutrient rich backwaters along the Upper-Tisza river (in Hungary)

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with 1 figure and 5 tables

Abstract. We assessed the relationship of vegetation composition and water chemical parameters in five nutrient rich backwaters in NE Hungary. We used 126 plots and water samples analysed for 19 water chemical parameters. Our hypothesis was that environmental variables might be decisive for macrophyte species composition in waters with different nutrient content. We also supposed that community-environment and species-environment relationship of nutrient rich water may differ from nutrient poor ones. TWINSPAN analysis was used to reveal the main vegetation units, and detrended canonical correspondence analysis (DCCA) was used to explore the water chemical demands of these communities and the species-water chemical parameters relationships.

We found 8 communities by TWINSPAN. Among the water chemical parameters Ca^{2+}, COD, NO$_2$, Mg^{2+}, Cl$^-$ were important in differentiating the communities. In the nutrient rich backwaters we found similar results as other authors found in nutrient poor waters and fens. Glycerietum maximae association found in waters with high amount of COD and NO$_2^-$, Typhetum angustifoliae association correlated negatively with these water chemical parameters and Sparganietum erecti and Potametum lucentis associations prefer both habitats. Bolboschoenion and Schoenoplectetum lacustris associations have been found to prefer waters with high amount of Cl$^-$. Trapetum natantis and Ceratophyllo-Nymphaeetum albae associations found to prefer waters with low amount of Ca^{2+}, COD, NO$_2^-$, Mg^{2+} and Cl$^-$, which proved the vulnerability of these protected associations in nutrient rich waters. In the case of species-water chemical parameters relationship we found high nitrogen correlation of C*eratophyllum demersum* and high Ca^{2+} correlation of *Potamogeton lucens*.

Keywords: detrended canonical correspondence analysis, macrophytes, vegetation, eutrophic backwaters.

Introduction

The ecology of aquatic macrophytes and their communities was the object of interest of many authors in the world (Wiegleb 1978, Srivastava et al. 1995, Toivonen & Huttunen 1995, Khedr & El-Demerdash 1997). Macrophytes and their communities are an important component of the littoral zone in various types of ponds. They form characteristic spatial patterns (Hutchinson 1975, Kłosowski 2006), which often constitute a transitional boundary between the open water and reedswamp communities. In addition, they play an important role in the process of overgrowing of ponds and modify the water and substrate properties, affecting the whole pond ecosystem (Carpenter & Lodge 1986).

Macrophytes have strong chemical effect on the water. Nutrient elimination from the water as well as nutrient pumping from the sediment into the water, oxygen production and elimination are the most important processes involved (Lee & McNaughton 2004). They have large part of the function of rivers and lakes and have important role on the rehabilitation of a water course (Dahl & Wiegleb 1984).

Both macrophytes and their communities may be good indicators of the changes occurring in ponds and other water bodies as a result of human-induced acidification (Arts 2002) and eutrophication (Arts 2002, Nurminen 2003). Their findings indicate that both macrophytes and their communities (in various regions) could not only reflect the effects of anthropogenic impact but can be also considered as indicators of various habitat conditions in water ecosystems (Vastergaard & Sand-Jensen 2000, Heegaard et al. 2001, Murphy 2002). Vegetation and environment relationship mostly studied in large or middle geographic scale (Pott 1983, Ellenberg 1988, Grasmuck et al. 1995, Khedr & El-Demerdash 1997, Mäkelä et al. 2004, Meilinger et al. 2005, Lacoul & Freedman 2006, Kłosowski 2006, Penning et al. 2008). There are several studies in Central-Europe, which studied the relationship of environmental variables and macrophyte communities (Tóth & Braun 1995, Somodi & Botta-Dukát 2004, Navrátilová & Navrátil 2005).

