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Temporal variability of *Achnanthidium minutissimum* (Kützing) Czarnecki and its relationship to chemical and hydrological features of the Torna-stram, Hungary

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SUMMARY: Establishment of indicator values of species used in any kind of environmental quality assessment system has been of essential importance. This need is increased in case of species that are abundant. *Achnanthidium minutissimum* has been, inevitably, one of the most frequently occurring diatom species all over Europe. Some authors list is as r-strategist aquatic weed that indicates disturbed environment. The aim of our study was to analyze the temporal distribution of *A. minutissimum* in relation to physical and chemical parameters and to evaluate the data on basis of the existing diatom indices. In 2004-2005, diatom samples were taken biweekly and water samples for chemical analyses were collected once a month in the Torna-stream, W-Hungary. The diatom assemblages showed marked seasonal distribution, and the relative abundance of the *A. minutissimum* also varied throughout the year. We could find no clear correlation between the relative abundance of the A. minutissimum and either the fluctuation of the nitrogen and phosphorus forms or the major ions. Instead, there was significant correlation with Si content of the water which correlated with the seasonal changes of the discharge. The relative abundance of the *A. minutissimum* showed significant positive correlation with three diatom indices (IBD, EPI-D, TDI): the higher abundance of the species resulted in better water quality. Against the IPS index (which is recommended to apply for ecological status assessment of Hungarian streams) we did not find significant correlation, consequently this index does not use the A. minutissimum as a potential indicator species.

Based on the data we conclude that the discharge-dependent Si content of the streamwater and the r-strategy of the species determine the distribution of the *A. minutissimum*; it typically reaches higher dominance after flood periods and therefore indicates natural disturbances. Since flooding is a natural phenomenon existing also in reference state, the species' abundance can not be used to assess the antropoghenic impacts. According to most diatom sampling protocols for WFD qualification, periods after floods should be avoided. In this view we may conclude that high contribution of A. minutissimum in any sample may indicate a preceding flood and therefore such samples do not provide a reliable basis for ecological status assessment.

INTRODUCTION

Establishment of indicator values of species used in any kind of environmental quality assessment system has been of essential importance. This need has been even more pronounced in case of species that are abundant. *Achnanthidium minutissimum* has been defined as freshwater species (Cholnoky, 1968; Patrick and Reimer, 1966). Inevitably, it is one of the most frequently occurring diatom species all over Europe with broad ecological spectrum (Round, 1991; Krammer and Lange-Bertalot, 1991-2000). The reasons of its wide distribution are manyfold, e.g. light adaptation (Barreto et al., 1998), shade tolerance (Villanueva and Albariño, 1999), strong attachment to stalks of arborescent diatoms (Roemer et al., 1984) in which respect it does not have special demands (Antoine and Benson-Evans, 1986). Some authors list it as r-strategist aquatic weed that indicates either physically, chemically or by biologically disturbed environments (Stevenson and Bahls, 1999). Fore and Grafe (2002) used its disturbance tolerance in their river diatom index. Later Ács et al. (2004) also applied this feature in assessment of ecological status of streams. Another study (http://deq.mt.gov/wqinfo/monitoring/SOP/pdf/12-1-2-0.pdf) demonstrated its dominance both in polluted and pristine streams and if the relative abundance of this species exceeded the 3% it was excluded from the further analysis. The species is tolerant to metals (Deniseger et al., 1986; Takamura et al., 1989), however, its abundance is decreasing along increasing salinity gradient (Herbst and Blinn, 1998).

The main aim of this study was to analyse temporal distribution records of *A. minutissimum* in view of the above outlined characterization and in context of the existing diatom indices.

MATERIAL AND METHODS

In 2004-2005, diatom samples were taken biweekly from stones and water samples for chemical analyses were collected once a month in the Torna-stream, W-Hungary between September of 2004 and 2005. Torna-stream is a middle altitude stream with calcareous hydrogeochemistry and rough bedrock. It is 51 km long with slight slope (1-3‰); the catchment area of the stream is 498 km^2.

The water samples were stored in dark and 7°C for the further analyses. Conductivity and pH were measured by laboratory sensors (Radelkis, OK-102/1; MultiLine P3). Ca^{2+}, Mg^{2+}, K^+, Na^+, SO_4^{2-}, Si were measured with ICP-OES (Optima 2000 ICP-OES). TP, PO_4^{3-} NO_2^-, NO_3^- and NH_4^+ were analyzed with spectrophotometry (Marczenko, 1976; Inczédy, 1996; Németh, 1998; Daniel and Pote, 2000). Cl^-, SO_4^{2-} was determined by titration (Inczédy, 1996; Németh, 1998). Water discharge data were provided by the regional Water Authority.

