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Use of desmids to assess the natural conservation value of a Hungarian oxbow (Malom-Tisza, NE-Hungary)*

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Abstract: A method recently proposed by Coesel that uses the desmid flora to assess the conservation value of aquatic habitats was applied to an alkaline and hypertrophic oxbow of the Upper Tisza river (NE Hungary). According to the macrophyte community the oxbow contains two distinct habitats, both of which provide suitable conditions for the development of a rich desmid flora. High temporal and spatial differences in the algal flora were observed in periphyton and plankton samples taken in June and August 2004. The sample of *Utricularia vulgaris* periphyton collected in August was characterised by the most species-rich desmid flora. The conservation value of this sample was the maximum according to Coesel's method. The latter also proved to be useful for the assessment of the conservation value of plankton net samples taken from among the macrophytes. The use of modified rarity value calculations as recently proposed by Fehér did not significantly affect the conservation value, but different enumeration methods to quantify the floristic diversity did result in different conservation values. We found that Coesel's desmid based method is a useful tool for assessing the conservation value of the studied oxbow. Based our results the Coesel method's applicability and usefulness depended on (i) the sampling location (open water or macrophytic region) samples were taken from open water or from macrophytic region; and (ii) species enumeration procedures (up to 400 specimens counted, or whole droplets counted).

Key words: oxbow; Desmidiales; Coesel's method; nature conservation value

Introduction

Recently, the water quality assessments have been at the forefront of research (Rott et al. 2003; Gutowski et al. 2004; Padisák et al. 2006; Borics et al. 2007). During the last decades several methods were developed for the characterisation of the saprobic and trophic state of water bodies (Järnefelt 1952; Teiling 1955; Heinonen 1980; Rosén 1981; Hörnström 1981; Tremel 1996; Lepistö 1999). Most of these studies were aimed at classifying the various standing and running water types on the basis of their pollution levels, and rank them on an absolute scale without consideration of their natural characteristics. As a consequence, the evaluation of naturally eutrophic water bodies is usually problematic. It is conceivable that by taking into account biological features like the diversity of the macrophyte flora, and that of the reptile, fish and bird fauna, a more accurate assessment of the biological and ecological value of several of these habitats is possible. Typical representatives of these water bodies are oxbows, alkaline bog-lakes and marshlands which feature rich stands of macrophytes and benthic communities.

For an evaluation of the quality of these habitats, a study of the benthic algae seems appropriate. For practical reasons, mostly diatom based metrics have been developed in recent years (Descy 1979; Watanabe et al. 1986; Schiefele & Schreiner 1991; Kelly et al. 1995; Lenoir & Coste 1996). Nevertheless non-diatom algae can also been used as indicators of biological integrity (Fjerdingstadt 1965; Palmer 1969; Hill et al. 2000; Blinn & Herbst 2003) although a number of problems have to be faced. Species identification in several groups of algae is difficult, and to decide what constitutes an individual (in the case of filamentous or colonial forms) can also be problematic.

Desmids which are characteristic elements of epiphytic communities (John et al. 2002) can also be used in environmental assessments. Several species of this group are closely related to certain types of aquatic habitats, and may be used as indicators of changes of pH or nutrient supply (Coesel 1984; Borics et al. 1998;

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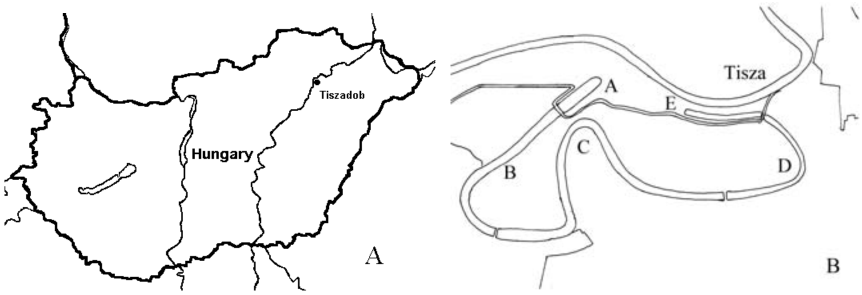

Fig. 1. **A.** Map of Hungary. **B.** Map of the Tiszadob oxbow system: A – Darab-Tisza; B – Falu-Tisza; C – Malom-Tisza; D – Szücs-Tisza; E – Felső-Darab-Tisza.

