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Ecological analyses on benthic diatom and invertebrate communities from the Someșul Mic catchment area (Transylvania, Romania)

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SUMMARY. The present study focused on benthic diatom and invertebrate communities from the Someșul Mic catchment area, between Someșul Rece and Apahida localities. Five sites were chosen, and they were sampled in spring, summer and autumn 2014. The area experienced major human impacts on aquatic communities, all caused by the existence of numerous urban and rural centers: discharges of waste waters into the natural streams, hydro-technical works for the production of energy or for water storage, hydropeaking, pollution coming from point or diffuse sources. The presence and the indicator value of the diatom species identified in the study area, together with the relative abundance of benthic invertebrate taxa were used to characterize the ecological status of the five sampling sites. Both diatoms and invertebrates showed the highest ecological status at the sampling site located on the Someșul Rece River, while the sampling sites located in or downstream Cluj-Napoca displayed the most impacted conditions. However, eutrophic conditions were characteristic to all sampling sites, showing affected biotic communities even in habitats with low human impacts.

Keywords: bio-indicators, human impacts, relative abundance, saprobity, trophic state

Introduction

Diatoms can be found in almost all aquatic habitats, so they can be used for comparison of streams, lakes, wetlands, oceans, estuaries, and even some ephemeral aquatic habitats (Amoros and van Urk, 1989). Diatoms are valuable indicators of environmental conditions in rivers, because they respond directly and sensitively to

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many physical, chemical, and biological changes in lotic ecosystems, such as temperature (Descy and Mouvet, 1984), or nutrient concentrations (Pringle and Browers, 1984; Pan *et al*., 1996).

The species - specific sensitivity of diatom physiology to many habitat conditions is manifested in the great variability in biomass and species composition of diatom assemblages in rivers (Patrick, 1961).

Diatoms have one of the shortest generation times of all biological indicators (Rott, 1991). They reproduce and respond rapidly to environmental change and provide early warning indicators of both pollution increases and habitat restoration success.

Benthic invertebrates represent by far the most studied and diverse group of organisms in rivers (Giller and Malmqvist, 1998). Their communities have the ability to reflect physical, chemical or biological changes of their habitat in time and in space (Cook, 1976). Thus, they integrate the effects produced by a complex of disturbing factors, offering valuable information on water quality, including abusive discharges, hard to identify based on a point chemical analysis (De Pauw and Hawkes, 1993; Metcalf, 1989).

The Someșul Mic River is the most important tributary of the Someș River, having a total length of 178 km, an average slope of 8‰, a 1.68 sinuosity coefficient and a total catchment area of 3773 km^2. Located in north-western Romania (Fig. 1), it is formed at the confluence of two rivers, the Someșul Cald and the Someșul Rece, both coming from the Apuseni Mountains. From this confluence in Gilău, the Someșul Mic flows eastwards and then northwards, through several urban and rural centers: Cluj-Napoca, Apahida and Gherla, up to Dej, where it meets the Someşul Mare River (Ghinea, 2000).

For the present study, a region affected by dissimilar impacts was chosen from the Someșul Mic catchment area: the sector stretching between Someșul Rece and Apahida localities. This sector is affected by three types of human impacts, as follows: i) the presence of numerous human settlements, many without waste water treatment plants; ii) the presence of different hydro-technical works for energy production, water supply etc.; and iii) pollution from point and diffuse sources, including industry and agricultural fields.

According to the Someș-Tisa Catchment Area Management Plan (*http://www.rowater.ro/dasomes/*), only 75 to 96% from the waste waters are connected to the central collection systems in Cluj-Napoca, while in Apahida the percentage does not exceed 40%. Secondly, the ICPDR Danube River Basin District Management Plan (2014) pointed out the existence of several hydropower plants in the Someșul Mic catchment area, upstream Cluj-Napoca, with both large (>10MW) and medium (1-10MW) generation capacities. The dam reservoirs from this area are multipurpose facilities: energy production, water supply, mitigation of floods or droughts etc. Thirdly, the same document showed high Total Nitrogen and Total Phosphorus emissions near Cluj Napoca, with long term averages (2000-2008) of more than 20 kg / ha / year for Nitrogen and around 5 kg / ha / year for Phosphorus.

Algal communities from the area were well studied beginning with 1992: in the Someșul Cald River (Rasiga *et al.*,1995/1996, 1996), in the Someșul Rece (Rasiga *et al.,* 1992, 1994, 1996), in the Someșul Mic (Rasiga *et al.,* 1995/1996, Rasiga, 2001), in the Someșul Mare and the Someș River (Rasiga *et al.,* 1998, 1999). Several studies focused on the assessment of saprobity levels using diatoms (Rasiga *et al.,* 1996, 1997, 1998, 1999), or on the assessment of river ecological status based on biotic communities (Momeu and Péterfi, 2007, Momeu *et al.,* 2007). Aquatic invertebrate communities from the study area were also investigated in previous research: Battes *et al.,* 2000/2001, Petrovici and Tudorancea, 2000/2001; Cîmpean and Tudorancea, 2001, Tudorancea and Tudorancea, 2002, Cîmpean, 2004, 2011, Avram *et al.,* 2005, 2009.

Even though the benthic algal and invertebrate communities were well studied in the Someșul Mic catchment area, the present paper focuses on the use of taxonomical richness, bioindicators and relative abundance for assessing the ecological status at five sampling sites, affected by different human impacts of different intensities. Hydropeaking and its major affects on biotic communities should be taken into consideration for further detailed studies.