Diatom samples were preserved in 3-5% formaline. Cold hydrogen-peroxide method was applied to clean the diatom valves that then were mounted in Zrax. Altogether 400 valves were identified and counted in each sample. Diatoms were identified at species level using light microscopy with phase contrast according manuals by Krammer & Lange-Bertalot (1991-2000), Lange Bertalot (1995-2002) and Krammer (2002). The counts were converted to relative abundance.

The diatom indices: TDI, GENRE, CEE, IPS, IBD, EPI-D (Kelly, 1998; Rumeau and Coste, 1988; Descy and Coste, 1991; Coste in Cemagref, 1982; Lenoir and Coste, 1996; Prygel and Coste, 2000; Dell'Uomo, 1996) and the diversity were calculated by the OMNIDIA 4.1 software (Lecointe et al., 1993). The correlation between two parameters followed the Pearson eqation (Quinn and Keough, 2004):

$$r_{y1,y2} = \frac{\sum_{i=l}^{n}[(y_{il} - \bar{y}_l)(y_{i2} - \bar{y}_2)]}{\sqrt{\sum_{i=l}^{n}(y_{il} - \bar{y}_l)^2 \sum_{i=l}^{n}(y_{i2} - \bar{y}_2)^2}}$$

RESULTS

Althogether 75 species were identified in the 23 samples. Seasonality was the most striking characteristics of the diatom vegetation. In summer and autumn, *Navicula gregaria* Donkin, *Nitzschia palea* Kützing W. Smith, and in spring and summer *Surirella brebissonii* Krammer and Lange-Bertalot and *Fragilaria capucina* Desmazières var. *vaucheriae* were the most characteristic species of the stream. *Navicula lanceolata* (C. Agardh) Ehrenberg was the only species which was dominant throughout the year.

In the one year study period *Achnanthidium minutissimum* was one of the dominant species with >5% contribution to the total abundance. Its abundance was < 5% only in December and February 2004/2005. In spring and early summer it maintained a moderate, however, constant abundance. In the end of summer it started to increase then reached the highest relative abundance in autumn. The Shannon-diversity changed between 1.2 and 3.93. It peaked in October (3.93 and 3.65). The diatom community was characterized by low diversity in winter then from the beginning of spring the compositional diversity increased (Fig 1.a). No significant correlation was found between relative abundance of *A. minutissimum* and Shannon-diversity (Table 1).

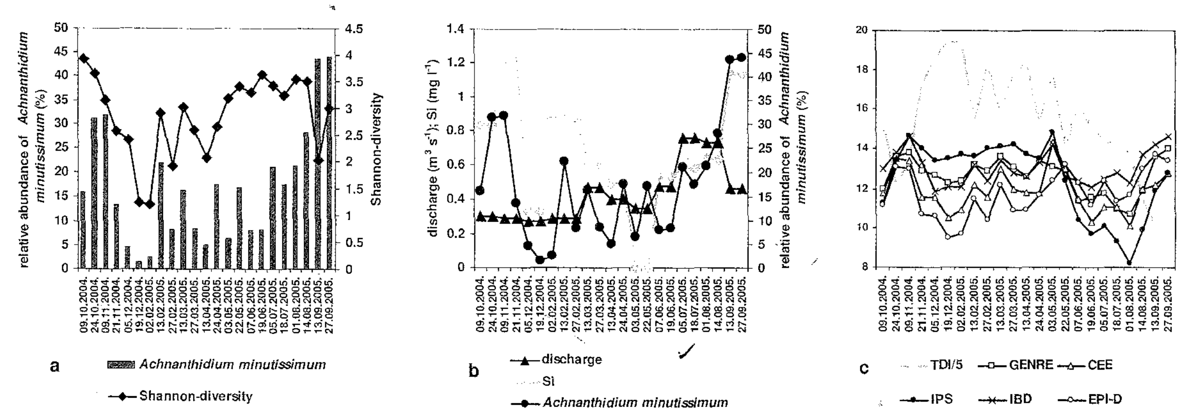

Fig. 1a: Relative abundance of *A. minutissimum and* Shannon-diversity; 1b: discharge and Si content 1c: changes of six diatom indices in the Torna stream during one year period

Different diatom indices exhibited different range of variation during the one-year study period (Fig. 1.c). The IPS and TDI varied in the widest range (12.5 ± 1.64 and 76.8 ± 10.65), changes in the EPI-D was smaller (11.7 ± 0.98). Changes of GENRE, CEE and IBD (12.6 ± 0.75; 11.9 ± 0.8 and 13 ± 0.69, respecitvely) were moderate. The TDI In general, most indices showed minimum values in summer and the highest index values were found in autumn. Three of the applied indices (IBD, EPI-D and TDI) showed significant correlations with *A. minutissimum* (Table 1).