Fehér 2003). On the bases of occurrence, rarity and maturity of desmid species a method was developed by Coesel (2003) for assessing the nature conservation value (NCV) (Coesel 1998) of aquatic habitats.

The Coesel method is presented for quantification of aquatic nature conservation value based on desmid assemblages present (Coesel 2001). Species richness (indicative of internal structural and functional differentiation of the ecosystem), the occurrence of rare taxa (often indicative of particular environmental conditions) and the presence of species indicative of ecosystem maturity are the parameters chosen to determine conservation value. For the sake of utility, schemes have been developed to transform the values scored for the various parameters to a simple scale ranging from 0 to 10, relative to regional and historical standards. During the first adaptation of this method for Hungary (Fehér 2007) the water qualities in the investigated lenitic waters were classified as oligotrophic to meso-eutrophic by trophic status based on desmid taxa.

The goal of our study was to investigate the applicability of the method of Coesel (2003) to the Malom-Tisza oxbow (Hungary). The large numbers of the Hungarian natural standing waters belong to the "oxbow type" (Dévai et al. 1999; Gőri et al. 2000). The macrophyte biodiversity indicates that the Malom-Tisza oxbow has a high natural value. In this study we tried to find answers to the following questions. (i) Are desmids important elements of the microflora of shallow, alkaline, hypertrophic oxbows? (ii) What kind of NCV values characterise the Malom-Tisza oxbow? (iii) Do the NCV values change during the course of the summer? (iv) Are there any differences in the NCV values between the different substrates? (v) Do the NCV values change after applying Fehér's (2007) modified rarity values? (vi) What are the differences, if any, in the NCV values if different species enumeration methods are used?

Material and methods

The investigated oxbow lies in the middle of the Tisza valley (110 m a.s.l.) in the neighbourhood of the village of Tiszadob (Fig. 1A). The eleven kilometres long oxbow is divided into five sections (A, B, C, D and E; Fig. 1B) by dams. Three sections (B, C and D) can be found outside the embankments. The others (A and E) are on the floodplain. The largest section is the Malom-Tisza oxbow (C).

Table 1. Chemical parameters of the Malom-Tisza oxbow at sampling points 1, 5 and 7 (cf. Fig. 2).

	June			August		
	1	5	7	1	5	7
Temperature (℃)	21.2	21.3	21.2	22.4	22.6	22.4
pH	7.93	7.51	8.56	7.61	7.33	7.39
Conductivity (μS cm^{-1})	283	289	287	299	297	295
Chlorophyll a (μg L^{-1})	10.7	2.2	2.3	5.5	5.3	7.6
NH_4^+ (mg L^{-1})	0.2	0.17	0.18	0.17	0.24	0.23
NO_2^- (mg L^{-1})	0	0	0	0	0	0.01
NO_3^- (mg L^{-1})	1.9	2.1	2.1	2.5	2.4	2.4
PO4-P (μg L^{-1})	40	30	40	60	70	60
COD-Mn (mg L^{-1})	10.6	9.3	9.8	8.9	8.6	10.7

Physical characteristics of the Malom-Tisza oxbow include: length 4.2 km, average width 80 m, surface area 46 hectares, average depth 3 m, maximum depth 12.5 m. Most of the oxbow is a typical pelagic ecosystem; at the eastern section of the oxbow a unique macrophyte association is present which covers almost the entire eastern lake-basin. This association (*Calamagrosti-Salicetum cinereae Thelypteridosum palustris* using Braun-Blanquet's (1964) phytosociological terminology) is the result of the ageing process of water bodies and probably has always been a characteristic association of Hungary's shallow lakes. For physico-chemical analyses (Table 1) water samples were taken from the immediate surface layer at sampling points 1, 5 and 7 and for phytoplankton investigations at points 1–7 of the oxbow (Fig. 2) on 24 June and 25 August 2004. Phytoplankton samples were obtained by filtering 10 L water through a plankton net (mesh size 20 μm). For the examination of the periphyton parts of macrophytes were collected. When different macrophyte species of smaller size (*Spirodela*, *Lemna* spp., *Riccia* sp.) occurred in a small area, so-called "mixed samples" were also taken, pressing the water from the macrophytes by hand and filtered it through the net (Fig. 2). The samples collected and their attributes are shown in Table 2. Samples were fixed with Lugol's solution. The periphyton samples were shaken and allowed to settle in 100 mL cylinders. Two 20 μL droplets of the settled materials were investigated with LEICA DMRB microscope equipped with brightfield, phase-contrast and Nomarski interference contrast optics. Two different enumeration methods were used to estimate the species richness of the samples: (i) counting up to 400 specimens, (ii) counting the whole volume of droplets. We also calculated the difference in the number of species based on the two enumeration methods. For the