The present work summarizes an ecological study about various aquatic macrophyte communities in backwaters of North-East Hungary. The Carpathian-Basin is very rich in these kinds of habitats. There are more than 160 backwaters along the river Tisza (Pálfai 2003). The main objectives of this study were to determine the habitat properties which best differentiated the aquatic and shoreline vegetation in nutrient rich backwaters. We compare the results of this study with the data reported by other authors (Tóth & Braun 1995, Hájková & Hájek 2003,

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Hájková et al. 2004, Somodi & Botta-Dukát 2004, Navrátilová & Navrátil 2005) from nutrient poor waters.

Materials and methods

Study area and vegetation

The studied backwaters are in the Carpathian Basin, at the Hungarian part of the Upper-Tisza region (NE Hungary). The main attributes of them are demonstrated by Table 1. The study was carried out in 2006 at the height of the growing season (end of July). Aquatic and shoreline plant communities were studied using 126 plots of 2 m by 2 m. The assignments were made with random sampling based on a GIS map and computerized randomization. The number of plots was correlated with the vegetation mosaic structure (Dubois et al. 1984) of each backwater (see Table 1). Percentage cover of macrophyte species was recorded in each plot. Plant names follows Simon (2000), the nomenclature of syntaxa follows Borhidi (2003).

Water chemical parameters

Five litre water column samples per community and backwater were taken into plastic containers at the same time of vegetation survey. Chemical-, and biological parameters of the water samples (Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, NH_4^{+}, NO_2^{-}, NO_3^{-}, a-chlorophyll, hydrogen-carbonate, carbonate, Kjeldahl-N, chloride, COD, conductivity, pH and total-phosphorus, dissolved orto-PO_4, SO_4^{2-}, p-alkalinity) were analyzed within 4 hours after the sampling. In situ measurements (conductivity and pH) were also carried out by a water quality multiprobe (Hydrolab 4a, Hach LDO™). These measurements provided the same results as laboratory surveying. For the a-chlorophyll assessment we used a photometer (Athelie, Secoman, France), and for the detection of Na, K, Ca and Mg we used an ICP-OES spectrometer (Vista-Pro, Varian Inc., USA). We measured the sulphate, ammonium, nitrite and nitrate and orto-phosphate concentrations by a double beam spectrophotometer (Cary 1-E, Varian Inc., USA). We also measured the pH in the laboratory by a SenTix electrode (inoLAB, WTW GmbH, Germany) and conductivity by a laboratory conductometer (Radelkis Ltd., Hungary).

Statistical analyses

Two related multivariate statistical techniques were used to analyse the data: two-way indicator species analysis (TWINSPAN) and detrended canonical correspondence analysis (DCCA). Each approach provides a different view of the structure of the data (Økland 1996, Lepš & Šmilauer 2003). Vegetation data from all plots were subjected to two-way indicator species analysis (TWINSPAN, Hill et al. 1975) to classify the plots into groups of communities. Cut levels were 0, 0.1, 2, 5, 10, 20, 40, 60 and 80 percentage cover. DCCA was used to assess the relationships between the plots of the studied plant communities, the percentage cover of plant species, and the measured environmental variables using CANOCO (Ter Braak & Šmilauer 2002). Percentage cover was square root transformed to decrease the influence of highly dominant species. We decided to use detrending because we found an arch-effect by CCA. These backwaters create successive stages of pond-succession; in these ceases (i.e. in the case of series) the detrending is also proposed by the literature to avoid arch-effect (Lepš & Šmilauer 2003). Significance tests of these relationships were also done using a Monte-Carlo permutation test (Ter Braak & Šmilauer 2002).

Results

Species composition and abundance

Altogether 51 plant species were found in the studied backwaters. The vegetation of backwaters was classified by division of TWINSPAN into eight communities (Table 2). Each community is named according to the dominant species. "Lesser reedmace beds" (Type 1) syntaxonomically belongs to the association Typhetum angustifoliae. "Water chestnut carpets" (Type 2) occurred in sites with medium-deep water, mainly in the shores of the open water. It belongs to the association Trapetum natantis. Dominant species were *Trapa natans* and *Ceratophyllum*

Table 1. The main attributes of the studied ponds.