Materials and methods

The samples were collected in 2014 from five sampling sites in three seasons: spring, summer, autumn. The following code was used to denominate the sampling sites for the present paper: S1_DD.MM.YY, where S1 is the sampling site; DD is the day, MM the month and YY the year of the sampling. Thus, S1_06.05.2014 represents the site located on the Someșul Rece, sampled on 6th of May, 2014 (Table 1, Fig. 1).

Number codes were assigned to sampling sites from upstream to downstream. Thus, the first site, S1, was located on the Someșul Rece River, at the highest altitude, in a deciduous forest, where trees and shrubs represented the riparian vegetation from both river banks, and the river substratum consisted mainly of large and small boulders, gravel and coarse sand. Human impacts were low in this area.

The second site, S2, was situated on the Someșul Mic River, in Gilău, downstream from the Gilău dam reservoir, where the river experienced a significant human impact, due to hydro-technical works: controlled water outlet from the reservoir, periodic alternation between the surge and low water (hydropeaking) and concrete river banks. Riverbed consisted in coarse and fine sand (Table 1, Fig. 1).

S3 was located on the Someșul Mic River, in Grigorescu district, just upstream Cluj-Napoca, where both river banks were covered in herbaceous vegetation, with concrete tiles on the left bank. Small boulders, coarse and fine sand formed the river substratum at this sampling site. The main human impacts in this area were represented by the dam reservoirs Florești I and II, located upstream, and possibly by domestic effluents coming from Gilău and Florești localities.

Table 1.

Main characteristics of the five sampling sites located in the Someșul Mic catchment area (Alt. – altitude; Max. – maximum).

Sampling site code	Sampling site name	Sampling site location	GPS coordinates	Alt. (m)	Max. depth (m)	Riverbed width (m)
S1_06.05.2014	Someșul Rece	The Someșul Rece River, upstream Somesul Rece village	N 46°41'23.9" E 23°17'45.5"	521	0.30	4.50
S1_23.08.2014					0.05	3.00
S1_02.11.2014					0.20	3.00
S2_06.05.2014	Gilău	The Someșul Mic River, downstream Gilău dam reservoir	N 46°45'09.7" E 23°23'37.2"	410	0.30	7.00
S2_23.08.2014					0.20	6.00
S2_02.11.2014					0.50	5.00
S3_06.05.2014	Grigorescu	The Someșul Mic River, upstream Cluj-Napoca	N 46°45'50.4" E 23°32'46.3"	357	0.50	20.00
S3_23.08.2014					0.50	20.00
S3_02.11.2014					1.00	20.00
S4_06.05.2014	Valea Popești	The Popești Rivulet, tributary to the Someșul Mic River	N 46°47'08" E 23°32'57"	355	0.20	2.00
S4_23.08.2014					0.04	1.80
S4_02.11.2014					0.20	1.50
S5_06.05.2014	Apahida	The Someșul Mic River, downstream Cluj-Napoca	N 46°48'56.6" E 23°44'54.7"	300	> 1.00	35.00
S5_23.08.2014					> 1.00	35.00
S5_02.11.2014					> 1.00	35.00

Figure 1. Location of the sites from the Someșul Mic catchment area, sampled in 2014 (abbreviaton of the sampling sites as in the Table 1) (source: Google Earth 2013).

S4 was placed on the Popești Rivulet, a left tributary of the Someșul Mic River, in Baciu District of Cluj-Napoca. Trees and shrubs were present on both river banks, while small boulders, gravel, coarse and fine sand made the substratum. Domestic effluents coming from Popești and Cluj-Napoca localities represented the major human impacts in the area, next to the deposits of organic debris left by the old chicken farms. The last sampling site - S5 was situated on the Someșul Mic River in Apahida, about 10 km downstream from Cluj-Napoca. Riparian vegetation on both banks consisted of trees, shrubs and herbaceous plants, while the river substratum was composed of large and small boulders, together with fine sand and clay. Human impacts concentrated at this site were represented by domestic effluents coming from all rural and urban centers upstream, but also by diffuse pollution coming from agricultural lands near-by (Table 1, Fig. 1).

Several physical and chemical parameters were recorded in the field or were measured subsequently in the laboratory. Thus, water temperature and dissolved oxygen were measured using the portable meter YSI 52, while the pH and the conductivity were measured in the laboratory. The values for water discharge, total phosphorus and total nitrogen were taken with permission from the Romanian Waters National Administration data base, The Someș – Tisa Basin Administration (ABAST). Diatoms were sampled by scraping the hard substratum or collecting the sediment using a pipette, while invertebrates were collected using a 250 µm mesh net for qualitative samplings. All samples were preserved in the field with 4% formaldehyde. Identifications were made to the species level in case of algae (Krammer, 2000, 2002, 2003; Krammer and Lange - Bertalot, 1986, 1988, 1991 a, b), and to different taxonomical levels in case of benthic invertebrates (Sansoni, 2001).

The species packing model was chosen to illustrate the numerical variation of diatom and invertebrate taxa along the water discharge gradient, using PAST version 2.14 (Hammer *et al*., 2001).

The ratio of araphid pennate to centric diatoms, namely the A/C diatom index (Stockner, 1972) was used to characterize the trophic state of the five aquatic habitats considered for the present paper. The values of the index indicate oligotrophy (<1), mesotrophy (1-2) or eutrophy (>2).

Multivariate analyses were used to visualize and interpret the data. Principal Component Analysis (PCA) was used for the physical and chemical parameters, due to its ability to project the data on a two dimensional map and to identify trends. Correspondence Analysis (CA) visualizes complex data, primarily data on categorical measurement scales, facilitating understanding and interpretation. Simple CA analyses the relationships between two variables, while Multiple CA (MCA) analyses several categorical variables. Multivariate analyses were performed using XLSTAT Version 2015.3.01.19199.

