THE EFFECT OF ANTHROPOGENIC CHANGE IN THE STRUCTURE OF DIATOMS AND WATER QUALITY OF THE ŻOŁYNIANKA AND JAGIELNIA STREAMS

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INTRODUCTION


Thanks to a short life cycle, diatoms can respond quickly to changes in the environment. Many species have specific, narrow ecological scale dependent on numerous habitat factors. Species composition and the abundance of diatoms reflects the state of aquatic environment in which they live, what makes them excellent indicators of the quality of surface waters [Denys 1991, Kawecka, Eloranta 1994, Coring 1996].

Algological studies have not been conducted on the territory of the Podkarpacie Province, with the exception of the upper and the middle sections of the San River, in which the diatom Didymosphenia geminata developed massively in the 90’s [Kawecka, Sanecki 2003]. Over the past few years studies have been carried out on diatom diversity [Noga, Siry 2010, Tambor, Noga 2011, Noga 2012, Bernat, Noga 2012, Noga et al. 2012, Pajączek et al. 2012, Noga et al. 2013a, 2014a,b] and research making use of the role of diatoms as an indicator to evaluate water quality [Noga et al. 2013 b,c,d].

ABSTRACT

The studies on bentic diatoms were conducted in 2009–2011 at eight samplings sites over the Żołynianka stream and its tributary, the Jagielnia. 427 diatom taxa were recorded in total. Achnanthidium minutissimum var. minutissimum, Aulacoseira ambigua, Fragilaria capucina var. capucina, Gomphonema parvulum, Navicula gregaria, Nitzschia palea and Planothidium lanceolatum were dominant taxa in both water-courses. Chemical analysis of water showed high chemical status of water at most of sampling sites. The results of diatomaceous analysis conducted with OMNIDIA software revealed moderate and poor condition of water. The best water quality was recorded in the Jagielnia stream (good or moderate status). The values of the analyzed indices showed the worst water quality on the Żołynianka at site four, showing bad ecological status. TDI index deviated the most from the other two indices (IPS and GDI), always indicating poorer water quality.

Keywords: ecological status, diatoms Bacillariophyceae, diversity, indexed IPS, GDI, TDI, flowing waters.
Preliminary information on the richness of diatom species in the Żołynianka and the Jagielnia streams, occurrence of endangered and rare species and new taxa to Poland were presented in two scientific papers [Noga et al. 2014 a,b].

The aim of this study was to evaluate water quality of the Żołynianka and the Jagielnia streams based on the diatom assemblages analysis and diatomaceous indices values calculated with Omnidia software.

STUDY AREA

The study was conducted over the Żołynianka and the Jagielnia (right tributary of the Żołynianka) streams, which flow from the North to the South in the area of Łańcut district, in the Podkarpackie province. According to Kondracki [2009], the studied area is located within two mesoregions – the southeastern part of Kolbuszowa Plateau (Płaskowyż Kolbuszowski) and the northern part of Subcarpathian Proglacial Valley (Pradolina Podkarpacka), the Carpathian and Podkarpackie province and the macroregion of Sandomierz valley.

The Żołynianka stream (left-bank tributary of the Wisłok River) is a 10.8 km long stream, with 37.7 km² of basin area and drop rate from 0.7 to 10‰. The stream valley is composed of sand and aeolian sands.

The “Tama” reservoir used for fish farming is located at the place where the Żołynianka and the Jagielnia connect. The “Rajszula” reservoir with an area of 4.25 ha was built on the Jagielnia, it performs similar functions as the Tama. On the Żołynianka there are also several smaller fish ponds, starting from the spring area and along the stream. The catchments of both streams are mostly of agricultural character [Michalczyk 1988, Lach, Wnuk 1998].

Studies were conducted at eight sampling sites in the period from June 2009 to May 2011 on the Żołynianka stream (sampling sites 1–5) and its tributary, the Jagielnia (sampling sites 6–8) (Figure 1). The sampling site number 5 is the only one to be located on the area of Białobrzegi village, the rest of them are located in Żołynia village.