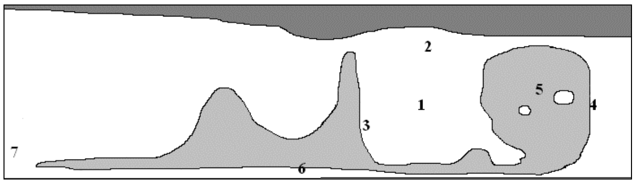

Fig. 2. Sampling locations in the Malom-Tisza oxbow. 1 – bog-lake; 2 – north of bog-lake; 3 – margins of the Salici-Alnetum (floating islands); 4 – right side of the Salici-Alnetum (floating islands); 5 – pools in Salici-Alnetum (floating islands); 6 – lag-zone; 7 – at the shore of Malom-Tisza.

Table 2. List of samples and their attributes. Sampling location designations 1–7 as in Fig. 2

Code	Type of the sample	Sampling location	Date
UN_06	*Utricularia* periphyton	2	24.06.2004.
CP_06	*Calliergonella* periphyton	5	24.06.2004.
PP_06	plankton	5	24.06.2004.
NM_06	netplankton	3	24.06.2004.
SM_06	*Salvinia* periphyton	3	24.06.2004.
PB_06	plankton	1	24.06.2004.
NB_06	netplankton	1	24.06.2004.
PL_06	plankton	6	24.06.2004.
SL_06	*Salvinia* periphyton	6	24.06.2004.
NL_06	netplankton	6	24.06.2004.
ML_06	mixed periphyton	6	24.06.2004.
PS_06	plankton	7	24.06.2004.
NS_06	netplankton	7	24.06.2004.
MS_06	mixed periphyton	7	24.06.2004.
UN_08	*Utricularia* periphyton	2	25.08.2004.
CP_08	*Calliergonella* periphyton	5	25.08.2004.
NP_08	netplankton	5	25.08.2004.
MP_08	mixed periphyton	5	25.08.2004.
VP_08	*Myriophyllum* periphyton	5	25.08.2004.
UP_08	*Utricularia* periphyton	5	25.08.2004.
HP_08	*Hydrocharis* periphyton	5	25.08.2004.
P1P_08	plankton	5	25.08.2004.
P2P_08	plankton	5	25.08.2004.
PR_08	plankton	4	25.08.2004.
SR_08	*Salvinia* periphyton	4	25.08.2004.
MR_08	mixed periphyton	4	25.08.2004.
PB_08	plankton	1	25.08.2004.
NB_08	netplankton	1	25.08.2004.
PS_08	plankton	7	25.08.2004.
NS_08	netplankton	7	25.08.2004.
MS_08	mixed periphyton	7	25.08.2004.

identification of the taxa we used Coesel (1982, 1983, 1985, 1991, 1994, 1996), and Růžička (1977, 1981).

The conservation value of the oxbow was determined according to Coesel (2001) which was based on the desmid flora. Determination of the index requires the following data: number of desmids species observed (d, usually referred to as diversity), rarity (r) scores and maturity (m) scores of the desmid species. Rarity and maturity scores are based on expert judgement proposed by Coesel (2001). Depending on the pH-type of the water the $\sum r$, $\sum m$, and d scores are transformed to the so-called M, R and D scores based on the suggection of Coesel (2001). The NCV is the sum of D (ranging from 1–3), R (ranging from 1–3) and M (ranging from 1–4); therefore the maximum of the $D + R + M$ scores is 10. The idea of nature conservation value has to connect with the rarity, replacement of component of the given ecosystem and the regeneration of the biocoenosis after any disturbance. It is evidence the nature conservation value elaborated in the Netherlands, is need to evaluation in other countries. On basis of detailed investigation of South-Hungarian water bodies' rarity values (r) of the desmid species have been modified by Fehér (2007). This study is the Coesel method very first evaluation for Hungary.