Results and discussion

Physical and chemical parameters

The physico-geographical conditions differed at the five sampling sites considered for the present study, even from one season to another (see table 1). The maximum depth of the river, for example, varied in most sampling sites, generally having the lowest values during summer. However, no significant correlations were found with the total number of diatom or invertebrate taxa ($p > 0.05$ in case of Spearman correlation).

Moreover, the water discharge measured at S1, S3 and S5 (ABAST database) was highly irregular, ranging from 0.038 m^3/s to 45.3 m^3/s. In summer, a high water discharge was recorded at S3 and S5, but not at S1 (0.552 m^3/s), showing an artificially increased flow of water coming from the hydropower plants located upstream on the Someșul Mic River.

Water discharge had drastic influences on the taxonomical richness of benthic diatom and invertebrate communities (Fig. 2). Only intermediate water discharge values were favorable to biotic communities, the trend showing the lowest number of taxa (expressed as percentage from the total number of taxa identified in the five sampling sites) connected to the highest discharge values.

In fact, these results are similar to the literature. Human impacts on the river natural flow regimes, by means of rapid changes in water releases below hydropower plants, are usually recognized as one of the most serious threats to aquatic biodiversity (Bunn and Arthington, 2002; Poff and Zimmerman, 2010; Chen *et al*., 2015). These changes has drastic effects on all benthic organisms, including diatoms (Smolar-Žvanut, 2013) and invertebrates (Richards *et al*., 2014).

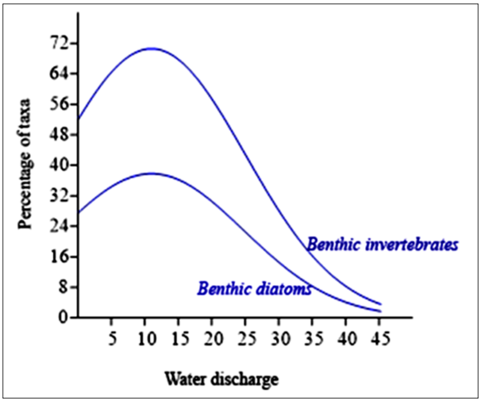

Figure 2. The relationship between the water discharge (m^3/s) and benthic diatom and invertebrate taxa (percentage from the total number present in all sampling sites) (sampling sites S2 and S4 not included).

The PCA biplot showed a tendency of the sampling sites to aggregate according to similar physical and chemical characteristics in different seasons (Fig. 3). Water temperature, pH and water discharge were best explained by F1, while dissolved oxigen by F2.

Conductivity was not discriminated; it was not well linked to F1, nor to F2, thus any interpretation could be hazardous. However, the highest values were recorded at S4 (exceeding 900 µS/cm in all sampled seasons). The conductivity values are linked to the dissolved ions present in the water, including nitrate or phosphate, whose high concentrations are mostly caused by agricultural fertilization.

Water temperature varied with the season, showing similar values in spring and summer 2014 and lower values in autumn. The pH values were circum-neutral, thypical for most surface freshwater systems. Dissolved oxygen ranged between 7 and 11 mg/L, with the lowest value at S4 in autumn 2014. Water discharge had very high values at S3 and S5 during summer 2014, as shown in Fig. 3.

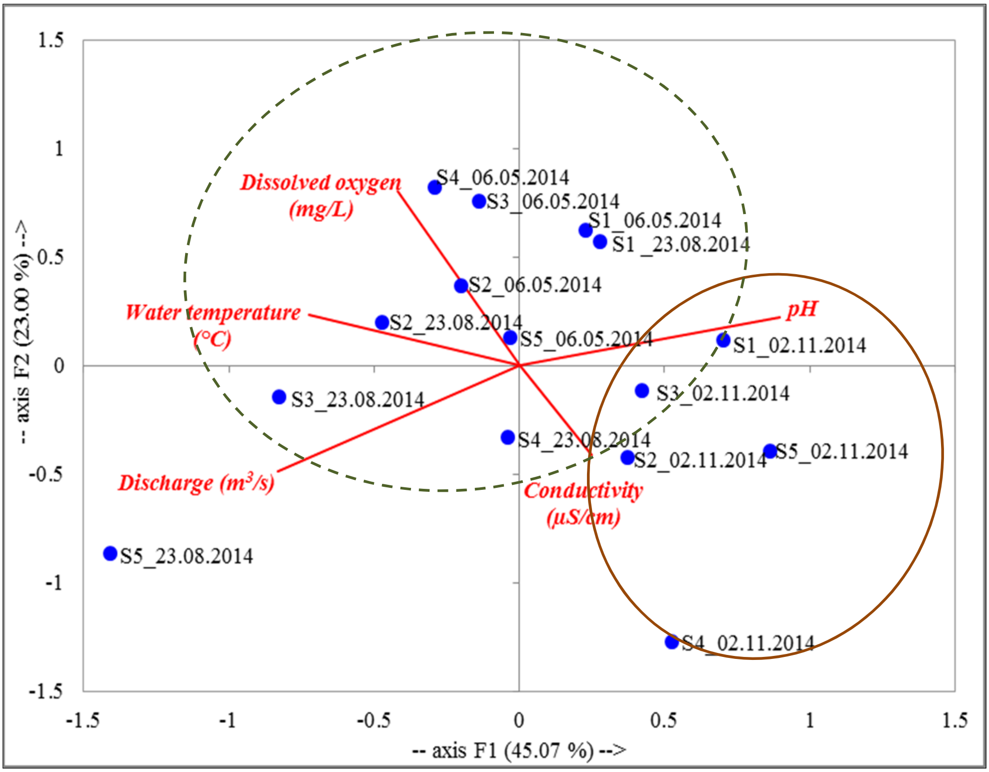

Figure 3. Principal Component Analysis (PCA) biplot (axes F1 and F2: 68.07 %) for the five sampling sites and three seasons considered for the present study, and their aggregation based on physical and chemical parameters (abbreviations as in Table 1).

