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Research Article

APPLICATION OF DIATOMS TO ASSESS THE QUALITY OF THE WATERS OF THE BARYCZKA STREAM, LEFT-SIDE TRIBUTARY OF THE RIVER SAN

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ABSTRACT

The Baryczka stream is a small (about 20 km long), left bank tributary of the River San (Podkarpackie Voivodeship). Studies on diversity of diatom communities using OMNIDIA software were conducted in 2010 and 2011. Diatomaceous indices IPS, GDI and TDI and Van Dam et al. classification system were used for water quality assessment. *Planothidium lanceolatum, Cocconeis placentula* var. *lineata, Achnanthidium minutissimum* var. *minutissimum*, *Nitzschia linearis, Rhoicosphenia abbreviata*, *Navicula lanceolata* and *Naicula gregaria* were the most numerous. Values of the IPS index indicate good water quality (II–III class). Based on the GDI index, waters of the Baryczka stream were classified to III class water quality. The TDI index indicated poor and bad ecological state on the most sampling sites. On all sampling sites alaliphilous (pH>7) diatoms taxa predominated. The most common were eutraphentic and hypereutraphentic diatoms. With respect to trophy, it was shown that α- and β-mesosaprobous diatoms were the most common (III and II class water quality).

Keywords: diatoms Bacillariophyceae; diatoms indices IPS, GDI, TDI; water quality; diversity; ecology; Baryczka stream

INTRODUCTION

Diatoms (Bacillariophyceae) are cosmopolitan, unicellular, microscopic algae, which occur in many different ecosystems (mainly water), their characteristic feature is a cell wall made of silica with a richly carved surface and specific construction of a frustule. They are sensitive to a variety of environmental factors needed for optimal growth: light, temperature, salinity, the presence of biogens, etc. In this way they are used as excellent indicators of changes taking place in water ecosystems, especially eutrophication, increased pollution and acidification [Rakowska 2001, 2003].

Many studies of water quality assessment using algae, including diatoms have been conducted on the territory of Poland [Kawecka et al. 1996, 1999, Kwandrans et al. 1998, Kawecka, Kwandrans 2000, Bogaczewicz-Adamczak et al. 2001, Rakowska 2001, Kwandrans 2002, Bogaczewicz-Adamczak, Dziengo 2003, Żelazowski et al. 2004, Dumnicka et al. 2006, Szczepocka 2007, Szczepocka, Szulc 2009, Rakowska, Szczepocka 2011].

Studies have been conducted over a period of a few years, on the territory of the Podkarpacie Province, concerning the diversity of diatoms in running waters and on soils [Noga 2005, Noga, Siry 2010, Tambor, Noga 2011, Noga et al. 2012a, Pajączek et al. 2012, Stanek-Tarkowska, Noga 2012, Peszek et al. 2012, Noga et al. 2013]. Fragmentary studies have also been conducted on the River San, below the dam reservoirs Solina – Myczkowce as a result of the massive development of *Didymosphenia geminata* diatoms [Kawecka, Sanecki 2003].

Phycological studies have not been conducted so far on the Baryczka stream. In 2007 the diversity of diatoms was studied in the Łubienka stream, the left bank tributary of the San River near the town of Dynów [Noga, Siry 2010], and the Mleczka River was studied from 2007–2009 [Pajączek et al. 2012].

The aim of this study was to present the diversity of diatoms communities developing in the Baryczka stream, which flows through agriculturally used areas, and to determine the degree of pollution of the stream waters, with using diatoms as indicators of water quality.

STUDY AREA

The Baryczka stream is a small (about 20 km. long), left bank tributary of the River San flowing through the Dynowskie Foothills (Figure 1). It flows for its entire length in a valley between two large hills. Springs are located at a height of 444 m a.s.l. The upper section is natural, free from human intervention, surrounded by forest, whereas the middle and lower sections of the stream are located near agricultural fields, residential buildings and farms. The Baryczka stream flows into the San River in the town of Nozdrzec at the altitude of 240 m a.s.l. The stream is mostly unregulated, regulative work has been carried out over the last few years in only a few places. The main pollutants come from agricultural production and urban waste water from of not fully canalised villages.

MATERIALS AND METHODS

Samples were collected in four research seasons: spring, summer and autumn 2010, and winter 2011 from each available habitat (mud, rocks, aquatic macrophytes). Four sampling sites along the stream were determined (Figure 1), and pH, electrical conductivity and water temperature were measured on each site.

Laboratory processing of the diatoms was carried out by applying the methods used by Kawecka [Kawecka 2012]. In order to obtain pure valves of diatoms, part of the obtained material was subjected to maceration in a mixture of sulphuric acid and potassium dichromate in a proportion of 3:1 and rinsed in a centrifuge (at 2500 revol./min). Solid diatomic preparations were fixed in the Pleurax synthetic resin.

Diatoms were identified using the optical microscope "Nikon ECLIPSE 80i", and the keys: Krammer, Lange-Bertalot [1986–1991], Lange-Bertalot [1993, 2001], Lange-Bertalot, Metzeltin [1996], Krammer [2000, 2002, 2003], Levkov [2009], Hofmann et al. [2011]. Pictures were taken using the same microscope. The selected taxa of diatoms of the Baryczka stream are presented in Plate 1–2.

The number of given species was obtained through calculating specimens in a random sample in the ocular fields of an optical microscope until a total number of 400 valves was obtained. Species whose participation in a given community was 5% or more were found to be most numerous.

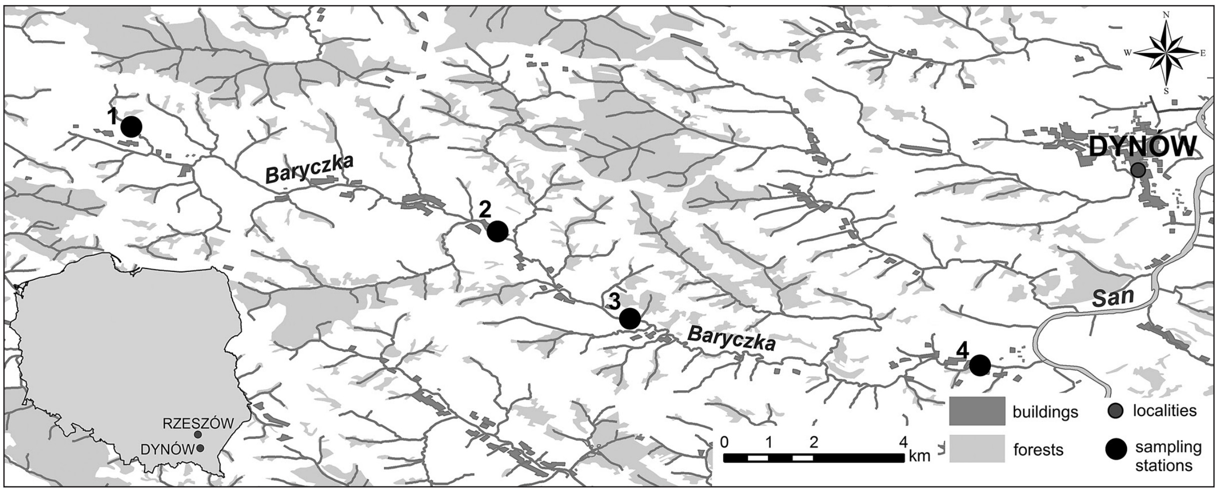

Fig. 1. Location of sampling sites at Baryczka stream (1–4 number of sites)