	Ponds name	Average deepness (m)	Area (ha)	Geographic coordinates East / North		Number of plots	Total	Average
							Number of species	
1	Ducskósi-morotva	0.5	3.5	8°13.9'09"	2°48'54.8"	23	18	4.1
2	Báka-szegi-morotva	0.6	6.78	8°4'51.9"	2°46'44.9"	30	24	3.5
3	Rózsás-dűlői-Holt-Tisza	0.9	14.45	7°59'41.4"	2°58'47.3"	14	20	6.2
4	Boroszló-kerti-Holt-Tisza	2.2	13.4	8°6'3.9"	2°47'8.2"	42	32	4.9
5	Ispán-szegi-Holt-Tisza	0.4	4.88	8°0'44.3"	2°52'37.0"	17	19	4.7

Table 2. Table of vegetation types (1–8) obtained by TWINSPAN classification. The species average covers are shown. Diagnostic species are highlighted by frames. Notations: 1 – Typhetum angustifoliae, 2 – Trapetum natantis, 3 – Ceratophyllo-Nymphaeetum albae, 4 – Sparganietum erecti, 5 – Glycerietum maximae, 6 – Potametum lucentis, 7 – Schoenoplectetum lacustris, 8 – Bolboschoenion.

Vegetation type	1	2	3	4	5	6	7	8
Number of plots	3	20	8	16	19	26	18	12
Typha angustifolia	$\boxed{80.00}$							
Stratiotes aloides			1.43					
Nymphaea alba	1.67	0.59	$\boxed{41.79}$	1.94	0.02			
Trapa natans	0.03	$\boxed{65.89}$	12.16	$\boxed{23.37}$	0.01			
Nuphar lutea		8.35		0.01				
Myriophyllum verticillatum		8.80	1.80	3.90				
Ceratophyllum demersum		$\boxed{30.20}$	8.40	3.80				
Alisma lanceolata		0.60	1.10					
Mentha aquatica			0.01					
Lysimachia nummularia				0.01				
Lemna trisulca			0.01					
Utricularia vulgaris	0.03		6.80	3.25	0.78			0.01
Rorippa amphibia		0.59	1.94	0.01	0.01	0.01	0.38	
Hydrocharis morsus-ranae	0.10		2.00	2.70				1.80
Sparganium erectum	0.03	0.59	7.51	$\boxed{30.12}$	2.32	11.64	9.62	1.32
Salvinia natans	11.67		0.01	0.01	0.02	0.10		1.58
Sagittaria sagittifolia							1.90	
Equisetum palustre			0.70	0.30	2.70			
Bidens tripartita			0.01	0.01	0.01			0.01
Potamogeton natans			0.00	0.88		2.34		
Polygonum amphibium		0.89	0.51	0.32	1.56	1.89	0.01	
Oenanthe aquatica			0.73	0.12		2.84		
Glyceria maxima		0.01	8.24	12.66	$\boxed{85.00}$	6.94	5.39	$\boxed{16.85}$
Potamogeton lucens	6.70		3.71	4.42	1.15	$\boxed{51.80}$	1.92	
Salix fragilis			0.01			2.50		0.01
Potamogeton trichoides						0.07		
Eleocharis palustris						1.00		
Alopecurus aequalis						0.01		
Typha latifola						1.00	6.92	
Schoenoplectus lacustris			0.57		0.54	7.24	$\boxed{56.69}$	9.37
Carex vesicaria					0.02			
Carex elata					0.20			
Lysimachia vulgaris	0.03			0.01	1.92	0.50	6.09	7.14
Lycopus europaeus				0.01	1.17			0.43
Lemna minor							0.15	0.11
Phragmites australis								0.11
Bolboschoenus maritimus						3.30		$\boxed{16.60}$
Stachys palustris				0.01	0.02		0.46	1.49
Symphytum officinale								0.01
Lythrum salicaria					0.38		0.01	3.55
Lycopus exaltatus								0.32
Amorpha fruticosa								0.30
Alisma plantago-aquatica					0.40	0.10	0.40	9.50
Rubus caesius								3.16
Polygonum lapathifolium								0.01
Phalaroides arundinacea								8.69
Euphorbia palustris								0.20
Calystegia sepium								1.60
Iris pseudacorus			0.36	0.01				3.11
Fraxinus angustifolius			0.40					1.60
Butomus umbellatus				0.35			0.01	0.81