As for nutrient concentrations, total phosphorus (TP) exceeded the admissible limit in surface waters according to Order no. 161/2006 only at S3 in May 2014. The value exceeded 1.2 mg/L (the Romanian Waters National Administration data base), indicating waters of poor quality as TP was concerned. No limitation was exceeded in case of total nitrogen (TN), however, higher values were recorded at S4 and S5 (over 2 mg/L, according to the Romanian Waters National Administration data base).

Benthic diatom communities

A total number of 116 diatom species, belonging to 27 genera, were identified in the five sampling sites from the Someșul Mic River in 2014 (Table 2). As in previous studies from the area (Rasiga *et al.*, 1995/1996), cosmopolitan taxa dominated the qualitative structure of the diatom communities from the Someșul Mic catchment area, while *Navicula* sp. and *Nitzschia* sp. dominated in all samples, in terms of number of species. In fact, numerous species identified in the five sampling sites were tolerant and adapted to survive in habitats with high organic matter loads: *Nitzschia palea, Fragilaria ulna, Fragilaria ulna* var. *acus, Gomphonema parvulum, Navicula accomoda, Navicula goeppertiana, Navicula veneta, Nitzschia umbonata*. Several planktonic algal species were identified in each sampling site, like: *Actinocyclus normanii, Asterionella formosa, Frustulia vulgaris, Melosira varians, Nitzschia fruticosa, Nitzschia intermedia, Nitzschia acicularis*. Their presence in benthic samples was due to several dam reservoirs, located upstream of the sampling sites: Someșul Rece, Gilău or Florești.

Eutrophic conditions were found in all five sampling sites, according to the A/C diatom index (Stockner, 1972). In fact, numerous indicator diatom species for eutrophic conditions were identified in the five sampling sites, as follows: *Actinocyclus normanii, Amphora veneta, Asterionella formosa, Cyclotella meneghiniana, Cyclotella radiosa, Cymatopleura solea, Gomphonema parvulum, Gyrosigma acuminatum, Navicula veneta, Navicula viridula, Nitzschia capitellata, Nitzschia fruticosa, Nitzschia intermedia, Nitzschia palea, Nitzschia paleacea, Nitzschia umbonata, Stauroneis phoenicenteron*. These eutrophic conditions can be explained at S4 by the remaining deposits of organic debris coming from the old chicken farms located in the area. However, at S1, where human impacts had low intensities, the bottom discharge coming from a lake located upstream could cause the higher nutrient loads, leading to the development of eutrophic diatom species.

Several halophilic elements were found in the study area: *Gyrosigma scalproides, Navicula cincta, Navicula goeppertiana, Nitzschia trivialis, Nitzschia constricta, Nitzschia hungarica, Nitzschia intermedia, Amphora veneta, Gomphonema augur, Navicula halophila, Navicula salinarum,* or *Nitzschia levidensis*. Rasiga *et al*. (1995/1996) reported similar findings, caused by the presence of salt water habitats in the Someș catchment area (Sălsig). The presence of these halophilic species can be also explained by the influence of diapir folds located on the Zăpodie and Becaş Rivers, as well as in Cojocna.

Table 2.

The qualitative structure of benthic diatom communities from the five sampling sites located in the Someșul Mic catchment area (sampling site codes as in Table 1).

Samples sites (→) **Algal taxa (↓)**	**S1**	**S2**	**S3**	**S4**	**S5**
Achnanthes biasolettiana Grunow in Cleve & Grunow 1880				✓	
Achnanthes bioretii Germain 1957		✓			
Achnanthes flexella (Kützing) Brun 1880			✓		
Achnanthes helvetica (Hustedt) Lange-Bertalot in Lange-Bertalot & Krammer 1989		✓			
Achnanthes lanceolata (Brébisson ex Kützing) Grunow in Van Heurck 1880	✓	✓	✓	✓	✓
Achnanthes minutissima Kützing 1833	✓	✓	✓	✓	✓
Actinocyclus normanii (Gregory) Hustedt 1957			✓		
Amphipleura pellucida (Kützing) Kützing 1844:		✓			
Amphora libyca Ehrenberg 1840			✓	✓	✓
Amphora ovalis (Kützing) Kützing 1844		✓	✓	✓	✓
Amphora pediculus (Kützing) Grunow ex A.Schmidt 1875	✓	✓	✓	✓	✓
Amphora veneta Kützing 1844		✓		✓	
Asterionella formosa Hassall 1850		✓	✓	✓	
Bacillaria paradoxa Gmelin 1788				✓	
Caloneis silicula (Ehrenberg) Cleve 1894				✓	
Cocconeis pediculus Ehrenberg 1838	✓	✓	✓	✓	✓
Cocconeis placentula Ehrenberg 1838	✓	✓	✓	✓	✓
Cyclotella bodanica var. *affinis* (Grunow) A.Cleve 1951		✓			
Cyclotella meneghiniana Kützing 1844			✓	✓	✓
Cyclotella radiosa (Grunow) Lemmermann 1900		✓	✓		
Cymatopleura solea (Brébisson) W.Smith 1851	✓		✓	✓	
Cymbella affinis Kützing 1844	✓	✓	✓		✓
Cymbella cistula (Ehrenberg) O.Kirchner 1878	✓		✓		
Cymbella formosa Hustedt 1955		✓			
Cymbella minuta Hilse in Rabenhorst 1862	✓	✓	✓	✓	✓
Cymbella prostata (Berkeley) Cleve	✓		✓		✓
Cymbella silesiaca Bleisch in Rabenhorst 1864	✓	✓	✓		✓
Cymbella simonsenii Krammer in Krammer & Lange-Bertalot 1985	✓				
Cymbella sinuata W.Gregory 1856	✓	✓	✓	✓	✓
Cymbella tumida (Brébisson) van Heurck 188	✓				✓
Denticula tenuis Kützing 1844		✓	✓		✓
Diatoma ehrembergi (Kütz.) Grunow 1862			✓		
Diatoma hyemalis (Roth) Heiberg 1863	✓				
Diatoma mesodon Kützing 1844		✓	✓		
Diatoma vulgaris Bory de Saint-Vincent 1824	✓	✓	✓	✓	✓
Didymosphenia geminata (Lyngbye) M.Schmidt, A.Schmidt 1899	✓	✓	✓	✓	✓
Diploneis elliptica (Kützing) Cleve 1894		✓	✓	✓	
Fragilaria arcus (Ehrenberg) Cleve 1898	✓				
Fragilaria capucina Desmazières 1830	✓	✓	✓	✓	✓
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot ex Bukhtiyarova 1995			✓		