MATERIALS AND METHODS

Materials for the studies were collected in 2009–2011 on the Żołynianka stream (five sampling sites) and its tributary the Jagielnia (three sampling sites) from all available habitats (stones, sand, slit, aquatic macrophytes). pH, conductivity and water temperature were measured at each site. Chemical analysis of the water was carried out in the Departmental Laboratory of Analysis of Environment Health and Materials of Agricultural

To obtain pure diatom valves a part of each sample has been subjected to maceration in sulfachromic mixture (mixture of concentrated sulfuric acid and chromic acid in proportion 3:1), then washed in a centrifuge (at 2500 rpm). The diatoms were mounted in permanent diatom slides with synthetic resin – Pleurax (refractive index 1.75). The material was prepared according to the methods applied by Kawecka [2012].

Diatoms were identified and counted under a Nikon ECLIPSE 80i light microscope (LM) under 1000× magnification, equipped with Plan Achromatic objective ×100 for oil immersion (NA 1.4) and differential interference contrast (DIC). For Scanning Electron Microscope (SEM) observations samples were coated at Turbo-Pumped Sputter Coater Quorum Q 150OT ES with a 20nm layer of gold and observed under a Hitachi SU 8010 microscope.

The identification was supported by the following references: Krammer, Lange-Bertalot [1986–1991], Lange-Bertalot [1993, 2001], Krammer [2000, 2002, 2003], Rumrich et al. [2000], Werum, Lange-Bertalot [2004], Levkov [2009], Hofmann et al. [2011].

Species composition in the collected samples was determined by counting specimens on randomly selected transects under light microscope. The number of valves counted was 400. Species with a content of 5% or above in a given diatom assemblage were defined as dominant.

Omnidia software [Lecointe et al. 1993] version 4.2, was used to calculate diatomaceous indices, including ecological and taxonomic data [Prygiel & Coste 1993].

Analysis of the diatom communities structure was conducted to determine the ecological status of the Żołynianka and the Jagielnia streams. The results of these analyses were presented applying chosen diatomaceous indices (Table 1), for which the range of ecological classes of water quality and the ecological status has been adopted according to Dumnicka et al. [2006]. Indices of organic pollution:

- IPS – Specific Pollution Sensitivity Index [Coste in CEMAGREF 1982], based on species,
- GDI – Generic Diatom Index [Coste, Ayphas-sorho 1991], based on genera. The indices are scaled from 1 to 20 (when water quality increases there is an increase of the value of the indicator).
- TDI – Trophic Diatom Index [Kelly, Whitton 1995], which is scaled from 1 to 100 (the higher the value, the higher trophic state of water).

The percentage of participation of species characteristic for organic pollution (PT) must be taken into account in the interpretation of the TDI index. There is a possibility of organic pollution if the values of PT are above 20%.

Species diversity in diatom assemblages was determined using Shannon-Wiener (H’) indicator:

\[
H' = \sum_{i=1}^{s} \left( \frac{n_i}{n} \log_2 \frac{n_i}{n} \right)
\]

where: \(n_i\) – number of individual diatoms of the \(i\) species,
\(n\) – total number of individual counts
\(\frac{n_i}{n}\) – relative abundance of the \(i\) species,
\(s\) – total number of diatom taxa which occurred in the sampling site.

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

RESULTS

Waters of the studied streams were characterized by a pH reaction which was near neutral or alkaline. The lowest pH values (6.5) were recorded on the spring section of the Jagielnia stream. The highest pH (8.2) was recorded in winter at the site number five over the Żołynianka stream. Electrolytic conductivity values ranged from 158 to 435 μS/cm and reached the highest values in the lower reaches of the Żołynianka. In spring 2011, chemi-

Table 1. The range of indices value and corresponding ecological status according to Dumnicka et al. [2006]

<table>
<thead>
<tr>
<th>Water Quality Class*</th>
<th>Ecological state</th>
<th>IPS</th>
<th>GDI</th>
<th>TDI</th>
<th>Trophic state</th>
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<td>I</td>
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<td>&gt; 17</td>
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<tr>
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<td>good</td>
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<td>14–17</td>
<td>35–50</td>
<td>oligo/mesotrophic</td>
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<tr>
<td>III</td>
<td>moderate</td>
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<td>11–14</td>
<td>50–60</td>
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</tr>
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<tr>
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<td>&lt; 8</td>
<td>&lt; 8</td>
<td>&gt; 75</td>
<td>hypertrophic</td>
</tr>
</tbody>
</table>

* According to the Decree of the Minister of the Environment from 9 Nov. 2011 (Dz. U. No 257, pos. 1545).
cal analysis of water was also performed. Most of the studied water parameters indicated a high chemical status. The largest deviation from the standards of quality corresponding to the high status were observed for nitrates at the site two (6.066 mg NO$_3$/l) and at the site six (14.224 mg NO$_3$/l), indicating a chemical status below good (Table 2, 3).