Discharge of the Torna-stream was quite constant from October to February. The raise in March was attributable to snowmelt. As a consequence of rainfall, discharge increased gradually from May to July then decreased. After high-discharge periods relative abundance of the species decreased gradually, while after the lower discharge the rate of *A. minutissimum* increased sharply. The Si concentration fluctuated quite parallel with *A. minutissimum* and it was the only chemical parameter which showed clear correlation (r = 0.54) with *A. minutissimum*. Similar correlation was observed between the species and the discharge of the stream (r = 0.56). There was no significant direct correlation between discharge and Si, however, if Si was lagged by two weeks the correlation was significantly positive (r = 0.82).

DISCUSSION

The relative abundance of the *Achnanthidium minutissimum* showed marked seasonal distribution in the calcareous Torna-stream. Moderate and constant abundance was observed in spring and early summer and it reached the highest relative abundance in autumn. This seasonal pattern was different from that in a Spanish calcareous stream where it reached the maximum in spring (Sabater, 1990). These results might be related to the observation that *A. minutissimum* is stimulated by exposure to UV radiation (Francoeur and Lowe, 1998). The species was also characteristic in other circumneutral streams with high buffering capacity (van Dam et al., 1994; Kovács et al., in press) as well as in alkaline boreal streams (Vilbaste, 2001). In contrast, in an acidic mountain stream the species was rare (Kwadrans, 1993). According to Peterson et al. (1998) this species is a typically grazer-resistant taxon which also can result in its the constant presence and dominance.

	relative abundance of *A. minutissimum*	significance level
PO_4^{3-}	-0.09	ns
TP	- 0.10	ns
NH_4^+-N	- 0.10	ns
$NO_2^-+NO_3^-$-N	- 0.24	ns
$NO_2^-+NO_3^-$-N	0.36	ns
TN	0.05	ns
K^+	0.22	ns
Ca^{2+}	0.20	ns
Na^+	0.13	ns
Mg^{2+}	0.34	ns
Si	**0.54**	**0.01**
SO_4^{2-}	0.18	ns
Cl^-	-0.154	ns
TDI	**-0.92**	**0.01**
GENRE	0.41	ns
CEE	0.40	ns
IPS	-0.05	ns
IBD	**0.75**	**0.01**
EPI-D	**0.81**	**0.01**
Shannon-diversity	0.29	ns
discharge	**0.56**	**0.01**

Table 1: Correlation and significance level between *Achnanthidium minutissimum* and physical - chemical parameters and diatom indices

In this study we did not find close correlation between the relative abundance of the *A. minutissimum* and either the fluctuation of nitrogen and phosphorus forms or the major ions. This observation accords to other studies that supported the species' occurrence in streams characterized by a wide range of nutrient conditions (Carrick, 2005; Kelly et al., 1995; Verb and Vis, 2000). *A. minutissimum* correlated significantly with the Si content of the water which followed seasonal changes of the discharge. Groundwater-derived Si seeping results higher Si concentration (Hagerthey and Kerfoot, 2005); however, origin of high Si values needs detailed hydrogeological studies.

The relative abundance of the *Achnanthidium minutissimum* showed significant positive correlation with three diatom indices (IBD, EPI-D, TDI): the higher abundance of the species resulted in better water quality. Against the IPS index (which is recommended to apply for ecological status assessment of Hungarian streams) we did not find significant correlation, consequently this index does not use the *A. minutissimum* as a potential indicator species.

Based on the data we conclude that the discharge-dependent Si content of the streamwater combined with the good colonization abilities (r-strategy) of the species are the major factors that influence the temporal distribution of the *Achnanthidium minutissimum*. It typically reaches higher dominance after flood periods and therefore indicates natural disturbances. Since flooding is a natural phenomenon existing also in reference state, the species' abundance can not be used to assess the anthropogenic impacts.