demersum. "Waterlily beds" (Type 3) were found in undisturbed sites. Dominant species were *Nymphaea alba*; other diagnostic species were *Trapa natans* and *Ceratophyllum demersum*. It belongs to the association Ceratophyllo-Nymphaeetum-albae. Marshes dominated by erect bur-reeds with the co-occurrence of water chestnut and shining pondweed are referred to as "erect bur-reed communities" (Type 4). It belongs to the association Sparganietum erecti. They separated but always grow together with "sweetgrass beds" (Type 5), which belongs to the association of Glyecrietum maximae and composed by several marshy and macrophyte species with low abundance. "Large pondweed beds" (Type 6) dominated by *Potamogeton lucens* and partly *Polygonum amphibium*. In many sites they grow together or near "erect bur-reeds". Common clubrush beds with *Lysimachia vulgaris* and *Schoenoplectus lacustris* creates Type 7. It belongs to the association Schoenoplectetum lacustris. It appeared in the transition zone of backwaters. Last TWINSPAN column represents the halophile clubrush beds (Type 8), which is dominated by *Glyceria maxima* and *Bolboschoenus maritimus*. It is very tolerant of drying, pollution and disturbance. Diagnostic species were *Lysimachia vulgaris*, *Calystegia sepium* and *Iris pseudacorus*. This community occurred in searing habitats and syntaxonomically belongs to the alliance Bolboschoenion.

Water chemical parameters

The means and standard error of our measurement of water chemical parameters in the eight communities are shown in Table 3. We found outlier values at a-chlorophyll, COD and NH_4^+ concentrations. Low concentrations of a-chlorophyll were found in water chestnut and waterlily beds. In contrast, a very high average concentration of a-chlorophyll was found in sweetgrass beds communities. COD concentration was the lowest in waterlily beds. Water chestnut, erect-bur reed and pondweed beds were also have low rates of COD. The concentration of NH_4^+ was the lowest in pondweed beds, common clubrush and halophile clubrush vegetation.

The forward selection of variables revealed COD, Mg^{2+}, Ca^{2+}, Cl^- and NO_2^- to be the most significant variables to explain the differences in species composition (Fig. 1). The convex hulls around the samples of the eight plant communities did only partly overlap (Fig. 1b). The first two DCCA-axes proved to be significant ($p= 0.002$), with a species-environment correlation of 0.856 and 0.716 respectively. They cumulatively explained 35.2% and 55.6% of the species-environment relations (explainable inertia), so we consider these results informative. NO_2^- and Mg^{2+} were significantly correlated ($p < 0.05$) to axis 1, while COD was significantly correlated to axis 2. Cl^- significantly correlated both axis and Ca^{2+} was not significantly correlated to any of the axes (Table 4).

Table 3. Water chemical characteristics (mean ± S.E) of vegetation types obtained by TWINSPAN. Notations are the same as in Table 2.