Our database has also been evaluated by the modified Coesel's method. The R-values were calculated in two different ways: as published originally by Coesel (2001) and follow the Fehér (2007) suggested modifications for indicator value based on Desmidiales taxa occurrences in Hungary, and with the modification according to Fehér (2007).

Table 3. Number of observed taxa.

	number of taxa		
	June	August	Total
CYANOBACTERIA	15	20	26
HETEROKONTOPHYTA			
Chrysophyceae	4	4	4
Bacillariophyceae	33	33	39
Xanthophyceae		2	2
CHLOROPHYTA			
Chlorococcales	44	48	60
Desmidiales	64	67	78
Volvocales	5	4	5
Other Chlorophyta	3	4	4
EUGLENOPHYTA	4	14	15
DINOPHYTA	6	11	11
CRYPTOPHYTA	3	1	3
Total	181	208	247

Results

Floristic composition

Altogether 247 taxa of algae were identified in 30 samples from the Malom-Tisza oxbow. The floristic compositions of the samples taken in June and August were slightly different (Table 3). The species number of Cyanobacteria, Euglenophyta and Dinophyta doubled in August. The species number of Euglenophyta (4) in June was very low. The microflora was dominated by Chlorophytes (147 taxa) and Bacillariophyceae (39). The number of desmids was surprisingly high: 78 (Table 4). Desmids that were present in at least 75% of the different habitats included *Cosmarium phaseolus*, *C. subprotumidum* var. *pyramidale*, *Sphaerozosma vertebratum*, *Staurastrum furcatum*, *S. polymorphum*, *S. tetracerum* and *Xanthidium antilopaeum*.

Conservation value of the oxbow

The differences in conservation values of the June and August samples were negligible (Figs 3, 4). The average conservation values (NCV) were 6.3 in June and 6.5 in August (based on the whole droplets method). NCV values ranged between 2 and 8 in June, and between 3 and 10 in August. The theoretical maximum of the NCV (10) was found in the periphyton sample of *Utricularia vulgaris* L., taken from the north of the bog-lake