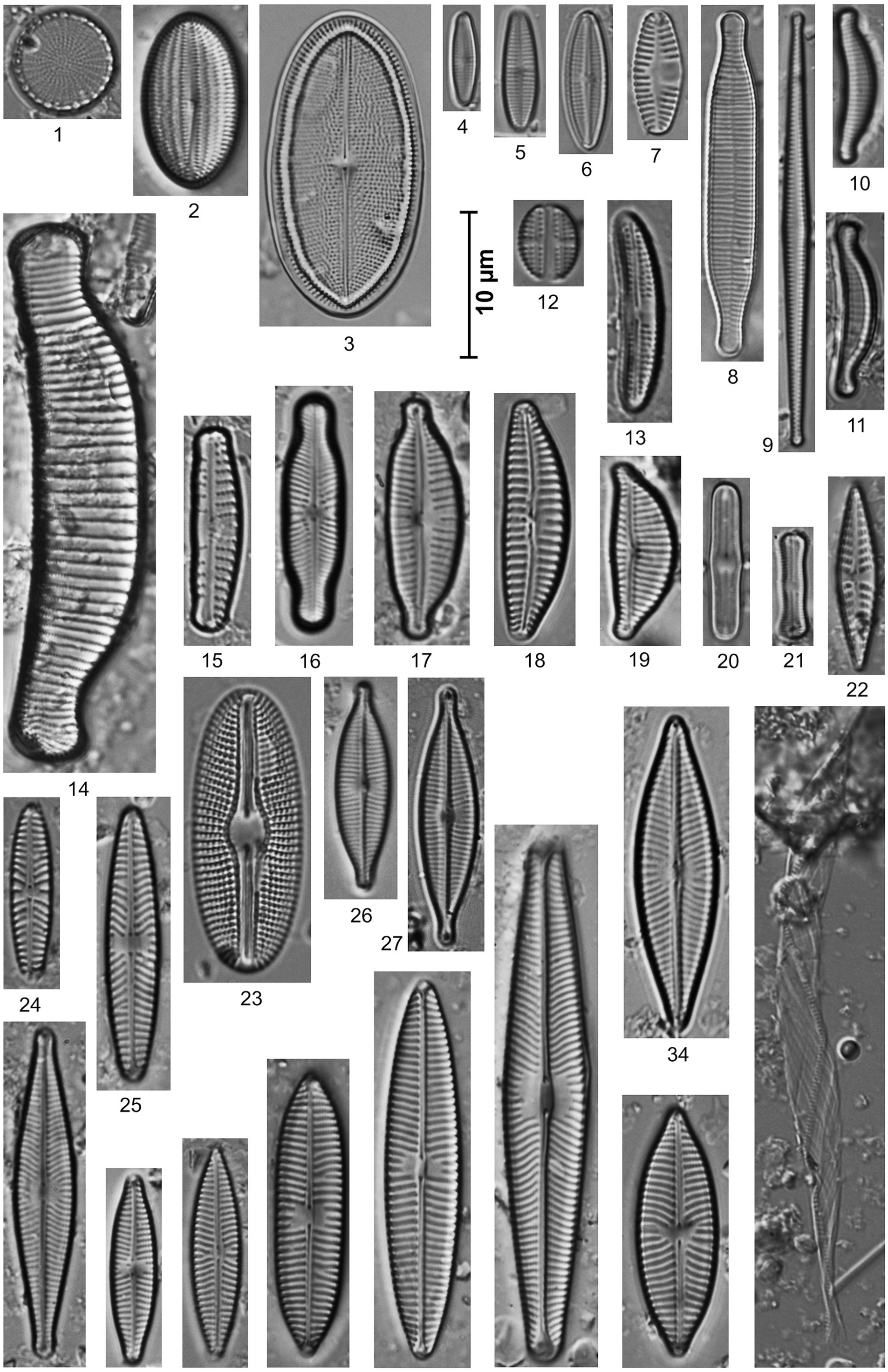

Plate I. Selected diatoms taxa in Baryczka stream: 1 *Stephanodiscus hantzschii* Grunow, 2–3 *Cocconeis placentula* var. *lineata* (Ehrenb.) Van Heurck, 4 *Achnanthidium minutissimum* (Kütz.) Czarnecki var. *minutissimum*, 5–6 *A. pyrenaicum* (Hust.) Kobayasi, 7 *Planothidium lanceolatum* (Bréb.) Round & Bukht., 8 *Fragilaria virescens* Ralfs, 9 *F. pararumpens* Lange-Bert., Hofmann & Werum, 10–11 *Eunotia exigua* (Bréb.) Rabenh., 12 *Amphora pediculus* (Kütz.) Grunow, 13 *A. micra* Levkov, 14 *Eunotia praerupta* Ehrenb., 15 *Reimeria uniseriata* Sala, Guerreo & Ferrario, 16 *Parlibellus protractoides* (Hust.) Witkowski & Lange-Bert., 17 *Cymbopleura amphicephala* (Nägeli) Krammer, 18 *Cymbella excisa* Kütz., 19 *Encyonema ventricosum* (Ag.) Grunow, 20 *Diadesmis paracontenta* Lange-Bert. & Werum var. *paracontenta*, 21 *D. contenta* (Grunow) D.G. Mann, 22 *Hippodonta costulata* (Grunow) Lange-Bert., Metzeltin & Witkowski, 23 *Diploneis krammeri* Lange-Bert. & Reichardt, 24 *Navicula cincta* (Ehrenb.) Ralfs, 25 *N. cari* Ehrenb., 26–27 *N. gregaria* Donkin, 28 *N. cryptocephala* Kütz., 29 *N. veneta* Kütz., 30 *N. cryptotenella* Lange-Bert., 31–32 *N. tripunctata* (O.F. Müller) Bory, 33 *N. lanceolata* (Ag.) Kütz., 34 *N. trivialis* Lange-Bert., 35 *N. upsaliensis* (Grunow) Paragallo, 36 *Cylindrotheca gracilis* (Bréb. & Kütz.) Grunow.