	1	2	3	4	5	6	7	8
a-chlorophyll ($\mu g\ l^{-1}$)	228.5 ± 223.15	17.25 ± 2.94	5.325 ± 2.33	48.065 ± 10.44	469.25 ± 120.67	48.703 ± 27.57	161.639 ± 34.31	233.629 ± 76.22
Ca^{2+} ($mg\ l^{-1}$)	28.967 ± 1.54	31.46 ± 1.03	29.662 ± 1.71	31.712 ± 1.10	54.203 ± 6.18	28.326 ± 0.68	26.05 ± 1.30	43.036 ± 5.15
hydrogen-carbonate ($mg\ l^{-1}$)	146.33 ± 21.34	134.63 ± 3.32	130.75 ± 5.07	142.4 ± 7.57	222.19 ± 35.78	158.679 ± 4.76	178.5 ± 5.75	217.986 ± 17.66
K^+ ($mg\ l^{-1}$)	3.393 ± 1.403	1.81 ± 0.042	1.874 ± 0.049	2.268 ± 0.323	2.481 ± 0.349	3.32 ± 0.312	5.05 ± 0.437	3.439 ± 0.578
carbonate ($mg\ l^{-1}$)	10 ± 10.000	3.65 ± 0.841	6 ± 1.342	4.447 ± 1.043	11.85 ± 2.817	5.5 ± 2.338	2.667 ± 1.893	7.286 ± 2.471
Kjeldahl-N ($mg\ l^{-1}$)	4.96 ± 2.16	3.5 ± 0.11	4.063 ± 0.17	3.559 ± 0.23	4.525 ± 0.64	3.263 ± 0.27	6.8 ± 0.61	5.414 ± 0.65
chloride ($mg\ l^{-1}$)	13.66 ± 4.17	9.18 ± 0.71	8.375 ± 0.32	13 ± 1.59	18.5 ± 0.95	15.458 ± 0.93	21.556 ± 1.08	16.857 ± 1.66
COD ($mg\ l^{-1}$)	159.63 ± 143.18	20.53 ± 1.88	16.037 ± 0.46	54.735 ± 17.59	421.17 ± 107.36	51.771 ± 17.81	198.394 ± 27.59	244.943 ± 65.89
Mg^{2+} ($mg\ l^{-1}$)	5.46 ± 1.317	4.75 ± 0.175	4.212 ± 0.194	6.259 ± 0.627	12.545 ± 1.691	7.454 ± 0.311	9.439 ± 0.211	11.971 ± 1.15
p-alkalinity ($mmol\ l^{-1}$)	2.4 ± 0.35	2.18 ± 0.05	2.125 ± 0.08	2.482 ± 0.08	4.38 ± 0.43	2.6 ± 0.07	2.928 ± 0.09	3.571 ± 0.29
Na^+ ($mg\ l^{-1}$)	14.28 ± 7.28	8.23 ± 0.71	7.7 ± 0.10	12.43 ± 1.88	17.40 ± 1.47	15.38 ± 1.71	25.694 ± 1.99	21.347 ± 2.174
NH_4^+ ($mg\ l^{-1}$)	0.066 ± 0.006	0.075 ± 0.003	0.0763 ± 0.002	0.08 ± 0.007	0.083 ± 0.015	0.107 ± 0.018	0.236 ± 0.020	0.354 ± 0.0737
NO_2^- ($mg\ l^{-1}$)	0.01 ± 0.0000	0.012 ± 0.0009	0.01 ± 0.0000	0.019 ± 0.0017	0.0194 ± 0.0026	0.011 ± 0.0009	0.0178 ± 0.0010	0.019 ± 0.0010
NO_3^- ($mg\ l^{-1}$)	0.37 ± 0.237	0.13 ± 0.006	0.109 ± 0.018	0.186 ± 0.024	0.261 ± 0.037	0.28 ± 0.035	0.497 ± 0.054	0.373 ± 0.0502
diss. orto-PO_4 ($mg\ l^{-1}$)	0.03 ± 0.0233	0.011 ± 0.0007	0.01 ± 0.0000	0.0288 ± 0.0070	0.0259 ± 0.0045	0.0338 ± 0.0079	0.0561 ± 0.0061	0.0407 ± 0.0080
total-phosphorus ($mg\ l^{-1}$)	0.65 ± 0.553	0.12 ± 0.013	0.0925 ± 0.005	0.631 ± 0.263	0.366 ± 0.193	0.478 ± 0.18	0.25 ± 0.0891	0.166 ± 0.013
sulphate ($mg\ l^{-1}$)	17.76 ± 10.269	8.45 ± 0.252	5.875 ± 0.639	11.695 ± 1.445	15.739 ± 1.955	16.148 ± 1.434	22.68 ± 1.698	22.107 ± 1.575
pH	7.38 ± 0.468	7.95 ± 0.0541	7.969 ± 0.0758	7.613 ± 0.119	7.454 ± 0.0953	7.165 ± 0.0957	6.727 ± 0.108	7.086 ± 0.134
conductivity (μS)	195.13 ± 19.433	200.45 ± 9.188	180.888 ± 5.786	225.50 ± 13.004	283.52 ± 10.301	225.5 ± 1.137	235.722 ± 4.701	270.743± 11.869