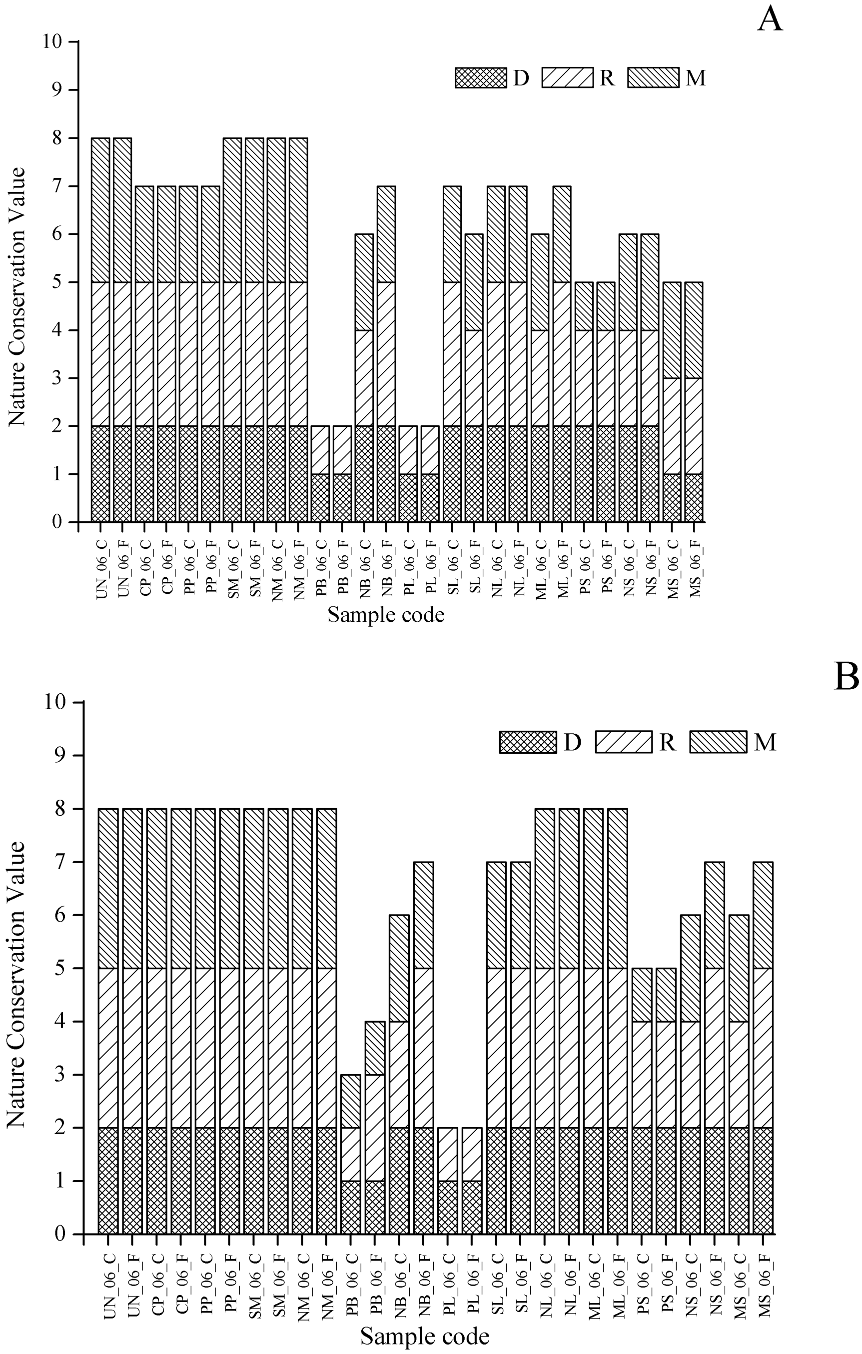

Fig. 3. NCV scores of the June samples (sample codes as in Table 2). (A) up to 400 specimens counted, (B) whole droplets counted. C – NCV calculated by Coesel's method; F – NCV calculated by Fehér's method.

(Fig. 2, map) in August. Differences of the NCV values between the samples are largely caused by the different R and M values, because D was almost constant (score 2) in every sample.

Habitat/Sampling areas

Due to the very low number of taxa observed, the NCV values of the open water proved to be very low too (NCV = 3). Higher values characterised the periphyton and the plankton net samples that were taken from small pools with a dense macrophyte vegetation. With respect to the number of observed species and the calculated NCV values, the periphyton sample of *Utricularia vulgaris* showed the highest scores (Fig. 4B).

Different sample enumeration methods

The two different sample enumeration methods (counting up to 400 specimens and analysis of the whole volume of the droplets) resulted in slight differences in the conservation values (Fig. 4). Approximately half of the samples showed an increase of one point. Nevertheless in the case of the *Utricularia vulgaris* sample in August, due to the more detailed microscopic analysis, a more substantial increase by 2 points was observed.

Table 4. Desmidiales flora of the oxbow. * rare taxa in Hungary (Fehér 2007). Sampling location designations 1–7 as in Fig. 2.