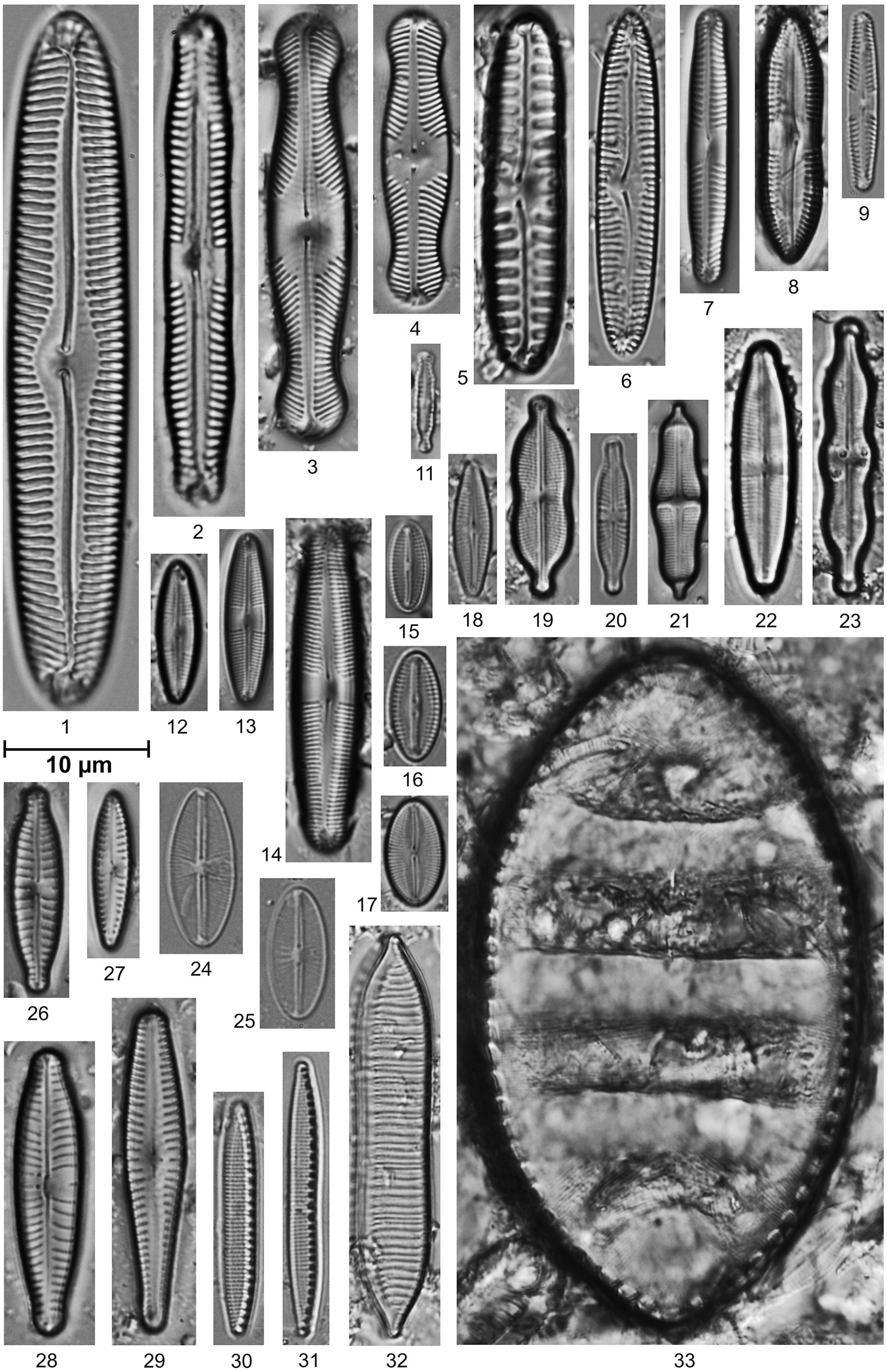

Plate II. Selected diatoms taxa in Baryczka stream: 1 *Pinnularia subrupestris* Krammer, 2 *P. nodosa* (Ehrenb.) W. Smith, 3–4 *P. globiceps* Gregory, 5 *P. borealis* Ehrenb. var. *borealis*, 6 *P. isselana* Krammer, 7 *P. sinistra* Krammer, 8 *P. schroederii* (Hust.) Cholonky, 9 *P. perirrorata* Krammer, 11 *Chamaepinnularia soehrensis* (Krasske) Lange-Bert. & Krammer, 12–13 *Caloneis lancettula* (Schulz) Lange-Bert. & Witkowski, 14 *C. molaris* (Grunow) Krammer, 15–16 *Fallacia insociabilis* (Krasske) D.G. Mann, 17 *F. pygmaea* (Kütz.) Strickle & D.G. Mann ssp. *pygmaea*, 18 *F. monoculata* (Hust.) D.G. Mann, 19 *Neidium binodeforme* Krammer, 20 *Stauroneis thermicola* (Petersen) Lund, 21 *S. smithii* Grunow, 22 *S. tackei* (Hust.) Krammer, 23 *S. leguminopsis* Lange-Bert. & Krammer, 24–25 *Cavinula lapidosa* (Krasske) Lange-Bert., 26 *Gomphonema productum* (Grunow) Lange-Bert. & Reichardt, 27 *G. pumilum* (Grunow) Reichardt & Lange-Bert., 28 *G. sarcophagus* Gregory, 29 *G. subclavatum* (Grunow) Grunow, 30–31 *Nitzschia bulnheimiana* (Rabenh.) Grunow, 32 *N. calida* (Grunow) Cleve & Grunow, 33 *Cymatopleura elliptica* (Bréb.) W. Smith

Ecological diatoms classification was presented according to the Van Dam at al. [1994] list. The following indicators were used: pH, saprobity and trophic state.

Biological water quality assessment was performed using OMNIDIA software [Lecointe et al. 1993], version 4.2. This also contains ecological and taxonomic data [Prygiel, Coste 1993]. Results of the analyses were presented applying the chosen diatomic indices, for which a range of ecological classes of water quality and the ecological status conforming to them was outlined by mutual agreement [Dumnicka et al. 2006]:

Water Quality Class*	Ecological state	IPS	GDI	TDI	Trophic state
I	high	> 17	> 17	<35	oligotrophic
II	good	15–17	14–17	35–50	oligo/ mesotrophic
III	moderate	12–15	11–14	50–60	mesotrophic
IV	poor	8–12	8–11	60–75	eutrophic
V	bad	<8	<8	>75	hypertrophic

* According to the Decree of the Minister of the Environment from 9 Nov. 2011 (Dz. U. No 257, pos. 1545).

Indices of organic pollution: the SPI – Specific Pollution Sensitivity Index [CEMAGREF 1982] and the GDI – Generic Diatom Index based on genera [Coste, Ayphassorho 1991] are scaled from 1 to 20 (when water quality increases there is an increase in indicator value). The TDI – Trophic Diatom Index [Kelly, Whitton 1995] is scaled from 1 to 100 (the higher the value, the bigger trophy of water). The percentage participation of species characteristic for organic pollution (PT) must be taken into account in interpretation of the TDI index. There is a possibility of organic pollution if PT values are above 20%.

Based on Siemińska et. al. [2006] The Red List of Algae created for Polish species at varying degrees of threat was distinguished (Ex – Extinct or probably extinct, E – Endangered, V – Vulnerable, R – Rare, I – Indeterminate).

RESULTS

The stream temperature ranged between 3 °C in winter and 17.5 °C in summer. The water's pH was characterized by an alkaline or close to circumneutral reaction (6.5–8.4). Lower pH occurred in the autumn and winter. The highest pH values (8.4) were measured in the summer. Electrolytic conductivity ranged from 164 µS/cm, on site one in spring to 528 µS/cm, on site three in summer (Table 1).

288 taxa diatom taxa were identified in the Baryczka stream, altogether, during the study in years 2010–2011. The most numerous were taxa of genus: *Nitzschia*, *Pinnularia* and *Navicula.* All sampling sites had similar species richness (see the list of diatoms taxa).

Table 1. Physico-chemical parameters with description of the Baryczka stream sites in years 2010–2011 (T – temperature, C – conductivity)

Site	Insolation	Width [m]	Depth [m]	Bottom	Current	Season	T [°C]	pH	C [µS/cm]
1	low	0.5–0.8	0.1	stony with dead organic matter	rapid	04.10	7.0	7.2	164
						08.10	14.5	8.4	328
						10.10	4.0	6.5	233
						02.11	3.0	6.6	167
2	high	4	0.2	sandy and stony	rapid	04.10	9.0	7.6	299
						08.10	15.5	8.4	492
						10.10	6.0	6.7	438
						02.11	4.0	6.8	407
3	high	3	0.3	silted with small stones	calm	04.10	10.0	7.7	302
						08.10	16.1	8.4	528
						10.10	7.0	6.7	393
						02.11	4.0	6.8	413
4	high	6–8	0.2–0.4	stony, places big stones and boulders in the bed	rapid	04.10	10.0	7.7	297
						08.10	17.5	7.1	353
						10.10	7.0	6.8	431
						02.11	3.0	6.9	415

17 taxa were defined as dominant. On site one they were: *Planothidium lanceolatum, Cocconeis placentula* var. *lineata, Achnanthidium minutissimum* var. *minutissimum*, *Nitzschia linearis* and *Rhoicosphenia abbreviata*, while on the other: *Navicula lanceolata, Navicula gregaria* and *Cocconeis placentula* var. *lineata* (Table 2).

Alkaliphilous taxa predominated on all studied sites (pH>7). Only a single taxa was classified into both circumneutral (pH=7) and alkalibiontic (exclusively occurring at pH>7) categories (Figure 2). Ecological analysis with respect to saprobity showed a definite advantage for α-mesosaprobous (II class) and β-mesosaprobous (III class) taxa (Figure 3). Along the whole length of the stream the highest populations were created by eutrophic, oligo-eutrophic and meso-eutrophic diatoms (Figure 4).