Table 2 (continued)

Fragilaria capucina var. *vaucheriae* (Kützing) Lange-Bertalot 1980	✓	✓	✓	✓	✓
Fragilaria construens (Ehrenberg) Grunow 1862		✓	✓		
Fragilaria crotonensis Kitton 1869		✓	✓	✓	
Fragilaria exigua (W.Smith) Lemmermann 1908			✓		
Fragilaria parasitica (W.Smith) Grunow in van Heurck 1881			✓		
Fragilaria pinnata Ehrenberg 1843		✓	✓		✓
Fragilaria pulchella (Ralfs ex Kützing) Lange-Bertalot 1980					✓
Fragilaria ulna (Nitzsch) Lange-Bertalot 1980	✓	✓	✓	✓	✓
Fragilaria ulna var. *acus* (Kützing) Lange-Bertalot 1980		✓	✓	✓	
Fragilaria ulna var. *claviceps* Hustedt 1937			✓		
Fragilaria virescens Ralfs 1843		✓	✓		
Frustulia vulgaris (Thwaites) De Toni 1891	✓				
Gomphonema acuminatum Ehrenberg 1832			✓		
Gomphonema angustum C.Agardh 1831	✓				
Gomphonema augur Ehrenberg 1840					✓
Gomphonema olivaceum (Hornemann) Brébisson 1838	✓		✓	✓	✓
Gomphonema parvulum (Kützing) Kützing 1849	✓	✓	✓	✓	✓
Gomphonema pseudoaugur Lange-Bertalot 1979					✓
Gomphonema truncatum Ehrenberg 1832	✓	✓			
Gyrosigma acuminatum (Kützing) Rabenhorst 1853				✓	
Gyrosigma nodiferum (Grunow) Reimer 1966			✓	✓	
Gyrosigma scalproides (Rabenhorst) Cleve 1894			✓	✓	
Melosira granulata (Ehrenberg) Ralfs in Pritchard 1861			✓		
Melosira varians C.Agardh 1827	✓	✓	✓	✓	✓
Navicula accomoda Hustedt 1950				✓	✓
Navicula atomus (Kützing) Grunow 1860					✓
Navicula capitata Ehrenberg 1838			✓	✓	
Navicula capitatoradiata Germain 1981	✓	✓	✓		✓
Navicula cincta (Ehrenberg) Ralfs in Pritchard 1861	✓	✓	✓		✓
Navicula cryptocephala Kützing 1844	✓	✓	✓	✓	✓
Navicula cryptotenella Lange-Bertalot in Krammer & Lange-Bertalot 1985	✓				
Navicula decussis Østrup 1910	✓	✓	✓	✓	
Navicula fonticola Grunow 1880		✓			
Navicula goeppertiana (Bleisch) H.L.Smith 1876					✓
Navicula gregaria Donkin 1861	✓	✓	✓		✓
Navicula halophila (Grunow) Cleve 1894					✓
Navicula lanceolata Ehrenberg 1838	✓		✓	✓	✓
Navicula minuscula Grunow in van Heurck 1880	✓				
Navicula mutica Kützing 1844					✓
Navicula mutica var. *ventricosa* (Kützing) Cleve & Grunow 1880					✓
Navicula radiosa Kützing 1844	✓	✓	✓		✓
Navicula recens (Lange-Bertalot) Lange-Bertalot 1985				✓	✓
Navicula reinhardtii (Grunow) Grunow in Van Heurck 1880			✓		
Navicula salinarum Grunow 1880					✓

Table 2 (continued)