Taxon	Sampling locations						
	1	2	3	4	5	6	7
**Actinotaenium turgidum* (Bréb.) Teil.			+	+	+		
Closterium aciculare T. West			+			+	
Closterium acutum Bréb.					+		+
Closterium acutum var *variabile* (Lemmerm.) Willi Krieg.						+	
Closterium dianae Ehrenb.	+	+	+	+	+		+
Closterium ehrenbergii Menegh. ex Rafls		+					
Closterium incurvum Bréb.					+		+
Closterium moniliferum (Bory) Ehrenb. ex Rafls					+		
Closterium sp. 1		+		+	+		
Closterium sp. 2					+		
Closterium venus Kütz. ex Ralfs	+	+	+	+	+	+	+
Cosmarium botrytis Menegh. et Ralfs	+	+	+	+	+		+
**Cosmarium connatum* Bréb.	+	+			+	+	+
Cosmarium contractum Kirchn.	+	+	+		+	+	+
Cosmarium contractum Kirchn. var. *contractum*					+		
Cosmarium contractum Kirchn. var. *ellipsoideum* (Elfv.) W. et G.S. West	+			+	+		
Cosmarium contractum Kirchn. var. *retusum* (W. et G.S. West) Krieg. et Gerl.				+			
Cosmarium contractum Kirchn. var *rotundatum* Borge	+			+	+		
Cosmarium crenulatum Ralfs ex Ralfs.		+	+	+	+		+
Cosmarium depressum (Nägeli) P. Lundell				+			
**Cosmarium fastidiosum* W. et G. S. West cf.					+	+	
Cosmarium formosulum Hoff				+			+
Cosmarium granatum Bréb. ex Ralfs	+	+		+	+	+	+
Cosmarium humile (F. Gay) Nordst.		+	+	+			+
Cosmarium margaritiferum (Turpin) Menegh. ex Ralfs	+		+				
Cosmarium moniliforme (Turpin) ex Ralfs	+	+			+		+
**Cosmarium notatum* (Grönbl.) Coes.					+		
Cosmarium phaseolus Bréb. ex Ralfs	+	+	+	+	+	+	+
Cosmarium portianum W. Archer					+		
**Cosmarium pseudoretusum* Ducell v. *inaequalipellicum* (W. et G. S. West) Krieg. et Gerl.						+	
**Cosmarium pseudoretusum* Ducell. var *pseudoretusum* Krieger et Gerloff					+		
Cosmarium punctulatum Bréb. cf.				+			
Cosmarium pygmaeum W. Archer cf.		+					
**Cosmarium pyramidatum* Bréb. cf.					+		
Cosmarium regnellii Wille						+	
Cosmarium regnellii Wille var. *minimum* B. Eichler et Gutw.		+		+	+		+
Cosmarium regnellii Wille var. *regnellii*		+	+	+			
**Cosmarium regnesi* Reinsch var. *montanum* Schmidle			+			+	+
Cosmarium reniforme (Ralfs) W. Archer	+	+	+	+	+	+	+
Cosmarium subprotumidum Nordst. var *pyramidale* Coes.		+	+	+	+	+	+
Cosmarium subprotumidum Nordst. var *subprotumidum* West et West		+					+
Cosmarium subtumidum Nordst.						+	
Cosmarium subundulatum Wille						+	
**Cosmarium tetraophthalmum* Bréb.		+			+	+	+
Cosmarium turpinii Bréb.	+	+	+		+	+	+
Desmidium aptogonum Bréb.			+			+	
Desmidium swartzii C. Agardh	+	+	+	+	+	+	+
Euastrum denticulatum (Kirchn.) F. Gay		+	+		+	+	+
**Euastrum germanicum* (Schmidle) Willi Krieg.		+	+	+		+	+
Heimansia pusilla (Hilse) Coes.	+	+	+	+			+
Micrasterias crux-melitensis (Ehrenb.) Hassal	+	+			+	+	+
Pleurotaenium trabecula var. *trabecula* (Ehrenb.) Nägeli		+	+	+	+	+	+
**Sphaerozosma laeve* (Nordst) Thom.		+	+				
**Sphaerozosma vertebratum* (Bréb.) Ralfs		+	+	+	+	+	+
Spondylosium planum (Wolle) W. et G. S. West	+	+		+	+	+	
Staurastrum anatinum Cooke et Wills			+				
**Staurastrum bieneanum* Rabenh.	+	+	+	+	+		+
**Staurastrum boreale* W. et G. S. West			+		+	+	
**Staurastrum boreale* W. et G. S. West var. *quadriradiatum* Kors.	+						
**Staurastrum furcatum* (Ehrenb.) Bréb.	+	+	+		+	+	+
Staurastrum furcatum (Ehrenb.). Bréb. (4 arms)							+
Staurastrum gladiosum W. B. Turner	+	+	+		+		+
Staurastrum hystrix Ralfs						+	
Staurastrum lunatum Ralfs						+	
Staurastrum manfedtii Delponte	+	+	+	+	+	+	+
Staurastrum orbiculare (Ehrenb.) Ralfs			+				
Staurastrum polymorphum Bréb.	+	+	+	+	+	+	+
**Staurastrum quadrangulare* Ehrenb. ex Ralfs	+	+			+		

Table 4. (continued).