OMNIDIA software was used for biological water quality assessment, based on three diatomaceous indices: IPS (Specific Pollution Sensitivity Index), GDI (Generic Diatom Index) and TDI (Trophic Diatom Index) – Figure 3. Values of the IPS index on all studied sites in spring and on the first site in other seasons indicate good quality waters (II class), on other sites, III class. Based on the GDI index, the waters of the Baryczka stream were classified as III class quality. Only in autumn on site number four there were waters classified as poor – IV class. The TDI index indicated V class water quality on most of the sampling sites. IV class (a poor ecological state) was recorded only in summer on sites number 1–3 and on site number two in autumn. The largest participation of species indicating organic pollution was observed in spring and winter seasons in the middle and lower sections of the Baryczka stream, the least – in summer and autumn in the upper course (Figure 5).

35 taxa from the Polish Red List of Algae [Siemińska et al. 2006] were noted during the studies. They made up 12% of the flora diatoms found in the studied material (see the list of diatom taxa).

Table 2. Dominance [%] in diatom communities in the Baryczka stream on sampling sites 1–4 in years 2010–2011

Station	1				2				3				4			
Taxa / Date	IV 2010	VIII 2010	X 2010	II 2011	IV 2010	VIII 2010	X 2010	II 2011	IV 2010	VIII 2010	X 2010	II 2011	IV 2010	VIII 2010	X 2010	II 2011
Achnanthidium minutissimum var. *minutissimum*	11-25	<5	<5	<5	<5	6-10	6-10	<5	<5	<5	<5	<5	<5	<5	<5	6-10
Amphora pediculus	<5	<5	<5	11-25	6-10	6-10	<5	6-10	<5	6-10	6-10	6-10	6-10	<5	<5	11-25
Cocconeis placentula var. *lineata*	<5	>25	11-25	6-10	<5	>25	6-10	6-10	<5	>25	6-10	6-10	<5	6-10	<5	<5
Diadesmis perpusilla	<5	<5	<5	6-10	<5	<5	<5	<5	<5	0	0	0	<5	<5	<5	<5
Diatoma vulgaris	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	6-10	<5	<5
Gomphonema olivaceum var. *olivaceum*	0	0	<5	<5	6-10	<5	<5	<5	6-10	<5	<5	<5	6-10	<5	<5	<5
Mayamaea atomus var. *permitis*	<5	0	0	0	<5	<5	<5	<5	<5	6-10	<5	<5	<5	<5	<5	<5
Navicula gregaria	<5	<5	<5	11-25	6-10	<5	11-25	<5	11-25	11-25	11-25	6-10	11-25	>25	11-25	6-10
Navicula lanceolata	6-10	6-10	<5	<5	>25	<5	<5	>25	>25	<5	<5	>25	>25	<5	<5	11-25
Nitzschia dissipata ssp. *dissipata*	<5	<5	<5	<5	<5	<5	<5	6-10	<5	<5	<5	11-25	6-10	11-25	6-10	<5
Nitzschia frustulum var. *frustulum*	0	0	0	0	0	<5	<5	<5	<5	<5	<5	<5	<5	6-10	<5	<5
Nitzschia linearis	6-10	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Planothidium lanceolatum	>25	>25	>25	11-25	<5	6-10	<5	<5	<5	<5	<5	<5	<5	<5	<5	11-25
Rhoicosphenia abbreviata	6-10	<5	6-10	<5	<5	6-10	<5	<5	<5	<5	6-10	<5	<5	<5	<5	<5
Surirella minuta	<5	<5	0	0	<5	<5	<5	<5	<5	6-10	<5	<5	<5	<5	6-10	<5

0 <5 6-10 11-25 >25

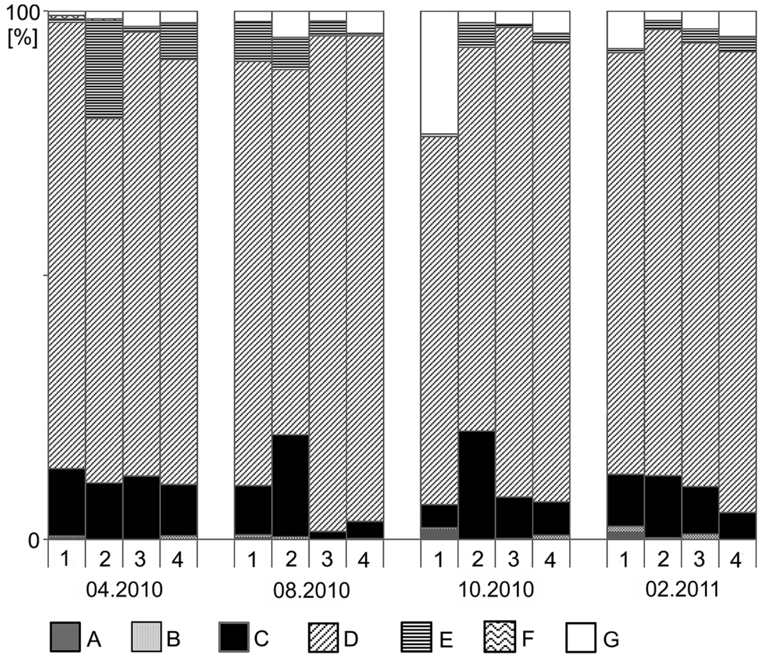

Fig. 2. Classification of ecological indicator values (according to Van Dam et al. 1994). pH range: A – acidobiontic, B – acidophilous, C – neutral, D – alkaliphilous, E – alkalibiontic, F – indifferent, no apparent optimum, G – unknown. Sampling sites: 1–4

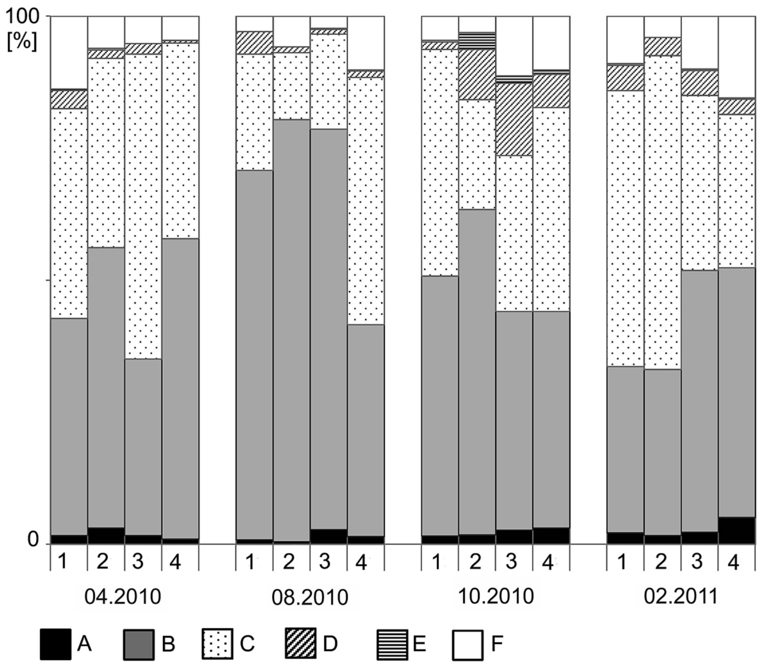

Fig. 3. Classification of ecological indicator values (according to Van Dam et al. 1994). Saprobity range: A – oligosaprobous, B – β-mesosaprobous, C – α-mesosaprobous, D – α-meso-polysaprobous, E – polysaprobous, F – unknown. Sampling sites: 1–4

DISCUSSION

The Baryczka stream was characterized by alkaline waters or a near to neutral pH. The highest values of electrolytic conductivity was measured on site three in summer – 592 μS/cm (Table 1). This would provide evidence that biogens have travelled from housing estates, or from nearby farmlands, into the stream waters. Small streams in the Podkarpacie Province area are often collectors of various types of anthropogenic pollutants and supplies of biogens, together with a surface confluence from agricultural lands [Noga, Siry 2010, Tambor, Noga 2011, Bernat, Noga 2012,