According to most diatom sampling protocols for WFD qualification, periods after floods should be avoided. In this view we may conclude that high contribution of *A. minutissimum* in any sample may indicate a preceding flood and therefore such samples do not provide a reliable basis for ecological status assessment within the WFD.

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REFERENCES

Ács, É. Szabó, K., Tóth, B., Kiss, K. T. 2004. Investigation of benthic algal communities, especially atoms of some Hungarian streams in connection with reference conditions of the Water Framework Directives. Acta Botanica Hungarica 46: 255-277.

Antoine, S.E., Benson-Evans, K. 1986. Phycoperiphyton development on artificial substrata in the River Wye system, Wales, U.K. Part 2.: Population dynamics. Acta hydochim. hydrobiol. 14: 347-363.

Barreto, S., Ács, É., Kiss, K., Makk, J. 1998. Jég alatti vizsgálatok a Soroksári-Dunán. Hidrológiai Közlöny 78: 300-302.

Carrick, H.J. (2005) Using periphyton to estimate TMDL endpoints and assess impairment in a urban-suburban stream (Skippack Creek, Pennsylvania) Final report. Department of Environmental Protection Harrisbourg, PA.

Cemagref 1982. Etude des méthodes biologiques quantitative d'appréciation de la qualité des eaux. Rapport Q.E. Lyon-A.F. Bassin Rhone-Méditerranée-Corse, Lyon, France.

Cholnoky, B. J. 1968. Die Ökologie der Diatomeen in Binnengewässern. Cramer, Lehre, 699 pp.

Daniel, T. C., Pote, D. H. 2000. Analyzing of Total Phosphorus and Total Dissolved Phosphorus in water samples. In G.M. Pierzynski (ed): Methods for P Analysis for soils sediments, residual and waters V.396: 94-97.

Dell'Uomo, A. 1996. L'indice diatomico di eutrofizzazione/polluzione (EPI-D) nel monitoraggio delle acque correnti. Linee guida. APAT.

Deniseger, J., Austin, A., Lucey, W.P. 1986. Periphyton communities in a pristine mountain stream above and below heavy metal mining operations. Freshwater Biol. 16: 209-218.

Descy, J.-P., Coste, M. 1991. A test of methods for assessing water quality based on diatoms. Verh. Int. Ver. Limnol. 24: 2112-2116.

Fore, L.S., Grafe, C.S. 2002. Using diatoms to assess the biological condition of large rivers in Idaho (U.S.A.). Freshwater Biol. 47: 2015- 2037.

Franceour, S. N., Lowe, R. L. 1998. Effects of ambient ultraviolet radiation on littoral periphyton: Biomass accrual and taxon-specific responses. J. Freshwat. Ecol. 13: 29-38.

Hagerthey, S. E., Kerfoot, W. C. 2005. Spatial variation in groundwater-related resource supply influences freshwater benthic algal assemblage composition. Journal of the North American Benthological Society 24: 807-819.

Herbst, D. B., Blinn, D. W. 1998. Experimental mesocosm studies of salinity effects on the benthic algal community of a saline lake. J. Phycol. 34: 772-778.

Inczédy, J. 1996. Analitikai laboratóriumi gyakorlat II. [Manual for chemical analyses II.] Veszprémi Egyetem. Veszprém [in Hungarian]. 289 pp.

Kelly, M. G. 1998. Use of trophic diatom index to monitor eutrophication in rivers. Water Research 36: 236-242.

Kelly, M. G., Penny, C. J., Whitton, B. A. 1995. Comparative performance of benthic diatom indices used to assess river water quality. Hydrobiologia 302: 179-188.

Kovács, Cs., Kahlert, M., Padisák, J. in press. Benthic diatom communities along pH and TP gradients in Hungarian and Swedish streams. Journal of Applied Phycology.

Krammer, K. 2002. Diatoms of Europe. Diatoms of the European Inland Waters and Comparable Habitats. Vol. 1-4. A.R.G. Gantner Verlag K.G, Ruggel.

Krammer, K., Lange-Bertalot, H. 1991-2000. Bacillariophyceae 1.-4. Teil: Naviculaceae. In: Pascher A (ed.) Süsswasserflora von Mitteleuropa. Band 2/1-4. Gustav Fischer Verlag, Heidelberg, Berlin.

Kwadrans, J. 1993. Diatom communities of acidic mountain streams in Poland. Hydrobiologia 269/270: 335-342.