Table 4. Correlation coefficients between environmental variables and canonical correspondence axis (see Fig. 1.)

	Axis 1	Axis 2
Ca^{2+}	-0.0587	0.2371
COD(Cr)	-0.3542	0.4110*
NO_2	-0.3428*	0.1578
Mg^{2+}	-0.5278*	0.1064
Cl^-	-0.7723*	0.1236*

*$P < 0.05$

The group type 1 included the samples of lesser reedmace beds. These samples correlated negatively with the amount of nutrients (COD), Ca^{2+} and NO_2^-. The group type 2 contained the communities of water chestnut which have a negative correlation with Cl^- and Mg^+. The group type 3 contained waterlily beds, which have the same correlation as former one. Erect bur-reed communities (Type 4) grouped into a scattered group between waterlily and sweetgrass beds. They have a weakly positive correlation with Ca^{2+}, and a negative correlation with Cl^-. The group type 5 contains samples from sweetgrass beds, which correlated positively with the amount of nutrients (COD), Ca^{2+} and NO_2^-. Another group (Type 6) contained large pondweed beds, which, in contrast with the former, have a weakly negative correlation with the amount of nutrients (COD), Ca^{2+} and NO_2^- and a weakly positive correlation with Cl^-. Clubrush vegetation (Type 7) positively correlated with Cl^-. Halophile clubrush beds plots (Type 8) were detached into two subgroups because of its non homogenous floristic composition. The main group positively correlated with Cl^-, while two plots were positively correlated with Ca^{2+}.

Discussion

Linkage of water chemical parameters and plant communities

Our results suggested that some of the macrophyte communities in nutrient rich backwaters were well defined, both in floristic terms and in terms of water chemical parameters as well. Nitrogen forms, organic compounds/pollutants, calcium, magnesium and chloride were the variables that significantly correlated to the structure of the communities. The result of DCCA ordination was consistent with the associations of classical phytosociology. This corroborates the results of BARENDREGT and BIO (2003) for macrophyte communities in running waters; TOIVONEN & HUTTUNEN (1995), HEEGAARD et al. (2001) and KŁOSOWSKI (2006) also reported similar results from oligotrophic lakes in Finland, Northern Ireland and Poland. Similar studies from Central Europe were reported from oligotrophic lakes and fens (TÓTH &