Taxon	Sampling locations						
	1	2	3	4	5	6	7
**Staurastrum smithii* G. M. Smith							+
**Staurastrum subavicula* (W. West) W. et G. S. West		+	+		+	+	+
Staurastrum teliferum Ralfs		+			+	+	+
Staurastrum tetracerum Ralfs	+	+	+	+	+	+	+
Staurodesmus cuspidatus (Bréb. ex Ralfs) Teil.		+	+		+		+
Staurodesmus dejectus (Bréb. ex Ralfs)	+	+	+		+	+	+
Staurodesmus dejectus (Bréb. ex Ralfs) v. *apiculatus* (Bréb.) Teil.	+			+	+		
**Staurodesmus glaber* (Ehrenb. ex Ralfs) Teil.	+	+	+				
Xanthidium antilopaeum (Bréb.) Kütz.	+	+	+	+	+	+	+
**Xanthidium variabile* (Nordst.) W. et G. S. West					+		

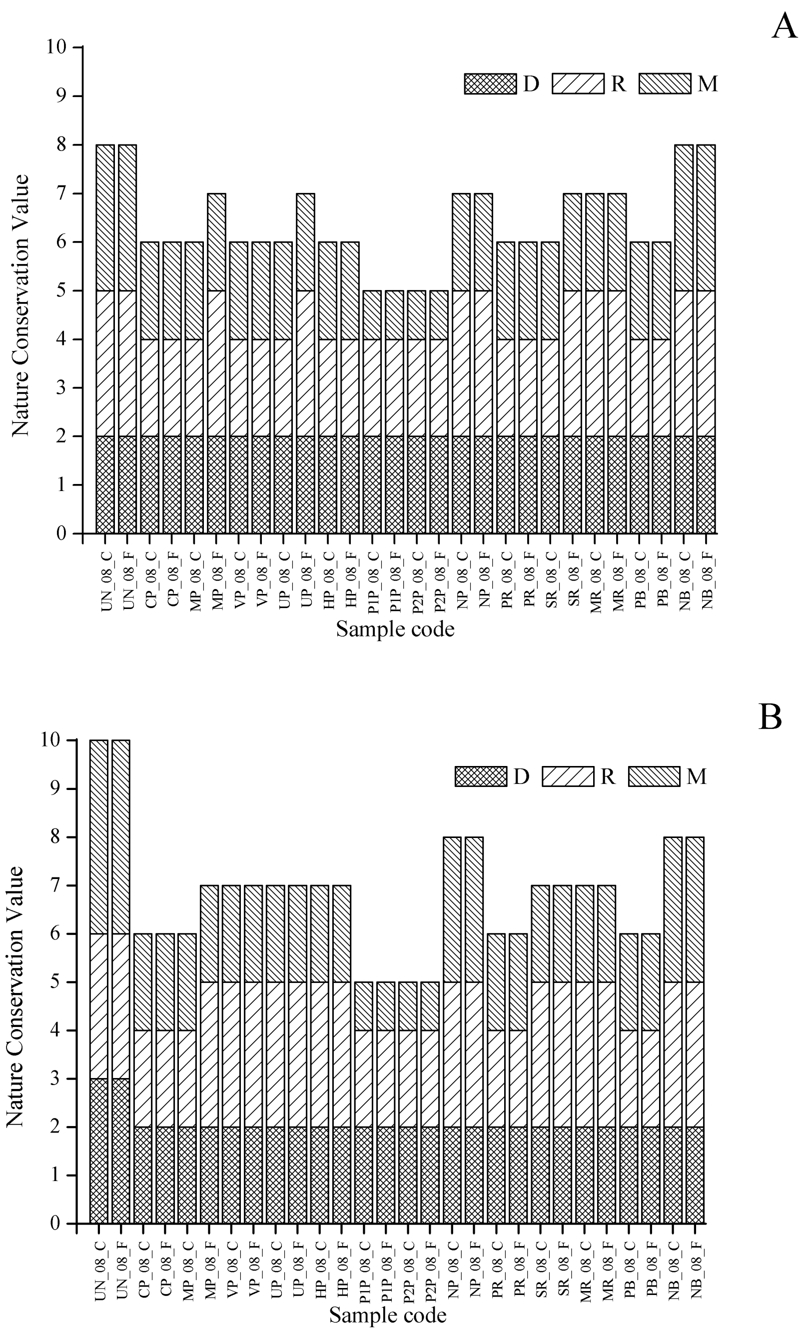

Fig. 4. As Fig. 3. NCV scores of the August samples

Calculation of the rarity values

Use of modified rarity values (Fehér 2007) did not significantly affect the value of the NCV-index (max. difference was ±1). Modification resulted in an increase of the NCV index by one point for those samples that originally had NCV values of 3 and 6. Samples that had very low and very high values were unaffected. A decrease of the NCV index was only found in sample SL06F, a periphyton sample from *Salvinia natans* (L.) All. taken in the lag-zone.

Discussion

The observed 247 algal taxa are indicative of a species-rich microflora in the Malom-Tisza oxbow. The relative share of the desmids was high (78 taxa). Only two Hungarian floristic accounts are available in which a larger number of species were reported, namely from a rice field (Kol 1954) and from Baláta, the largest Hungarian bog-lake (Borics 2001), respectively.

Several species that are considered to be acidophilic (e.g. *Cosmarium margaritiferum, Staurastrum furcatum*), acido-neutrophilic (e.g. *Cosmarium contractum*, *Xanthidium antilopaeum*), and prefer oligotrophic (e.g. *Cosmarium pyramidatum, Teilingia excavata*) or oligomesotrofic environments (e.g. *Cosmarium pseudoretusum, Staurodesmus dejectus*) were observed. It is not clear whether these unexpected findings are due to the limited knowledge about the tolerance of these species, or to the existence of ecotypes.