Lange-Bertalot, H. 1995-2002. Iconographia Diatomologica. Annotated Diatom Micrographs Vol. 1.-9. Koeltz Scientific Books. Königstein, Germany.

Lenoir, A. Coste, M. 1996. Development of a practical diatomic index of overall water quality applicable to the French National Water Board Network. In: Rott, E. (ed.) 2nd Workshop on Algae for Monitoring Rivers, Innsbruck 18-19 Sept. 95, Studia Student. G.m.b.H., Innsbruck.

Lecointe, C., Coste, M., Prygiel, J. 1993. "OMNIDIA" software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270 : 509-513.

Marczenko, Z. 1976. Spectrophotometric determination of elements. Ellis Horwood Ltd. Coll House, Westergate, Chichester, Sussex England and Wydawnictwa Naukowo-Techniczne, Warsaw, Poland. 643 pp.

Németh, J. 1998. A biológiai vízminősítés módszerei [Methods for biological qualification of surface waters]. Vízi Természet-és Környezetvédelem 7. Környezetgazdálkodási Intézet, Budapest [in Hungarian]. 304 pp.

Patrick, R., Reimer, W. 1966. The diatoms of United States. 1st Vol. Mon. Acad. Nat. Sci. Phil. 13. Philadelphia. 688pp.

Pásztó, P. 1998 Vízminőségvédelem, vízminőségszabályozás [Water quality protection and managment] Veszprémi Egyetem, Veszprém.[in Hungarian]. 200 pp.

Peterson, C.G., Vormittag, K.A., Valett, H.M. 1998. Ingestion and digestion of eplithic algae by larval insects in a heavily grazed montane stream. Freshwater Biol. 40: 607.

Prygiel, J., Coste, M. 2000. Guide Méthodologique pour la mise en oeuvre de l'Indice Biologique Diatomées. NF T 90-354. Etude Agences de l'Eau-Cemagref Bordeaux, March 2000, Agences de l'Eau. 134pp.

Quinn, G.P., Keough, M.J. 2004. Experimental design and data analysis for biologists. Cambridge Univ. Press. 537 pp.

Round, F. E. 1991. Use of diatoms for monitoring rivers. In Whitton, B.A., Rott, E. Use of algae for monitoring rivers I. Institute für Botanik, Universität Innsbruck:25-32.

Roemer, S. C., Hoagland, K. D., Rosowski, J. R. 1984. Development of freshwater periphyton community as influence by diatom mucilages. Can.J.Bot.62:1799-1813.

Rumeau, A., Coste, M. 1988. Initiation a la systematique des Diatomees d'eau douce pour l'utilisation pratique d'un indice diatomique generique. Bulletin Francais de la peche et de la Pisciculture 309: 1-69.

Sabater, S. 1990. Composition and dynamics of a highly diverse diatom assemblage in a limestone stream. Hydrobiologia 190: 43-53.

Stevenson, R. J., Bahls, L. 1999. Chapter six: periphyton protocols. In : Rapid Bioassessment Protocols for Use of Streams and Wadeable Rivers, Periphyton, Benthic macroinvertebrates and Fish, 2nd edn (Eds M.T. Barbour, J.Gerritsen, B. D. Snyder & J. B. Stribling), pp. 6.1-6.22. EPA 841-B-99-022. US Environmental Protection Agency, Office of Water, Washington, DC.

Takamura, N., Kasai, F., Watanabe, M. M. 1989. Effects of Cu, Cd and Zn on photosynthesis of freshwater benthic algae. J. appl. Phycol. 1: 39–52.

van Dam, H., Mertens, A., Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms and ecological indicator values of freshwater diatoms from Netherland. Neth. J. Aquat. Ecol. 28: 117-133.

Verb, R.G. Vis, M. L. 2000. Comparison of benthic diatom assemblages from streams draning abandoned and reclaimed coal mines and nonimpacted sites. Journal of the North American Benthological Society 19: 274-288.

Vilbaste, S. 2001. Benthic diatom communities in Estonian rivers. Boreal Environ. Res. 6: 191.203.

Villanueva, V.D., Albariño, R. J. 1999. Feeding habit of *Notoperla archiplatae* (Plecoptera) larvae in a North Patagonia Andean stream, Argentina. Hydrobiologia 412: 43-52.

http://deq.mt.gov/wqinfo/monitoring/SOP/pdf/12-1-2-0.pdf

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