Navicula tenelloides Hustedt 1937			✓		
Navicula tripunctata (O.F.Müller) Bory de Saint-Vincent 1822	✓	✓	✓	✓	✓
Navicula trivialis Lange-Bertalot 1980		✓		✓	
Navicula veneta Kützing 1844	✓				
Navicula viridula (Kützing) Ehrenberg 1836	✓		✓		✓
Nitzschia acicularis (Kützing) W.Smith 1853				✓	
Nitzschia amphibia Grunow 1862		✓	✓	✓	
Nitzschia capitellata Hustedt in Schmidt et al. 1922				✓	✓
Nitzschia constricta (Gregory) Grunow 1880				✓	✓
Nitzschia dissipata (Kützing) Rabenhorst 1860	✓	✓	✓	✓	✓
Nitzschia fonticola (Grunow) Grunow in Van Heurck 1881	✓	✓	✓		✓
Nitzschia frustulum (Kützing) Grunow in Cleve & Grunow 1880		✓	✓		✓
Nitzschia fruticosa Hustedt					✓
Nitzschia hungarica Grunow 1862				✓	
Nitzschia inconspicua Grunow 1862		✓			✓
Nitzschia intermedia Hantzsch ex Cleve & Grunow 1880	✓	✓	✓		
Nitzschia levidensis (W.Smith) Grunow in van Heurck 1881				✓	
Nitzschia linearis W.Smith 1853	✓				
Nitzschia palea (Kützing) W.Smith 1856	✓		✓	✓	✓
Nitzschia paleacea Grunow in Van Heurck 1881					✓
Nitzschia sinuata (Thwaites) Grunow in Cleve & Grunow 1880		✓			✓
Nitzschia sinuata var. *tabellaria* (Grunow) Grunow in van Heurck 1881			✓		
Nitzschia umbonata (Ehrenberg) Lange-Bertalot 1978			✓	✓	
Nitzschia vermicularis (Kützing) Hantzsch in Rabenhorst 1860					✓
Pinnularia borealis Ehrenberg 1843		✓			
Pleurosigma elongatum W.Smith, 1852					✓
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot 1980	✓	✓	✓	✓	✓
Stauroneis phoenicenteron (Nitzsch) Ehrenberg 1843	✓				
Surirella angusta Kützing 1844	✓	✓	✓	✓	
Surirella brebissonii Krammer and Lange-Bertalot 1987	✓		✓	✓	✓
Tabellaria fenestrata (Lyngbye) Kützing 1844		✓			
Tabellaria flocculosa (Roth) Kützing 1844		✓			
TOTAL TAXA	**48**	**55**	**67**	**50**	**57**

Benthic invertebrate communities

A total number of 17 taxa of benthic invertebrates was found in the five sampling sites (Table 3). Only oligochaetes and dipterans (chironomids and other groups) were present in all five sampling sites. S1 was the only site where stoneflies (Plecoptera) and alderflies (Megaloptera) were present, even if the highest number of taxa was recorded in S3. On the other hand, the lowest number of taxa was found at S2 (Table 3): for example, in spring 2014 only chironomids were present. This decreased taxonomical richness could be due to high variations of water discharge and to high substratum instability. From the total number of taxa identified at S4 and S5, 7 were common to both sampling sites, and all were characterized as tolerant to habitat degradation.

Integrative analyses

The number of diatom species identified in the study area ranged between 14 and 45, depending on the sampling season, while the number of benthic invertebrates ranged between 1 and 12.

The highest diatom species richness was recorded at S3 in November 2014, with a total number of 45 taxa (Fig. 4). In fact, higher number of diatom taxa were identified in autumn (94) compared to spring (51) and summer (69). These results are partially in agreement with those from the work of Patrick (1977), according to which diatoms have two development peaks, one in the spring and one in the autumn.

This trend of higher number of taxa in autumn was displayed by the benthic invertebrates, too (Fig. 4). In fact, the high water discharge values from August 2014 led to high variations of the water level (hydropeaking), thus negativelly influencing the number of taxa. Similar findings were reported in the literature (Vannote *et al.*, 1980, Voelz and McArthur, 2000).

Table 3.

List of benthic invertebrate taxa identified in the five sampling sites from the Someșul Mic catchment area (sampling site codes as in Table 1).

Taxa	S1	S2	S3	S4	S5
Platyhelminthes			✓		
Nematoda		✓	✓	✓	✓
Annelida, Oligochaeta	✓	✓	✓	✓	✓
Annelida, Hirudinea			✓	✓	✓
Mollusca, Gastropoda	✓		✓		✓
Mollusca, Bivalvia		✓	✓		
Arthropoda, Chelicerata, Acari, Hydrachnidia	✓		✓	✓	✓
Arthropoda, Crustacea, Isopoda		✓			✓
Arthropoda, Crustacea, Amphipoda			✓	✓	
Athropoda, Hexapoda, Insecta, Ephemeroptera	✓		✓	✓	✓
Athropoda, Hexapoda, Insecta, Plecoptera	✓				
Athropoda, Hexapoda, Insecta, Trichoptera	✓		✓		✓
Athropoda, Hexapoda, Insecta, Odonata	✓		✓		
Athropoda, Hexapoda, Insecta, Megaloptera	✓				
Athropoda, Hexapoda, Insecta, Chironomidae	✓	✓	✓	✓	✓
Athropoda, Hexapoda, Insecta, Diptera - others	✓	✓	✓	✓	✓
Athropoda, Hexapoda, Insecta, Coleoptera	✓			✓	
TOTAL TAXA	**11**	**6**	**13**	**9**	**10**

There are numerous systems of assessing the quality of aquatic habitats based on indicator algal species; a thorough review was made by Dokulil, 2003. The saprobic system represents one of the oldest (Kolkwitz and Marsson, 1902), still in use today. Saprobity represents a direct measure of water quality, since xeno- or oligosaprobic waters contain low quantities of decomposing organic matter, indicating clean conditions, while polysaprobic habitats are heavily polluted with organic loads.

From the total number of diatom species, 66 indicated different values of saprobity: from xenosaprobic, to oligosaprobic, β-mesosaprobic, α-mesosaprobic and polysaprobic waters. The most numerous group was the one indicating β-mesosaprobic waters, with more than 12 species in each sampling site. The intermediate group including β-α-mesosaprobic taxa followed, with more than 6 species / sampling site (Fig. 5).