Contrary to expectations, the NCV values of the late summer samples compared to those taken in June were not significantly higher. Species that are characteristic for mature periphyton assemblages (Coesel 1998) (e.g. *Sphaerozosma vertebratum*, *Micrasterias crux-melitensis*, *Cosmarium regnessi, Desmidium swartzii*) were already present in June; thus, the maturity and rarity values were almost identical. Nevertheless it is worth mentioning that a possibly higher score of the NCV (10) was observed only in August.

Considerable differences in the NCV values of the microhabitats sampled were observed. The microhabitat of *Utricularia vulgaris* was characterised by the highest diversity and maturity values. Compared to other macrophytes like *Myriophyllum verticillatum*, *Ceratophyllum demersum* and *C. submersum*, the leave structure of *Utricularia vulgaris* is more delicate and provides an ideal habitat for periphytic assemblages.

The plankton of pools with a rich vegetation are also characterised by high NCV values. Due to mechanical disturbances caused by the sampling procedure, a large number of desmids end up in the tychoplankton.

We observed considerable differences between the two species enumeration methods. Analysis of the total volume of the droplets resulted in an approximately 20% increase in the species number. Nevertheless this increase did not result in a change of the D value (Figs 3, 4).

We calculated the NCV values also with the modified "r" values as suggested by Fehér (2007), but this resulted only in slight changes in the NCV values.

The Malom-Tisza oxbow had a high NCV value which demonstrates that naturally hypertrophic systems can be valuable habitats. Our results demonstrate that different sampling strategies and enumeration methods only result in small differences in the natural values (NCV scores). Coesel (2001) has suggested that the method should be based on species and that the use of lower taxa should be avoided, but there are cases where lower taxa (forms, varieties) have different ecological requirements or behaviour. Our opinion based on the field experience of this study is that forms or varieties, provided they can be identified reliably, may be considered in NCV assessment studies.

In conclusion, our results suggested that Coesel's (2001) method was a useful tool for evaluating the NCV values of the Hungarian oxbow, but for wider acceptance of the method standardisation of the sampling and species enumeration procedures was needed.

Acknowledgements

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