427 diatom taxa were recorded in the Żołynianka and the Jagielnia streams in total (see list of diatom taxa). The greatest species diversity occurred at the site number three at which 244 taxa were found. The smallest number of diatom taxa (94) was recorded at the site number six in the upper reaches of the Jagielnia (see list of diatom taxa). The greatest abundance of diatom taxa were recorded from genera: Pinnularia (49), Navicula (41), Nitzschia (40), Fragilaria (34) and Gomphonema (27).

Shannon-Wiener (H’) species diversity index was calculated for all sampling sites, its high values ranged from 4.2 at the site number four to 7.2 at the site number three (Table 2).

Forty diatom taxa were classified as dominant i.e. their number at the sampling site was higher or equal to 5%. In the Żołynianka stream twenty-seven taxa were recorded as dominant, twenty in the Jagielnia. Seven taxa reached the rank of dominant in both streams and they were as follows: Achnanthidium minutissimum var. minutissimum, Aulacoseira ambigua, Fragilaria capucina var. capucina, Gomphonema parvulum, Navicula gregaria, Nitzschia palea and Planothidium lanceolatum. The most frequent dominant taxa in the Żołynianka stream were: Aulacoseira distans, Navicula lanceolata and Nitzschia fonticola. In the Jagielnia the most com-

<table>
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<th>Site</th>
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<th>C [µS/cm]</th>
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<td>6.8</td>
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<td>15.7</td>
<td>7.2</td>
<td>257</td>
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</table>
The mon dominants were: *Achnanthidium minutissimum* var. *minutissimum* and *Planothidium lanceolatum*. In all study seasons, the greatest abundance in assemblage reached: *Cocconeis placentula* var. *euglypta* (50.6%) – in summer at the site four, *Navicula tripunctata* (29.1%) in spring and *Achnanthidium minutissimum* var. *minutissimum* (26.7%) in summer at the site seven (Plate 1–3).

The degree of organic pollution and the amount of nutrients were determined by using the Specific Pollution Sensitivity Index (IPS). The highest values of this index (15.3) were recorded during summer and spring in the Jagielnia stream and in autumn and winter at the spring section of the Żołynianka stream (15.2). The lowest value was recorded in summer at the site four (5.9). The values of Generic Diatom Index (GDI) determining content of organic and inorganic nutrients were the lowest at the site four (from 7.9 in summer to 9.1 in winter). The highest values (>14) of GDI index were noted at the sites six and seven. The assessment of inorganic nutrient concentrations was determined based on the Trophic Diatom Index (TDI), which values ranged from 38.1 in the Jagielnia to 83.8 in the Żołynianka in July at the site four. Along with the TDI index, the occurrence of taxa resistant to organic pollution (%PT) was analyzed. PT values were low and did not exceed 20% at most sites. The site number four was an exception, PT index values in all sampling seasons exceed 30% there, while in the spring season it exceeded even 50% (Figure 2).

60 diatom taxa from the Polish Red List of Algae were recorded, which constituted 14% of the total number of identified taxa (see list of diatom taxa, Plate 4, 5).

**DISCUSSION**

The Żołynianka stream and its tributary the Jagielnia are small watercourses flowing mainly during summer and spring in the Jagielnia stream and in autumn and winter at the spring section of the Żołynianka stream (15.2). The lowest value was recorded in summer at the site four (5.9). The values of Generic Diatom Index (GDI) determining content of organic and inorganic nutrients were the lowest at the site four (from 7.9 in summer to 9.1 in winter). The highest values (>14) of GDI index were noted at the sites six and seven. The assessment of inorganic nutrient concentrations was determined based on the Trophic Diatom Index (TDI), which values ranged from 38.1 in the Jagielnia to 83.8 in the Żołynianka in July at the site four. Along with the TDI index, the occurrence of taxa resistant to organic pollution (%PT) was analyzed. PT values were low and did not exceed 20% at most sites. The site number four was an exception, PT index values in all sampling seasons exceed 30% there, while in the spring season it exceeded even 50% (Figure 2).