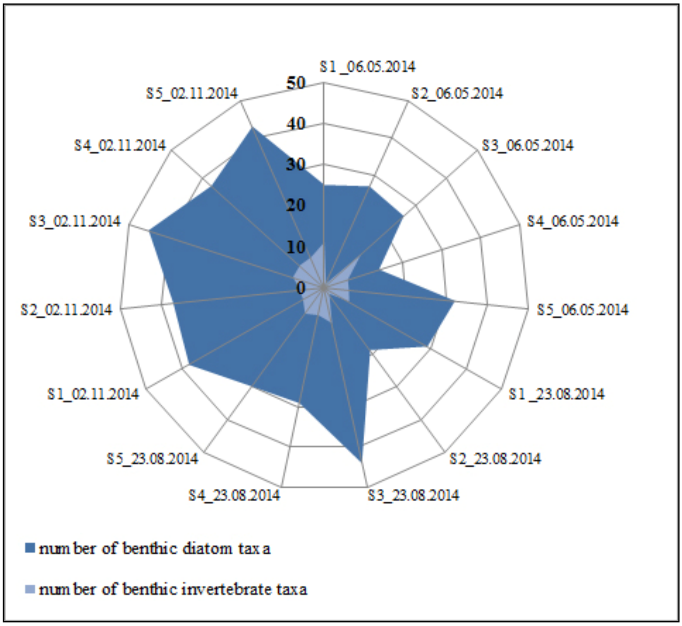

Figure 4. Total number of diatom and invertebrate taxa identified in the five sampling sites from the Someșul Mic catchment area in 2014.

The highest number of diatom taxa indicating polysaprobic conditions was recorded in S4, thus showing the worst conditions, in terms of high organic load, low or no dissolved oxygen content, high content of ammonia or hydrogen sulphide. Only slightly better conditions were indicated by diatom taxa at S5: α-mesosaprobic and α-mesosaprobic - polysaprobic taxa. The remaining sampling sites however were characterized by lower organic loads, as showed in Fig. 5. These results are in agreement with previous works: Rasiga *et al.* (1995/1996) found critical levels of saprobity in the lower Someș River.

The relative abundance was calculated for the 17 taxa categories of benthic invertebrates. As depicted in Figure 6, chironomids and oligochaetes - tolerant taxa - were common to all sampling sites, recording higher abundances in S4 and S5. Stoneflies and alderflies (Plecoptera and Megaloptera), known to survive only in habitats with clean water, were identified only at S1, while flatworms were present only at S3 (Fig. 6).

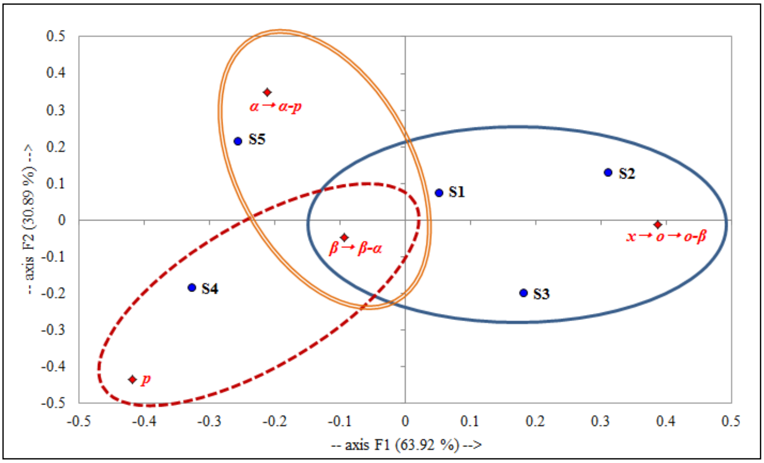

Figure 5. Correspondence Analysis (CA) symmetric plot (axes F1 and F2: 94.80 %) showing the aggregation of sampling sites with the number of indicator diatom species (S1 – S5 as in Table 1; ***x→o→o-β***: xenosaprobic, oligosaprobic and oligosaprobic-β-mesosaprobic taxa; ***β→β-α***: β-mesosaprobic and β-α-mesosaprobic taxa; ***α→α-p***: α-mesosaprobic and α-mesosaprobic-polysaprobic taxa; ***p***: polysaprobic taxa).

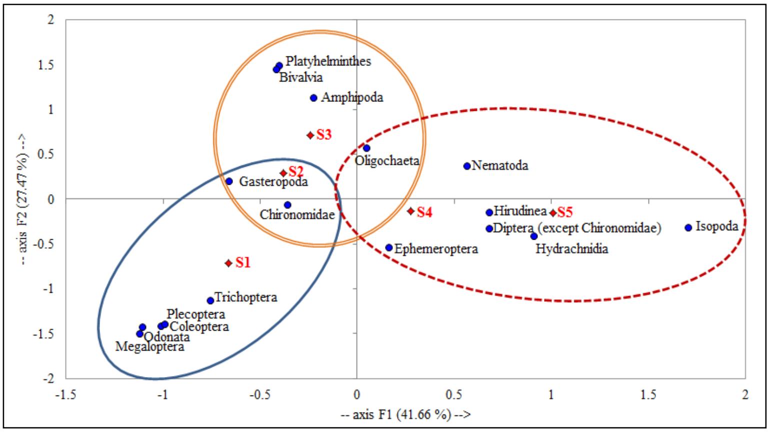

Figure 6. Correspondence Analysis (CA) symmetric plot showing the aggregation of the sampling sites with the 17 taxa categories of benthic invertebrates, in terms of their relative abundances (axes F1 and F2: 69.13 %) (S1 – S5 as in Table 1).

To summarize, benthic diatom and invertebrate communities sampled in 2014 from the Someșul Mic catchment area reflected the major human impacts present in the region stretching from Someșul Rece to Apahida, as shown in Figure 7. The sampling sites S2 and S3 were strongly affected by hydro-technical works: the presence of dam reservoirs, hydropeaking, river regularization etc. At the other sampling sites, other impacts prevaled: the negative effects of waste waters coming from the numerous human settlements and pollution from point or diffuse sources, as agricultural fields treated with fertilizers.

