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The effect of hydro-morphological modifications of streamflow compositional features of attached diatom assemblages in Hungarian streams

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SUMMARY: Hydro-morphological modifications have significant effect on the species composition of attached diatom assemblages. The diversity of natural, undisturbed streams is different from that of the hydromorphologically modified (e. g. dammed) water bodies. The proportion of attached against planktonic species indicated very well of the hydromorphological influences (both upstreams and downstreams). In high altitude sampling sites *Stephanodiscus minutulus*, in middle altitude sampling sites *S. hantzschii, S. minutulus* and *Adlafia minuscula* were the indicator species downstream modifications. *Gomphonema angustatum* was the only significant indicator for the upstream sampling sites in low altitude, medium fine substrata streams. The downstream modifications were signalled by *Amphora veneta, Ctenophora pulchella*, while lowland damming by *Melosira varians* and *Cocconeis placentula*.

INTRODUCTION

The Water Framework Directive (WFD) aims to reach good ecological status of surface waters by 2015 in terms of biological, hydromorphological and physico-chemical parameters. The investigated biological elements are phytobenthos (diatoms), phytoplankton, macrophytes, macroinvertebrates and fish. Especially the latter three are good indicators of the hydromorphological modifications. For instance, the in-stream damming results in lentic conditions that favour phytoplankton and represent barrier to migraton of fish (Boulton & Brock, 1999). Hydro-morphological changes can modify structural and functional features of other components of aquatic biota through the interactive network of aquatic ecosystems.

Diatoms are valuable indicators of the anthropogenic influences on ecological quality of streams and therefore numerous diatom indices were developed for status assessment (Rumeau and Coste, 1988, Schiefele and Kohmann, 1993). They reflect well acidification and enrichment in organic or mineral contents. However, they give no weight to the effect of hydro-morphological modifications of the streamflow. A number of studies (Kelly et al., 1995, Kwadrans et al., 1999, Descy and Ector, 1999, Vilbaste, 2004) have dealt with ecological status of rivers using diatom indices and chemical parameters. Similar studies on the effect of hydromorphological parameters are missing despite they are of primary importance in the WFD implementations. Without assessing the effect of hydro-morphological modifications on attached diatom assemblages we cannot even define reference conditions, because even though the water quality can be high (high value of indices) the species composition, the charactheristic species and diversity can deviate from the expected status. Schönfelder and Gelbrecht (2002) addressed the importance of species richness and diversity of undisturbed running waters and Briede et al. (2005) investigated the different degradation classes of morphological conditions in the River Habitat Survey.

The goal of our research was to analyze which hydro-morphological modifications have significant effect on the species composition of attached diatom assemblages and to describe the influence of the type of these modificatons on species richness and diversity. Furthermore, we aimed to find indicator species of the modifications compared to undisturbed reference conditions.

MATERIAL AND METHODS

This study represents a part of the first nationwide survey of phytobenthic diatoms in Hungarian streams (ECOSURV, 2005). In the basic study, diatoms and environmental data were collected and analyzed to find the master variables that determine species composition of diatoms in order to validate if the existing diatom indices can be applied in Hungary or not. In multivariate analyses, the physical factors like current velocity, altitude, shading and valley form were found as the most important factors, while nutrient status of streams was of lesser importance. The suggested index for use in Hungary was the IPS (Indicie de Polluosensibilité Spécifique or Index of Pollution Sensitivity; Cemagref, 1982).

In this study, we used from 181 streams of the complete data set consisted of 339 streams. They belong to 17 different river types (Table 1). The common feature of these streams is the calcareous hydrogeochemistry. Concerning river-bed, they all have rough or medium-fine material (Table 1). All the 181 streams included in this study were of good or excellent status based on their IPS values. This criterion was set in order to eliminate the influence of organic and inorganic pollutions and to focus only on the effects that are, at all possibility, attributable to hydromorphological modifications.

Type number	Type description	Number of sampling sites	Group number
2	High-alt_Calc_Rou-subs_small	13	A
3	High-alt_Calc_Rou-subs_medium	4	A
4	Mid-alt_Calc_Rou-subs_small	14	A
5	Mid-alt_Calc_Rou-subs_medium	18	A
6	Mid-alt_Calc_Rou-subs_large	10	A
7	Mid-alt_Calc_Rou-subs_v-large	3	A
8	Mid-alt_Calc_Med-fine-subs_small	26	B
9	Mid-alt_Calc_Med-fine-subs_medium	14	B
10	Mid-alt_Calc_Med-fine-subs_large	3	B
11	Lowl-Calc_Rou-subs_small	4	C
12	Lowl-Calc_Rou-subs_medium	6	C
13	Lowl-Calc_Rou-subs_large	10	C
14	Lowl-Calc_Rou-subs_v-large	4	C
15	Lowl-Calc_Med-fine-subs_small	18	D
16	Lowl-Calc_Med-fine-subs_ small-vflat-area	8	D
17	Lowl-Calc_Med-fine-subs_medium_vflat-area	7	D
18	Lowl-Calc_Med-fine-subs_medium	19	D