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**DISCUSSION**

The Żołynianka stream and its tributary the Jagielnia are small watercourses flowing mainly

<table>
<thead>
<tr>
<th>Site</th>
<th>mg Cl/l</th>
<th>mg NO₂/l</th>
<th>mg NO₃/l</th>
<th>mg SO₄²⁻/l</th>
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<td>5.96</td>
<td>BQL</td>
<td>1.20</td>
<td>19.66</td>
</tr>
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BQL – below the limit of quantification

Chemical status of water

- high
- good
- below good

**Table 3.** Chemical water parameters of Żołynianka and Jagielnia streams measured in spring 2011 (chemical status of water according to the Decree of the Minister of the Environment from 9 Nov. 2011, Dz. U. No 257, pos. 1545)

**Figure 2.** The values of diatomaceous indices GDI, IPS, TDI and %PT for sites in Żołynianka (1–5) and Jagielnia (6–8) streams in 2009–2011
Plate 3. SEM micrographs of the selected centric diatoms taxa: 1-3 – *Cyclostephanos dubius* (Hust.) Round, 4-5 – *Stephanodiscus hantzschii* Grunow, 6 – *S. minutulus* (Kütz.) Cleve & Möller, 7-8 – *Cyclostephanos invistatus* (Holm & Hellermann) Theriot, Stroermer & Håksson, 9-10 – *Discostella pseudostelligera* (Hust.) Houk & Klee, 11-12 – *Melosira varians* Agardh, 13-14 – *Cyclotella meneghiniana* Kütz., 15 – *Aulacoseira distans* (Ehrenb.) Simonsen
The waters of these streams have not been subjected to any monitoring studies until now. These studies are the first of this type and allow to determine the ecological status of water which is an important part of the valorization of the environment of the area.

The values of physico-chemical parameters classify the Żołynianka and the Jagielnia waters to I and II quality class (according to the Regulation by the Minister of the Environment dated 9 November 2011 on classification of the uniform parts of surface waters and on environmental quality standards for priority substances).

Average values of electrolytic conductivity in all sampling seasons were below 350 μS/cm. This is a typical value for this type of stream, i.e. sandy lowland stream such as the Żołynianka. Water pH values ranged from 6.5 to 8.2 and slightly exceeded typical values (6–7.5) [Picińska-Fałtynowicz et al. 2007].

The Żołynianka is a small watercourse (about 10 km), the Jagielnia is similar (less than 4 km long), in spite of both streams were characterized by significant richness of diatom species. 427 diatom taxa were recorded in total in both streams. The Żołynianka is a left-site tributary of the Wisłok River, it was subjected to complex studies of diatomological character. Although the studies were conducted at eight sampling sites located from the spring to the estuary, the number of identified taxa was four hundred and one, and it was lower than in the Żołynianka and the Jagielnia streams [Noga 2012]. Other rivers and streams in the Subcarpathian region were also characterized by lower species richness of diatoms compared to the studied watercourses [Noga, Siry 2010, Tambor, Noga 2011, Bernat, Noga 2012, Pajączek et al. 2012, Noga et al. 2013c,d, Noga et al. 2014a].

Huge diatom species richness in both streams was also confirmed by the value of the Shannon-Wiener (H’) species diversity indicator, which ranged from 4.2 at site four in summer to 7.1 in autumn at site three. Diatoms species richness of the Żołynianka and the Jagielnia is comparable to large rivers of the Podkarpackie (for example the Wisłok River). The reason for this may be the fact that along the entire length of the stream there are small fish ponds, which can significantly influence water chemistry. It can be of special importance in a spring section, where the lower trophic waters from the spring mix with the fertile waters of ponds. This specific mixing environment may favor the development of a wider group of diatoms compared to the typical streams in the Podkarpacie.