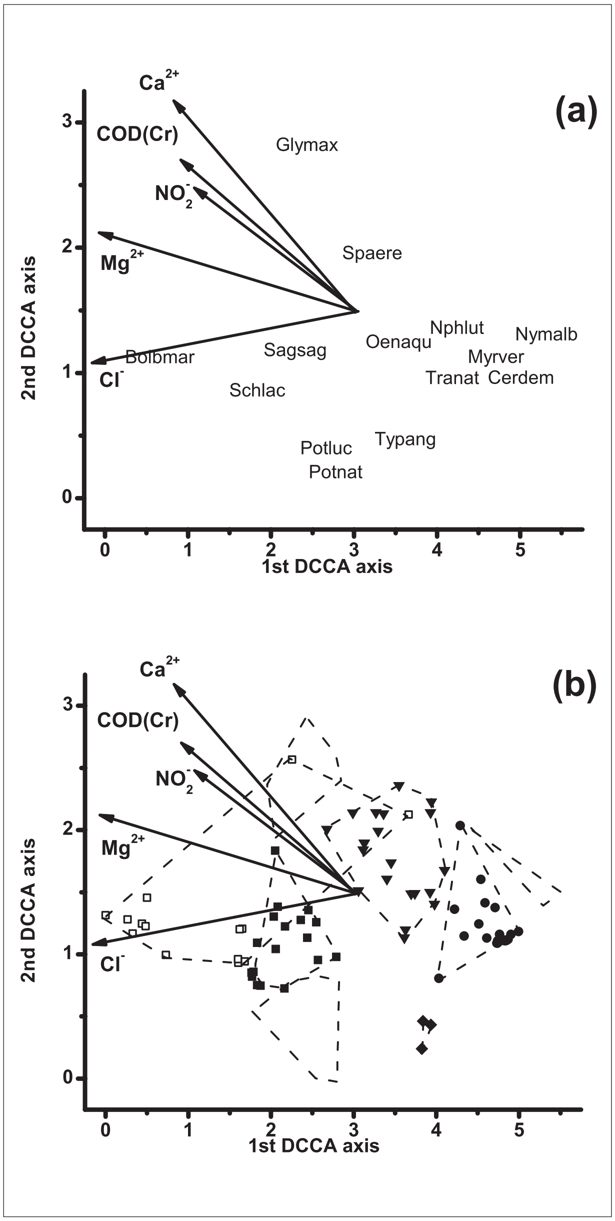

Fig. 1. DCCA ordination biplots. (a) Biplot of plant species and water chemical parameters. (b) Biplot of plots and water chemical parameters with the indication of TWINSPAN categories, see also Table 2. Notations: full rhomboid – *Typhetum angustifoliae*, full circle – *Trapetum natantis*, open triangle – *Ceratophyllo-Nymphaeetum albae*, full triangle – *Sparganietum erecti*, open circle – *Glycerietum maximae*, open rhomboid – *Potametum lucentis*, full square – *Schoenoplectetum lacustris*, open square – *Bolboschoenion*. (Eigenvalues: 0.599 and 0.252, sum: 13.93.) Frequent species and their percentage values of the variance are shown: Bolbma – *Bolboschoenus maritimus* (58.1 %); Cerdem – *Ceratophyllum demersum* (35.6 %); Glymax – *Glyceria maxima* (70.25 %); Myrver – *Myriophyllum verticillatum* (21.08 %); Nphlut – *Nuphar lutea* (15.51 %); Nymalb – *Nymphaea alba* (50.94 %); Potluc – *Potamogeton lucens* (71.87 %); Potnat – *Potamogeton natans* (7.57 %); Sagsag – *Sagittaria sagittifolia* (3.52 %); Schlac – *Schoenoplectus lacustris* (60.04 %); Spaere – *Sparganium erectum* (59.2 %); Tranat – *Trapa natans* (52.82 %); Typang – *Typha angustifolia* (32.78 %).

Braun 1995, Hájková & Hájek 2003, Hájková et al. 2004, Somodi & Botta-Dukát 2004, Navrátilová & Navrátil 2005) and they get pH, nitrogen forms, Ca^{2+}, Mg^{2+} and organic matters as important variables. Furthermore Kłosowski (2006) determined that COD, sulphate and Cl^- were important water chemical variables that differentiating the habitats of communities. Except pH all of them were influencing the vegetation in the nutrient rich backwaters. It seems that at the level of communities these variables are the important factors not only in nutrient poor but in nutrient rich waters as well.