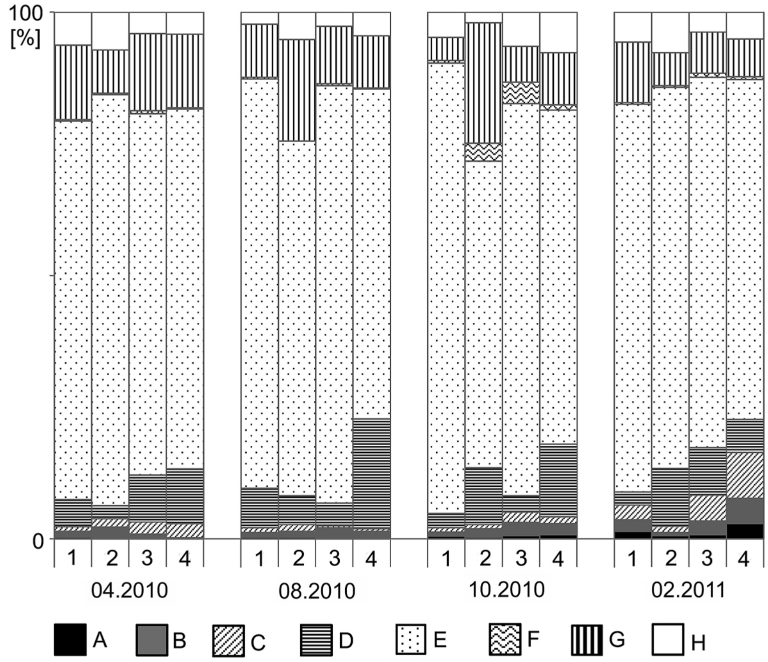

Fig. 4. Classification of ecological indicator values (according to Van Dam et al. 1994). Trophic state range: A – oligotraphentic, B – oligo-mesotraphentic, C – mesotraphentic, D – meso-eutraphentic, E – eutraphentic, F – hypereutraphentic, G – oligo- to eutraphentic, H – unknown. Sampling sites: 1–4

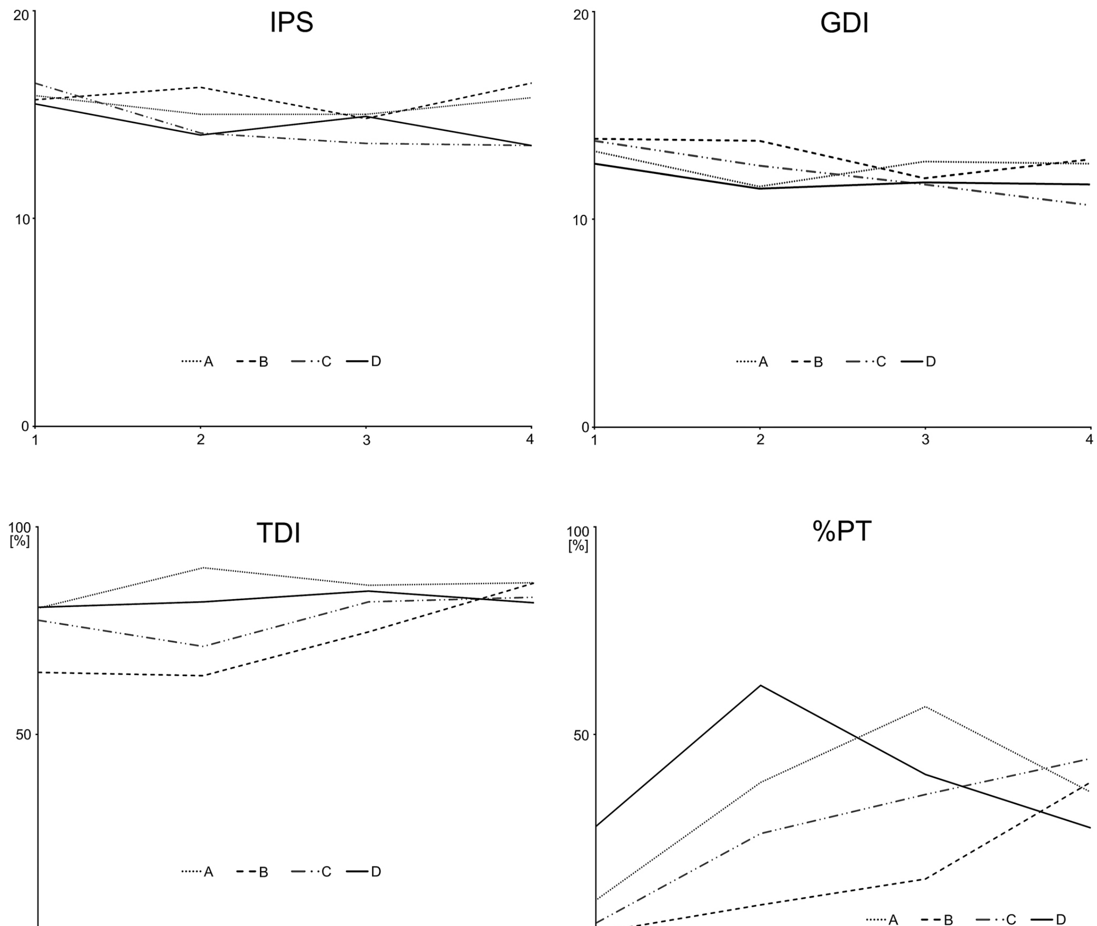

Fig. 5. The values of diatomaceus indices GDI, IPS, TDI and %PT for sites in Baryczka stream in 2010–2011 (1–4 numbers of sampling sites; A – 04.2010, B – 08.2010, C – 10.2010, D – 02.2011)

Noga et al. 2013]. The Baryczka stream was characterized by a great richness of species – in total 288 taxa were identified on the four sampling sites. Also, numerous studied rivers and streams on the territory of the Podkarpacie Province are characterized by a large diatm species diversity. On average over 200 diatom taxa are noted in most of the studied rivers and streams [Pajączek et al. 2012, Noga et al. 2013]. An exceptionally high species richness (more than 400 taxa) was noted in Żołynianka stream and River Wisłok [Noga 2012, Peszek 2012]. A much smaller number of diatom taxa was noted in the Łubienka stream (132 taxa), on which studies were conducted in three seasons in 2007. Łubienka, like Baryczka, is a small stream, which flows through parallel valley to Baryczka and into the River San in the town of Nozdrzec [Noga, Siry 2010].

17 taxa were defined as dominant, among which the most numerous were: *Amphora pediculus, Cocconeis placentula* var. *lineata, Navicula gregaria, N. lanceolata* and *Planothidium lanceolatum* (Table 2).

A similar domination structure was noted in the Łubienka stream in the Dynowskie Foothills, in which 22 taxa were defined as dominant, and the most numerous were: *Navicula lanceolata*, *Planothidium lanceolatum* and *Rhoicosphenia abbreviata*. Other similar studied streams on the territory of the Podkarpacie Province have a similar number of diatom taxa and dominants. The most numerously developed are *Achnanthidium minutissimum* var. *minutissimum, Navicula lanceolata*, *N. gregaria*, *Planothidium lanceolatum* and *Amphora pediculus* [Noga, Siry 2010, Tambor, Noga 2011, Noga 2012, Noga et al. 2012b, Pajaczek et al. 2012, Noga et al. 2013].

Planothidium lanceolatum was dominant in the spring section in all studied seasons, reaching over 40% share in the community. It is a cosmopolitan diatom species, very commonly occurring in Central Europe, preferring waters with a high content of calcium and rich in electrolytes. C*occoneis placentula* var. *lineata* reached a nearly 40% share in the community, especially in summer, on sites 1 – 3. It is cosmopolitan and epiphytics diatoms, in flowing and standing waters on stones and wood, which can create massive populations [Krammer, Lange-Bertalot 1986–1991].

Achnanthidium minutissimum var. *minutissimum* was another numerous dominant. It is one of the most common diatoms, with a wide ecological range. It prefers waters from oligo- to eutrophic, and develops numerously in mountain streams with no antrophogenic impact [Krammer, Lange-Bertalot 1986–1991, Hofmann et al. 2011]. The Tatra Mountain streams were characterized by numerous developments of this species. It is an indicator of water with a high oxygen content, and prefers mountain streams, especially the upper sections [Kawecka 1993, Van Dam et al. 1994].