Forty dominant diatom taxa were recorded in both streams. Twenty-seven dominant taxa were found in the Żołynianka and twenty in the Jagielnia. Seven of them were common to both courses: *Achnanthidium minutissimum* var. *minutissimum*, *Aulacoseira ambigua*, *Fragilaria capucina* var. *capucina*, *Gomphonema parvulum*, *Navicula gregaria*, *Nitzschia palea* and *Planothidium lanceolatum*. They are cosmopolitan species, often forming numerous populations in Poland and Europe [Krammer, Lange-Bertalot 1986–1991, Hofmann et al. 2011].

The dominant which occurred numerously in most sampling sites was *Navicula gregaria*, one of the most frequently recorded species in Central Europe. The tolerance of the species ranges from oligotrophic to α-mesotrophic waters. They can occur both in salt and sweet waters. They develop well in oligotrophic waters with high silicate content [Krammer, Lange-Bertalot 1986–1991, Hofmann et al. 2011].

*Planothidium lanceolatum* was also cosmopolitan species, which frequently occurred in studied watercourses. It occurs both in waters very fertile and poor in nutrients, it abundantly and frequently develops in the streams of the Tatra Mountains. Despite its wide ecological range of tolerance, it avoids acidic water [Krammer, Lange-Bertalot 1086–1991, Kawecka 1996, Hofmann et al. 2011].

At all investigated sampling sites *Achnanthidium minutissimum* var. *minutissimum* developed frequently, it is one of the most common species in Central Europe. It occurs in a wide range of pH: from 4.3 to 9.2 and is an indicator species for water rich in oxygen. Ecological optimum is difficult to determine, because it occurs in oligotrophic and rich in nutrients waters. Taxon was frequently recorded in the streams of the Tatra Mountains and Zakopane Basin [Krammer, Lange-Bertalot 1986–1991, Van Dam et al. 1994, Kawecka 2012].

All taxa discussed above are some of the most common diatoms in most of the rivers and streams in the Podkarpacie. *Achnanthidium minutissimum* var. *minutissimum* and *Planothidium lanceolatum* dominated mainly in the upper part of watercourses, while *Navicula gregaria* developed frequently in the middle and lower reaches of the studied rivers [Noga, Siry 2010, Tambor, Noga 2011, Noga 2012, Pajączek et al. 2012, Noga et al. 2013c,d, Noga et al. 2014].

*Aulacoseira* genus, including *Aulacoseira ambigua* and *A. distans* were also found among domi-
nant taxa. All species of the genus *Aulacoseira* are planktonic forms occurring most frequently in stagnant water reservoirs with high trophy [Krammer, Lange-Bertalot 1986–1991]. The probable reason of occurrence of such a large number of diatoms from genus *Aulacoseira* in the studied streams was the presence of fish ponds in the spring sections. On the Jagielnia stream during spring season *Aulacoseira ambiguа* created numerous populations – over a dozen percent of the whole assemblage of diatoms. This took place at the site eight directly behind the Rajszula water reservoir.

In the areas where there was surface runoff from agricultural or pollutant inputs from industry, assemblage dominated by specific diatoms taxa developed, including mainly: *Nitzschia palea*, *Gomphonema parvulum*, *Amphora pediculus*, *Navicula radiosa*, *Melostra varians*, *Planothidium lanceolatum*, *Cocconeis placentula*, *Navicula cryptcephala* and *Diatoma vulgaris*, the appearance of which is indicative of the deterioration of water quality. *Nitzschia palea*, in particular, can be considered as an indicator of water rich in organic material and nitrogen. It often forms large populations in streams fertilized by urban waste water [Kawecka 1993, Richardson et al. 1996]. Such taxonomic assemblage composition was present at the site four, where most of the above mentioned taxa formed one of the most numerous population. This site was located near residential and commercial buildings and in the short distance from the ponds. Good insolation and no trees along the watercourse enhanced the described phenomenon.

Assessment of ecological status of the studied streams was possible due to the physico-chemical analysis of water and calculation of diatomaceous indices with Omnidia software [Lecointe et al. 1993].

Chemical analysis showed that water at most sites was of very good status. Deviations from standards corresponding to first quality class showed only nitrates, which classify studied waters at the site sixth as below good. Most of the rivers and streams of Podkarpackie (approx. 55%) also have a very good or good chemical status [WIOŚ 2010].