The correlation of vegetation data with water chemical parameters permits further clarification of vegetation differentiation between the associations of Phragmiti-Magnocaricetea class (Borhidi 2003) and clarifies the role of environmental factors. The presence of reed sweetgrass bed vegetation correlated with high organic compounds or pollutants (COD) and NO_2^- content of water. In contrast lesser reedmace beds correlated negatively with these parameters, while erect bur-reed communities prefer both habitats. Furthermore, Bolboschoenion and clubrush vegetation prefers a third kind of waters determined by high concentration of Cl^-. This result concluded that reed bed communities located in the littoral of eutrophic backwaters may indicate different nutrient availability. The presence of Trapetun natantis and Ceratophyllo-Nymphaeetum albae associations in waters with low amount of Ca^{2+}, COD, NO_2^-, Mg^{2+} and Cl^- indicate heterogenic habitats where different water courses (bays, dead-arms) creates mosaic patterns of vegetation. This phenomenon can prove the vulnerability and rarity of these protected associations (Borhidi & Sánta 1999) in nutrient rich waters.

Correlation between vegetation and water chemical parameters gave implications on plant species requirements as well. Our results obtained for these relationships were in agreement with the data reported from numerous works of other authors (Hutchinson 1975, Toivonen & Huttunen 1995, Vastergaard & Sand-Jensen 2000, Heegaard et al. 2001), who pointed to the important role of the carbonate complex in influencing the distribution of submerged plants. Our results also confirm the findings of Pietsch (1982) and Kłosowski (2006) for the high calcium-hydrocarbonate complexes (means low Ca^{2+} concentration) and the nitrogen complexes demands of *Potamogeton lucens* and *Myriophyllum verticillatum*. In the case of the communities of *Potamogeton* species and *Trapa natans* revealing water chemical parameters were determined. We found that *Nymphaea alba, Nuphar lutea, Trapa natans, Ceratophyllum demersum, Myriophyllum verticilatum*, and *Salvinia natans* prefers water with markedly poor organic matters.

In some cases, however, the present findings were inconsistent with the data of other authors. The data of Pietsch (1982), who defined the ranges of water properties for many species of macrophytes from various regions of Europe, confirm the relationship of *Ceratophyllum demersum* and its communities to hard, alkaline waters rich in Cl^-. Similar observations were made by Wiegleb (1978). The relationship of *Ceratophyllum demersum* and its phytocoenoses to waters rich in nitrogen forms (Pietsch 1982) as well as the association of Potametum lucentis with rich Ca^{2+} (Pietsch 1982) were not confirmed by this study demonstrating the ecological plasticity of these plants.

Vegetation composition was separated out well according to water chemical conditions, but our results also suggest that some of the species in eutrophic waters may behave not in the same way as in oligotrophic waters. Hence we emphasize that species-environment and/or habitat-environment relationship assessments should derived from waters with wide range of trophy and geography distribution.

Conservation outlook

The present data and those obtained by other authors show that in spite of the high ecological plasticity of macrophytes (Wiegleb 1984) as well as typological and geographical diversity of water habitats (Murphy 2002), many communities-habitat relationships have not only regional but also general character. Being dominated by specific submerged aquatic species the communities are distinct with respect to their phytocoenotic structure (dominant species, number of species), ecology (demands, plasticity, community-environmental relationship), and could be good indicators of various habitat conditions in pond (backwater) ecosystems. There are hundreds of nutrient rich ponds in Central- and Southern-Europe; hence it is an especially useful tool to provide water chemistry and quantitative data of the macrophyte communities, and to explore macrophyte and water chemistry characteristics. This kind of information can be useful in the countries having nutrient rich standing waters during the strategic development of EU Water Framework Directive for plant communities.

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