Navicula lanceolata was a dominant species (20–39% share in the community) in most of the studied sites (except in the spring section) especially in spring and winter seasons. *Navicula lanceolata* prefers waters rich in electrolytes and it has a wide range of occurrence. It occurs in springs habitats as far as salt waters. In the summer months it reduces reproduction and, prefers cooler temperatures, so it is massively developed even in winter. *Navicula gregaria* was numerously developed, and together with *N. lanceolata*, reached a 40% share in the lower section of the stream. It is a cosmopolitan diatom, which prefers oligotrophic, brackish and fresh water with a medium electrolytes content [Krammer, Lange-Bertalot 1986–1991, Hofmann et al. 2011].

Various pollutants and a supply of biogens, together with a surface confluence of fertilizers from agricultural lands, could be the reason for numerous development, especially of the *Navicula* genus, in the middle and lower sections of the Baryczka stream. Many homesteads do not have a sewage system.

On all sampling sites alkaliphilous (pH>7) diatom taxa predominated, a few were in the alkalibiontic category, i.e. preferring waters definitely over pH 7. On all sites the most common diatoms were eutraphentic and hypereutraphentic, which indicate high fertility of the Baryczka stream waters. Ecological analysis with respect to trophy showed, that the α- and β-mesosaprobous diatoms were the most common diatoms, characteristic for classes of III and II water quality [Van Dam et al. 1994].

Similar results were obtained for the Łubienka stream, dominated by alkaliphilous diatoms. Relating to trophy, the most common were eutraphentic diatoms, characteristic for fertile waters [Noga, Siry 2010]. Studiese conducted in the Wielopolka, Różanka, Mleczka and Morwawa streams, also showed the domination of alkaliphilous diatoms taxa, characteristic for eutraphentic and α- and β-mesosaprobous waters (water quality class III and II) [Mucha et al. 2009, Tambor, Noga 2011, Pajączek et al. 2012].

Monitoring studies with the application of diatoms to assess water quality have been conducted in recent years in many countries, including Poland. Benthic diatoms are used in assessment of water quality in many European countries [Prygiel, Coste 1993, 1999, Whitton, Rott 1996, Kwandrans et al. 1998, Prygiel 2002, Kelly 2003, Wojtal 2004, Żelazowski et al. 2004, Dumnicka et al. 2006, Żelazna-Wieczorek, Mamińska 2006, Kelly et al. 2008, Rakowska, Szczepocka 2011].

IPS – Specific Pollution Sensitivity Index [CEMAGREF 1982], GDI – Generic Diatom index [Coste, Ayphassorho 1991] and TDI – Trophic Diatom Index [Kelly, Whitton 1995] were used for biological assessment of water quality.

The IPS index in the upper section of the stream in all studied seasons indicated good water quality – class II. Downstream, the water quality was worse, this would provide evidence that biogens have travelled from housing estates, or from nearby farmlands, into the stream waters. The GDI index values on most studied sites indicated a medium pollution level (class III). The TDI index reached high values, which indicated bad water quality and eutrophic character.

The studies on the diversity and the indicative role of diatoms have been conducted in rivers and streams in the Podkarpackie and Małopolskie Provinces over the past few years. The quality of waters was assessed with use of the same IPS, GDI and TDI diatomaceus indices. The best water quality was found in the River Biała (class II – good ecological state), whereas, the worst quality was found in the Wisłok, Wisłoka and Matysówka, [Peszek 2012, Noga et al. 2013, Noga et al. – in press).

In 2003 studies were conducted on fish fauna and ecological state of the Vistula, Raba Dunajec and Wisłoka, and diatomaceus indices were also used to assess water quality. Studies indicated III class water quality (moderate ecological state) on most sampling sites [Dumnicka et al. 2006].

The TDI index lowered the quality of the studied waters considerably in comparison with the IPS and GDI indices, similarly to other studies from Poland [Szczepocka, Szulc 2009].

The percentage participation of species characteristic of organic pollution (%PT) which is directly linked to the trophic index (TDI),was was calculated. The highest values of PT were noted in the spring and winter seasons (30–60%), lower – in summer and autumn in the upper section of the Baryczka stream. High values of PT indicate organic pollution and a risk of the existence of the phenomenon of eutrophication [Kelly, Whitton 1995].

35 diatoms taxa were noted from the Red List Algae of Poland, which accounted for 12% of the total diatom flora (288 diatoms taxa).

In the upper section of the stream the *Cavinula lapidosa* (Krasske) Lange-Bert. diatom was recorded – it was deemed to be extinct in Poland (Ex category). It was recorded in the form of individual specimens, at pH<7 and with low and moderate electrolytes content, mostly between mosses growing on the rocks. In 2005, one cell of *C. lapidosa* was found in the Syhlec stream at the foot of Babia Góra Mountain [Noga 2005]. Another record of this species on the territory of Poland comes from springs areas in the River Warta valley [Żelazna-Wieczorek, Mamińska 2006].

Eight diatoms taxa were noted as endangered (E), among these, half were species from the genus *Pinnularia*: (*P. nodosa, P. schoenfelderi, P. subrupestris, P. viridiformis*), mostly as individual specimens, especially on site number four. *Pinnularia nodosa* is observed in flowing waters in Central Europe, in springs and on moors with low electrolyte content and a pH below 5.5, mostly as individual specimens [Hofmann et al. 2011]. In the Baryczka stream it was found on a spring site, in a forest area (no significant anthropopression). In the Podkarpacie Province they were recorded only as individual specimens from the Żołynianka stream [Noga, Peszek 2011].

Pinnularia viridiformis and *P. schoenfelderi* are cosmopolitan species, preferring oligo- to mesotrophic waters, with low to moderate electrolyte content.

Pinnularia subrupestris was found on sampling site three and four. Occurring in the Holarctic region, it is numerous in some places and crates large populations. It prefers oligo- to dystrophic waters, with high oxygen content, a low electrolyte content, and a pH of about 6, and it develops in mountains, especially in epipelon [Krammer 2000].

Pinnularia subrupestris and *P. viridiformis* are often recorded in Podkarpacie Province waters, however, they are always rare, and appear as individual specimens. They were found in the Wisłok River and the Rzeszów reservoir, and in many tributaries of the Wisłok [Tambor, Noga 2011, Noga 2012, Noga et al. 2012b, Pajączek et al. 2012, Noga et al. 2013]. *P. viridiformis* was recorded in the Kobylanka stream, in the Krakowsko-Częstochowska upland [Wojtal 2009].

Endangered species of the genus *Eunotia* (*E. botuliformis* and *E. flexuosa*) have not yet been recorded in Poland. *Eunotia botuliformis* was found on sites number one and four, and *E. flexuosa* only on site four as an individual specimen. Both species prefer anthropogenically transformed, oligo- to dystrophic waters, with low electrolyte content. *Eunotia botuliformis* has its optimum occurrence in lowland streams in northern Germany, rich in silicates, and forms more numerous populations in these places [Hofmann 2011].

Although the stream is exposed to the influence of anthropopression, due to unregulated water and wastewater management and sewage it is also the habitat of many rare and threatened diatom taxa, especially in the spring section of the stream. An example of this is the occurrence of *Cavinula lapidosa* – a species considered to be extinct in Poland. The building of sewage systems in all villages located in the catchment area, will undoubtedly contribute to the improvement of water quality and a reduction of water trophy, especially in the middle and lower sections of the Baryczka stream.

The list of diatoms taxa found in waters of Baryczka stream in years 2010–2011 with category of threatened according to Siemińska et al. [27]: Ex –Extinct or probably extinct, E – Endangered, V – Vulnerable, R – Rare, I – Indeterminate

Achnanthes coarctata (Bréb.) Grunow [R]

Achnanthidium minutissimum (Kütz.) Czarnecki var. ***minutissimum***

Achnanthidium pyrenaicum (Hust.) Kobayasi

Achnanthidium saprophillum (?) (Kobayasi & Mayama) Round & Bukht.