Table 1: Type number, type description number of sampling sites and group number based on classification by diatoms. Abbreviations: High-alt: high altitude; Mid-alt: middle altitude; Lowl: lowland; Calc: calcareous; Rou-subs: river bed is of rough substrate; med-fine-subs: river bed is of medium-fine substrate; small: catchment area 10-100 km^2; medium: catchment area 100-1000 km^2; large: catchment area 1000-10000 km^2; v-large: catchment area > 10000 km^2; vflat-area: sligh-slope catchment area.

In preliminary analyses (Ács et al., 2004; Kovács et al., 2005), four groups (A,B,C,D; see Table 1) were segregated from the 17 river types. Basically, the diatom composition of streams with high and middle altitude differed markedly from the lowland rivers, furthermore the bedrock substratum (rough, middle fine and fine) had significant effect on species composition.

Sampling was carried out from March to July in 2005. Most of the samples were collected from stones. Other substrata (chiefly *Phragmites*) were considered only in absence of stones (this was frequently the case in lowland streams). A minimum of 400 valves were counted on each slide. Diatom samples were treated with hot hydrogen-peroxide method and then were mounted in Zrax or Hyrax. They were identified at least to species level according to Krammer & Lange-Bertalot (1991-2000), Lange Bertalot (1995-2002) and Krammer (2002).

Shannon diversity was calculated with the Omnidia software 4.1 version. Pearson correlation was used for measuring the strength of the relationship between two variables. IndVal analysis (Dufrêne and Legendre, 1997) was used to find indicator species and species assemblages characterizing groups as well as hydromorphological modifications. Indicator species were defined as the most characteristic species of each group, which are present in the majority of the given group's sites and were found chiefly in this single group. The program calculates indicator index for each species and this index for a given species is independent of the other species' relative abundances.

The calculation of index follows the next equation: $IndVal_{ij} = A_{ij}$ 1 B_{ij} 1 100, where A_{ij} is the mean abundance of species *i* in the sites of group *j* compared to all groups and B_{ij} is the relative frequency of occurrence of species *i* in the sites of group *j*. The significance level of the character species was 0.01, if character species was not found on this level, the significance level was changed to 0.05.

In principle, we investigated different modifications that were sorted into three main types. Comparison included a) pristine streams (no damming), b) upstream inconnectivity (due to the modification the longitudnal connectivity upstreams is not guaranteed), c) lowland damming d) downstream inconnectivity.

RESULTS

The diversity of the Group A varied between 2.7-3.37. No significant effect of upstream modifications was traced on diversity and species number. On the contrary, downstream damming resulted in an increase both in the diversity and species number (Table 2). Although the rate of euplanktonic species did not increase, the rate of the definitely attached species decreased. Furthermore, the relative contribution of the *Stephanodiscus minutulus* (Kützing) Cleve& Möller valves was significantly higher (Table 2).

In Group B upstream modifications caused a slight increase in diversity but if modification occurred downstreams of the sampling site the effect was more expressed. Moreover, contribution of attached species dropped in upstream sites (from 90.57% to 88.3%) and in the downstream sites the rate of the euplanktonic species increased significantly (from 2% to 7.2%) due to two planktonic species: *Stephanodiscus hantzschii* Grunow and *Stephanodiscus minutulus* (Kützing) Round. This effect was also characterized by *Adlafia minuscula* (Grunow) Lange-Bertalot.

Group C comprised lowland rivers and their catchment area varied in a wide range. The diversity of these types ranged between 2.81 and 3.82 without any clear pattern concerning the catchment area. The median of the diversity was 3.41 in pristine sites. In upstream sites, diversity was higher than in pristine sites. Change in the rate of the euplanktonic/attached species was observed, lowland damming caused decreasing tendency in the rate of attached species and diversity. Character species were not found at the upstream sites, but the pristine sampling sites in this group were characterised by presence of *Nitzschia palea* (Kützing) W. Smith and *Surirella brebissonii* Krammer & Lange-Bertalot.

Group D differed from Group C only in riverbed quality: each stream in this group had medium fine substrata. The diversity of the streams with medium large catchment area was similar (2.59; n=14) to that of small ones if there was no hydromorphological modification. In the case of lowland damming the diversity was lower (2.39; n=11). The effect of the downstream modification increased markedly (the diveristy was 3.17; n = 3). The proportion of euplanktonic taxa was 1.63% in the pristine streams and was only 1% if modificaton appeared upstreams. In the dammed section and in the downstreams this proportion was 1.87% and 2.08%. Hydro-morphological modifications upstreams from the sampling sites were indicated only by *Gomphonema angustatum* (Kützing) Rabenhorst. Streamflow modifications occuring downstreams were indicated by two species (*Amphora veneta* Kützing and *Ctenophora pulchella* (Ralfs ex Kützing) Williams & Round and also two species (*Melosira varians* C. Agardh and *Cocconeis placentula* Ehrenberg) indicated lowland damming.