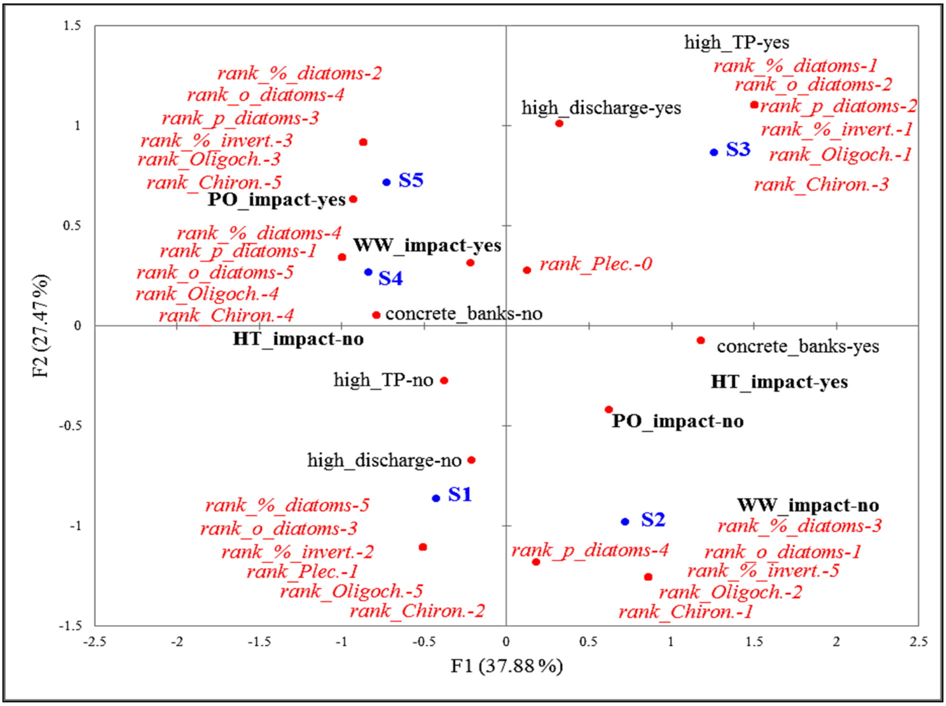

Figure 7. Multiple Correlation Analysis (MCA) symmetric plot (axes F1 and F2: 65.35 %) of the five sampling sites considered for the present study and: i) the main human impacts (**WW_impact**: impact caused by waste waters; **HT_impact**: impact caused by hydro-technical works; **PO_impact**: impact caused by pollution); ii) different biological elements, ranked descending between the five sampling sites (*rank_%_diatoms*: the percentage of diatom taxa present, from the total number; *rank_o_diatoms*: the number of diatom taxa indicating oligosaprobic waters; *rank_p_diatoms*: the number of diatom taxa indicating polisaprobic waters; *rank_%_invert.*: the percentage of invertebrate taxa present, from the total number; *rank_Plec.*: the abundance of Plecoptera taxa present; *rank_Chiron.*: the abundance of Chironomidae taxa present; *rank_Oligoch.*: the abundance of Oligochaeta taxa present; iii) other elements (concrete_banks: the presence of concrete banks along the river; high_TP: high concentration of Total Phosphorus; high_discharge: the presence of high discharge).

At S3, both diatoms and invertebrates recorded the highest percentage, in terms of number of taxa. However, diatoms recorded the highest number of taxa indicating polisaprobic waters, while oligochaetes, a very tolerant group to organic pollution, were ranked with the highest relative abundance. Thus, the highest taxonomic richness was not linked to a good ecological status of the environment.

On the other hand, at S1, both biotic communities recorded lower percentages of taxa: for example, diatoms were ranked 5 (Fig. 7). However, diatoms recorded a higher percentage of oligosaprobic indicator taxa, and the presence of Plecoptera, a group of invertebrates characteristic to clean waters, showed a better ecological status. These conflicting findings depict a less impacted, but still affected community.

S4 recorded the worst ecological status shown by both biotic communities, with the highest percentage of polisaprobic indicator taxa for diatoms, probably due to the nutrient-rich waters coming from the remaining deposits of organic debris left by the old chicken farms. The characteristics of S5 were not very different, also showing negative impacts.

An unclear situation depicted S2, where high hydro-technical impacts led to high abundances of oligochaetes and chironomids. Diatoms however exhibited the highest percentage of oligosaprobic taxa, probably due to the constant flushing of the substratum by water releases from the hydropower plants upstream.

Conclusions

Both benthic diatom and invertebrate communities reflected the ecological status characteristic to five sampling sites from the Someșul Mic catchment area, in the area stretching from Someșul Rece to Apahida localities.

The number of taxa in case of diatoms, and relative abundances of major benthic invertebrate groups showed more balanced conditions at S1, on the Someșul Rece River, where human impacts had lower intensities.

At S3, upstream of Cluj-Napoca, inspite of the highest taxonomical richness, the ecological status was clearly affected, as shown by the high percentage of tolerant or polisaprobic taxa. The influence of the urban center of Cluj-Napoca and its near-by industrial and agricultural facilities were reflected in the characteristics of biotic communites from S4, located on the Popești Rivulet, a tributary of the Someșul Mic River, and S5 – Apahida. The conflicting findings about S2, located downstream Gilău dam reservoir, led to the conclusion that biotic communities must be drastically affected by sudden fluctuations of the water discharge.

The present study revealed more or less affected biotic communities at all sampling sites, showing the drastic effects of human influences in the area.

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