Adlafia brockmannii (Hust.) Bruder & Hintz

Amphipleura pellucida (Kütz.) Kütz. [R]

Amphora cimbrica Østrup [R]

Amphora copulata Ehrenb.

Amphora inariensis Krammer

Amphora micra Levkov

Amphora minutissima ? W. Smith

Amphora ovalis Kütz.

Amphora pediculus (Kütz.) Grunow

Brachysira vitrea (Grunow) Ross [E]

Caloneis amphisbaena (Bory) Cleve

Caloneis fontinalis (Grunow) Lange-Bert. & Reichardt [R]

Caloneis lancettula (Schulz) Lange-Bert. & Witkowski [R]

Caloneis molaris (Grunow) Krammer [R]

Caloneis silicula (Ehrenb.) Cleve

Caloneis cf. ***fontinalis*** (Grunow) Lange-Bert. & Reichard

Caloneis sp.

Cavinula cocconeiformis (Gregory) D.G. Mann & Stickle [V]

Cavinula lapidosa (Krasske) Lange-Bert. [Ex]

Chamaepinnularia soehrensis (Krasske) Lange-Bert. & Krammer [V]

Cocconeis pediculus Ehrenb.

Cocconeis placentula var. ***euglypta*** (Ehrenb.) Grunow

Cocconeis placentula var. ***lineata*** (Ehrenb.) Van Heurck

Cocconeis pseudolineata (Geitler) Lange-Bert.

Craticula ambigua (Ehrenb.) D.G. Mann

Craticula molestiformis (Hust.) D.G. Mann

Cyclostephanos dubius (Fricke) Round & Theriot

Cyclotella distinguenda Hust. var. ***distinguenda***

Cyclotella meneghiniana Kütz.

Cyclotella cf. ***cyclopuncta*** Håkansson & Carter

Cylindrotheca gracilis (Bréb. & Kütz.) Grunow

Cymatopleura elliptica (Bréb.) W. Smith

Cymatopleura solea var. ***apiculata*** (W. Smith) Ralfs

Cymatopleura solea (Bréb.) W. Smith var. ***solea***

Cymbella excisa Kütz.

Cymbella parva (W. Smith) Kirchner & Cohn

Cymbella subcistula (Ehrenb.) Kirchner

Cymbella tumida Bréb.

Cymbella sp.

Cymbopleura amphicephala (Nägeli) Krammer

Cymbopleura naviculiformis (Auerswald) Krammer

Denticula tenuis Kütz.

Diadesmis contenta (Grunow) D.G. Mann

Diadesmis paracontenta Lange-Bert. & Werum var. ***paracontenta***

Diadesmis perpusilla (Grunow) D.G. Mann

Diadesmis sp. (cf. ***brekkaensis***) (Petersen) D.G. Mann

Diadesmis sp.

Diatoma moniliformis Kütz.

Diatoma vulgaris Bory

Diploneis elliptica (Kütz.) Cleve

Diploneis fontanella Lange-Bert.

Diploneis krammeri Lange-Bert. & Reichardt

Stauroneis anceps Ehrenb.

Stauroneis gracilis Ehrenb. [V]

Stauroneis kriegerii Patrick

Diploneis separanda Lange-Bert.

Diploneis ovalis (Hilse) Cleve [R]

Discostella pseudostelligera (Hust.) Houk & Klee

Discostella stelligera (Cleve & Grunow) Houk & Klee

Encyonema minutum (Hilse) D.G. Mann

Encyonema prostratum (Berkeley) Kütz.

Encyonema silesiacum (Bleich) D.G. Mann

Encyonema ventricosum (Ag.) Grunow

Encyonopsis microcephala (Grunow) Krammer

Eolimna minima (Grunow) Lange-Bert.
Eolimna subminuscula (Manguin) Lange-Bert. & Metzeltin
Epithemia adnata (Kütz.) Bréb.
Eunotia bilunaris (Ehrenb.) Schaarschmidt
Eunotia botuliformis Wild, Nörpel & Lange-Bert. [E]
Eunotia mucophila (Lange-Bert. & Nörpel) Lange-Bert.
Eunotia diodon Ehrenb.
Eunotia exigua (Bréb.) Rabenh.
Eunotia flexuosa (Bréb.) Kütz. [E]
Eunotia islandica Østrup
Eunotia minor (Kütz.) Grunow
Eunotia praerupta Ehrenb.
Eunotia tridentula Ehrenb.
Eunotia cf. ***crista-galli*** Cleve
Eunotia cf. ***groenlandica*** (Grunow) Nörpel. & Lange-Bert.
Eunotia sp.
Fallacia insociabilis (Krasske) D.G. Mann
Fallacia monoculata (Hust.) D.G. Mann
Fallacia pygmaea (Kütz.) Strickle & D.G. Mann ssp. ***pygmaea***
Fallacia subhamulata (Grunow) D.G. Mann [R]
Fragilaria biceps (Kütz.) Lange-Bert.
Fragilaria capucina Desmaziéres var. ***capucina***
Fragilaria gracilis Østrup
Fragilaria mesolepta Rabenh.
Fragilaria pararumpens Lange-Bert., Hofmann & Werum
Fragilaria parasitica (W. Smith) Grunow var. ***parasitica***
Fragilaria parasitica var. ***subconstricta*** (W. Smith) Grunow
Fragilaria vaucheriae (Kütz.) Petersen
Fragilaria virescens Ralfs [E]
Frustulia vulgaris (Thwait) De Toni
Gomphonema augur Ehrenb.
Gomphonema cymbelliclinum Reichardt & Lange-Bert.
Gomphonema exilissimum (Grunow) Lange-Bert. & Reichardt
Gomphonema micropus Kütz.
Gomphonema olivaceum (Hornemann) Bréb. var. ***olivaceum***
Gomphonema olivaceum var. ***olivaceolacuum*** (Lange-Bert. & Reichardt) Lange-Bert. & Reichardt
Gomphonema parvulum (Kütz.) Kütz. var. ***parvulum***
Gomphonema. parvulum (Kütz.) Kütz. var. ***parvulum*** f. ***saprophilum***
Gomphonema productum (Grunow) Lange-Bert. & Reichardt
Gomphonema pumilum (Grunow) Reichardt & Lange-Bert.
Gomphonema sarcophagus Gregory [V]
Gomphonema subclavatum (Grunow) Grunow
Gomphonema tergestinum (Grunow) Fricke [I]
Gomphonema utae Lange-Bert. & Reichardt
Gomphonema sp.
Gyrosigma acuminatum (Kütz.) Rabenh.
Gyrosigma attenuatum (Kütz.) Rabenh.
Gyrosigma obtusatum (Rabenh.) Cleve
Gyrosigma sciotonense Cleve
Gyrosigma sp.
Halamphora montana Krasske
Halamphora normannii (Rabenh.) Levkov
Hantzschia abundans Lange-Bert.
Hantzschia amphioxys (Ehrenb.) Grunow
Hippodonta capitata (Ehrenb.) Lange-Bert., Metzeltin & Witkowski
Hippodonta costulata (Grunow) Lange-Bert., Metzeltin & Witkowski
Lemnicola hungarica (Grunow) Round & Basson
Luticola acidoclinata Lange-Bert. [R]
Luticola mutica (Kütz.) D.G. Mann
Luticola nivalis (Ehrenb.) D.G. Mann
Luticola ventriconfusa Lange-Bert.
Luticola ventricosa (Kütz.) D.G. Mann
Luticola sp. (cf. ***paramutica***) (Bock) D.G. Mann
Mayamaea atomus var. ***alcimonica*** (Kütz.) Lange-Bert.
Mayamaea atomus (Kütz.) Lange-Bert. var. ***atomus***
Mayamaea atomus var. ***permitis*** (Hust.) Lange-Bert.
Mayamaea cf. ***agrestis*** (Hust.) Lange-Bert.
Meridion circulare Ag. var. ***circulare***
Meridion circulare var. ***constrictum*** (Ralfs) Van Heurck
Navicula antonii Lange-Bert.
Navicula aquaedurae Lange-Bert.
Navicula bacilloides Hust.
Navicula capitatoradiata Germain
Navicula cari Ehrenb.
Navicula cincta (Ehrenb.) Ralfs
Navicula cryptocephala Kütz.
Navicula cryptotenella Lange-Bert.
Navicula cryptotenelloides Lange-Bert.
Navicula gregaria Donkin
Navicula kotschyi Grunow
Navicula lanceolata (Ag.) Kütz.
Navicula novaesiberica Lange-Bert.
Navicula radiosa Kütz.
Navicula recens (Lange-Bert.) Lange-Bert.
Navicula reichardtiana Lange-Bert.
Navicula tenelloides Hust.
Navicula tripunctata (O.F. Müller) Bory
Navicula trivialis Lange-Bert.
Navicula upsaliensis (Grunow) Paragallo [R]
Navicula veneta Kütz.
Navicula vilaplanii (Lange-Bert. & Sabater) Lange-Bert. & Sabater
Navicula viridula (Kütz.) Ehrenb.
Navicula sp. (cf. ***suchlandtii***) Hust.
Neidium affine (Ehrenb.) Pfitzer
Neidium ampliatum (Ehrenb.) Krammer [V]
Neidium binodeforme Krammer
Neidium dubium (Ehrenb.) Cleve [I]
Nitzschia acicularis (Kütz.) W.M. Smith
Nitzschia acidoclinata Lange-Bert.
Nitzschia alpina Grunow
Nitzschia angustata Grunow
Nitzschia archibaldii Lange-Bert.
Nitzschia brevissima Grunow [R]
Nitzschia brunoi Lange-Bert.
Nitzschia bulnheimiana (Rabenh.) Grunow [R]
Nitzschia calida (Grunow) Cleve & Grunow
Nitzschia capitellata Hust.
Nitzschia communis Rabenh.