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		Group A	Group B	Group C	Group D
median of diversity	pristine	3.01	2.77	3.41	2.62
	Upstream-mod.	3.1	3.05	3.67	2.52
	Downstream-mod.	3.38	3.57	-	3.17
	lowland damming	-	-	2.66	2.39
median of species number	pristine	28	32	42	27
	Upstream-mod.	28	30	31	25
	Downstream-mod.	34	32	-	24
	lowland damming	-	-	28	28
proportion of planktonic species (%)	pristine	1.76	2.00	5.86	1.63
	Upstream-mod.	1.37	1.58	3.08	1
	Downstream-mod	1.00	7.2	-	2.08
	lowland damming	-	-	0.36	1.87
proportion of attached species (%)	pristine	85.9	90.57	87.05	91.75
	Upstream-mod.	86.05	88.30	92.47	90.44
	Downstream-mod	81.6	78.3	-	85.44
	lowland damming	-	-	79.95	90.7
character species	pristine	ns	ns	*Nitzschia palea1 Surirella brebissonii1*	ns
	upstream	ns	ns	ns	*Gomphonema angustatum2*
	downstream	*Stephanodiscus minutulus1*	*Stephanodiscus hantzschii1 Stephanodiscus minutulus1 Adlafia minuscula1*	-	*Amphora veneta2 Ctenophora pulchella2*
	lowland damming	-	-	*ns*	Melosira varians2 Cocconeis placentula2

Table 2: Median of the diversity and species number, proportion of planktonic and attached species and the character species of pristine, upstream, downstream and lowland damming sections of the streams in Group A, B, C, D.

(1 significance level 0.01; 2 significance level 0.05; ns: not significant; in some cases sum of the attached and planktonic species is < 100% which is attributable to species of unclear character in this respect.)

DISCUSSION

One of the general goals of the water policy of the European Union is the conservation of freshwaters and aquatic biodiversity (EU, 2000). The diversity can be a characteristic feature of the reference status, but the basic information about the diversity of pristine waters is scarce or even absent in most of the countries (Schönfelder and Gelbrecht, 2002). The fact that the species richness and diversity is significantly higher in agricultural and/or organically polluted streams than in undisturbed ones is well-known (Jüttner et al., 1996). Hydromorphological modifications can result in similar phenomena. According to our results, the diversity of natural, undisturbed streams is different from the hydromorphologically modified water bodies. According to our data hydromorphological modifications increased downstream diversity in the majority of river-types despite nutrient enrichment was not observed.

Hydromprphological modifications caused a substantital change as compared to the pristine status. Our results demonstrate that they may have different effects in different water types. Damming had almost no effect on the diatom diversity upstreams in high- and middle altitude streams (Group A), but had more considerable effect in middle- and lowland altitude streams (Group B, C). Consequently the judgement of damming can be considerably different in different water types, which is also indicated by other organisms (fish, macroinvertebrates; Somlyódi and Szilágyi, 2004; Szilágyi et al., 2004).

Damming clearly caused a character change in the physical environment of running waters. Current velocity is the basic feature of all rivers and streams, because it acts as direct physical force within the water column as well as on the substrate surfaces (Allan, 1995). The proportion of attached against planktonic species indicated very well of the hydromorphological influences (both upstreams and downstreams) on two ways:

(a) the relative contribution of attached species decreased in the total encountered species (attached, planktonic and unknown life-form)

(b) the proportion of planktonic species increased.

Furthermore, character species indicated hydro-morphological changes in physical environment of running waters. In high altitude sampling sites *Stephanodiscus minutulus*, in middle altitude sampling sites *S. hantzschii, S. minutulus* and *Navicula minuscula* were the indicator species of hydro-morphological modifications on downstream sections. In low altitude, rough substrata streams *Nitzschia palea* and *Surirella brebissonii* were characteristic to the pristine sites. It is less of problem that these species indicate eutrophic state in several indices included in the OMNIDIA. More of a problem, that according to some indices they reflect polysaprobic conditions. These uncertainties will have to be clarified in further studies (for example, on a selected data-set that comprise only polluted sites). *Gomphonema angustatum* was the only significant indicator for the upstream sampling sites in low altitude, medium fine substrata streams, while the downstream modification and lowland damming were signalled by two - two species, like *Amphora veneta*, *Ctenophora pulchella* and *Melosira varians*, *Cocconeis placentula.*

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