Nitzschia constricta (Kütz.) Ralfs
Nitzschia debilis (Arnott) Grunow
Nitzschia dissipata (Kütz.) Grunow ssp. ***dissipata***
Nitzschia dissipata var. ***media*** (Hantzsch) Grunow
Nitzschia dubia W. Smith
Nitzschia frequens Hust.
Nitzschia frustulum (Kütz.) Grunow var. ***frustulum***
Nitzschia graciliformis Lange-Bert. & Simonsen
Nitzschia gracilis Hantzsch
Nitzschia heufleriana Grunow
Nitzschia homburgiensis Lange-Bert.
Nitzschia hungarica Grunow
Nitzschia intermedia Hust.
Nitzschia linearis (Ag.) Smith
Nitzschia palea (Kütz.) W. Smith
Nitzschia perminuta Grunow
Nitzschia pusilla Grunow
Nitzschia pura Hust.
Nitzschia recta Hantzsch
Nitzschia salinarum Grunow
Nitzschia sigma (Kütz.) W. Smith
Nitzschia sigmoidea W. Smith
Nitzschia sociabilis Hust.
Nitzschia solgensis Cleve-Euler
Nitzschia subtilis (Grunow) Hust.
Nitzschia subacicularis Hust.
Nitzschia supralitorea Lange-Bert.
Nitzschia tenuis (W. Smith) Grunow
Nitzschia umbonata (Ehrenb.) Lange-Bert.
Nitzschia vermicularis (Bory) Hantzsch
Nitzschia cf. ***capitellata*** Hust.
Nitzschia cf. ***pura*** Hust.
Nitzschia cf. ***ovalis*** Arnott
Parlibellus protracta
(Grunow) Witkowski, Lange-Bert. & Metzeltin
Parlibellus protractoides (Hust.) Witkowski & Lange-Bert. [R]
Pinnularia appendiculata (Ag.) Cleve
Pinnularia borealis Ehrenb. var. ***borealis***
Pinnularia brebissonii (Kütz.) Rabenh.
Pinnularia gibba Ehrenb.
Pinnularia globiceps Gregory
Pinnularia grunowii Krammer
Pinnularia isselana Krammer
Pinnularia lundii Hust.
Pinnularia marchica Schönfelder var. ***marchica***
Pinnularia microstauron (Ehrenb.) Cleve var. ***microstauron*** [V]
Pinnularia nodosa (Ehrenb.) W. Smith [E]
Pinnularia obscura Krasske
Pinnularia oriunda Krammer
Pinnularia perirrorata Krammer
Pinnularia schoenfelderi Krammer [E]
Pinnularia schroederii (Hust.) Cholonky
Pinnularia septentrionalis Krammer
Pinnularia silvatica Petersen
Pinnularia sinistra Krammer
Pinnularia subcapitata var. ***elongata*** Krammer
Pinnularia subcapitata Gregory var. ***subcapitata***
Pinnularia subcommutata var. ***nonfasciata*** Krammer
Pinnularia subrupestris Krammer [E]
Pinnularia viridiformis Krammer [E]
Pinnularia viridis (Nitzsch) Ehrenb.
Pinnularia sp. (***viridiformis*** ?) Krammer
Pinnularia sp.
Placoneis clementis (Grunow) Cox
Placoneis constans (Hust.) Cox
Placoneis elginensis (Gregory) Cox
Placoneis paraelginensis Lange-Bert.
Planothidium frequentissimum (Lange-Bert.) Round & Bukht.
Planothidium lanceolatum (Bréb.) Round & Bukht.
Psammothidium grischunum (Wuthrich) Bukht. & Round
Psammothidium lauenburgianum (Hust.) Bukht. & Round [V]
Psammothidium subatomoides (Hust.) Bukht. & Round [V]
Reimeria sinuata (Gregory) Kociolek & Stoermer
Reimeria uniseriata Sala, Guerreo & Ferrario
Rhoicosphenia abbreviata (Ag.) Lange-Bert.
Scoliopleura peisonis Grunow
Simonsenia delognei (Grunow) Lange-Bert.
Sellaphora bacillum (Ehrenb.) D.G. Mann [V]
Sellaphora joubaudii (Gremain) Aboal
Sellaphora pupula (Kütz.) Mereschkowsky
Sellaphora seminulum (Grunow) D.G. Mann
Selaphora sp. (cf. ***pseudopupula***) (Krasske) Lange-Bert.
Sellaphora sp. (***stroemii*** ?) (Hust.) D.G. Mann
Sellaphora sp.
Stauroneis acidoclinata Lange-Bert. & Werum
Stauroneis anceps Ehrenb.
Stauroneis kriegerii Patrick
Stauroneis leguminopsis Lange-Bert. & Krammer
Stauroneis parathermicola Lange-Bert.
Stauroneis phoenicenteron (Nitzsch) Ehrenb. [V]
Stauroneis reichardtii Lange-Bert.
Stauroneis smithii Grunow
Stauroneis subgracilis Lange-Bert. & Krammer
Stauroneis tackei (Hust.) Krammer
Stauroneis thermicola (Petersen) Lund [R]
Stephanodiscus hantzschii Grunow
Stephanodiscus minutulus (Kütz.) Cleve & Möller
Surirella angusta Kütz.
Surirella biseriata Bréb.
Surirella brebissonii Krammer & Lange-Bert. var. ***brebissonii***
Surirella brebissonii var. ***kuetzingii*** Krammer & Lange-Bert.
Surirella helvetica Brun
Surirella minuta (Bréb.) Kütz.
Surirella ovalis Bréb.
Surirella splendida (Ehrenb.) Kütz.
Surirella terricola Lange-Bert. & Alles
Surirella cf. ***brightwelli*** W. Smith
Surirella cf. ***terricola*** Lange-Bert. & Alles
Tabellaria flocculosa (Roth.) Kütz.
Thalassiosira pseudonana ? Halse & Heimal
Ulnaria acus (Kütz.) M. Aboal
Ulnaria ulna (Nitzsch) P. Compère

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