The results of analyzes carried out with Omnidia software showed moderate or poor ecological status of waters at most sampling sites. The best water quality was at the sites located in the Jagielnia – good or moderate ecological status (II–III quality class). In the Żołynianka stream good ecological status was found only at the site number one in autumn and winter. The values of the analyzed indexes were the worst in the classification at the site four, it frequently demonstrated bad ecological status (V class). TDI index values were most different from the other two (IPS and GDI), always indicating worse quality of water. This is probably the result of the fact that the index does not take the calculation of centric diatoms into account, and it was originally adapted for the waters in the United Kingdom. Diatomaceous indices analysis for Poland showed, that the best indicators to determine the water quality are IPS and GDI indices, and this is why they are recommended for our country [Kawecka et al. 1999, Kelly et al. 2001, Szczepeocka, Szulc 2009, Noga et al. 2013b,c,d].

The percentage of species participation characteristic for organic pollution (%PT) were also calculated, and it was found that only the Jagielnia waters showed no organic pollution. This stream flows in a large part through forest areas and areas not used for agricultural purposes, therefore it contains a small percentage of taxa tolerant to pollution (5.5–17.7%). In the Żołynianka, definitely the highest PT index values occurred at the site four and five (>50%). Such a large percentage of taxa resistant to organic pollution may indicate a risk of eutrophication [Kelly, Whitton 1995]. Slight signs of organic pollution were at the site one and three during spring season.

Diatomaceous analysis with TDI, GDI and IPS indices was also used for assessment of water quality from other watercourses of Podkarpackie: the Baryczka, the Matysówka and the Wisłok [Noga et al. 2013b,c,d]. The waters of the studied streams showed mostly moderate and poor quality (III and IV class), similar to the waters of the Jagielnia and the Żołynianka streams. Also other rivers and streams in Poland were analyzed by diatomaceous indices, and showed similar ecological status [Dumnicka et al. 2006, Szczepeocka 2007, Szczepeocka, Szulc 2009, Rakowska, Szczepeocka 2011].

Sixty diatom taxa were recorded from the Polish Red List of Algae [Siemińska et al. 2006]. Eleven taxa from endangered category (E) and among them, most of the genus *Pinnularia* [Noga et al. 2014b].

The studied streams are small watercourses flowing through areas used for agriculture, therefore every human activity in catchment can have a decisive impact on the quality of the waters. Significant impact on the studied waters had fish ponds located along the stream (from the spring to the estuary) and the Rajszula reservoir at the Jagielnia which serve as a fish pond. They can contribute to an increase in nutrients and organic matter, and
The list of diatom taxa recorded in Żołynianka (Z) and Jagielnia (J) in 2009–2011, and endangered category according to Red List of Algae [Siemińska et al. 2006]

| Achnanthes exigua | Grunow [Z,J] R |
| Achnanthes affinis (Grunow) Czarnecki [Z] |
| A. eutrophilum (Lange-Bert.) Lange-Bert. [Z,J] |
| A. linearoides (Lange-Bert.) Lange-Bert. [J] |
| A. minutissimum var. jaccii (Rabenb.) Lange-Bert. [J] |
| A. minutissimum (Kütz.) Czarnecki var. minutissimum [Z,J] |
| A. pyrenaicum (Hust.) Kobayasi [Z,J] |
| A. saprophilum (Kobayasi & Mayama) Round & Bukht. [Z] |
| Adlafia brockmannii (Hust.) Bruder & Hinz [Z,J] |
| Amphora alpestris Levkov [Z,J] |
| A. cimbrica Østrup [J] R |
| A. copulata (Kütz.) Schoeman & Archibald [Z,J] |
| A. eutrophilum (Lange-Bert.) Lange-Bert. [Z,J] |
| A. linearoides (Lange-Bert.) Lange-Bert. [J] |
| A. minutissimum var. minutissimum (Rabenh.) Lange-Bert. [J] |
| A. minutissimum (Kütz.) Czarnecki var. minutissimum [Z,J] |
| A. pyrenaicum (Hust.) Kobayasi [Z,J] |
| A. saprophilum (Kobayasi & Mayama) Round & Bukht. [Z] |
| Adlafia brockmannii (Hust.) Bruder & Hinz [Z,J] |
| Amphora alpestris Levkov [Z,J] |
| A. cimbrica Østrup [J] R |
| A. copulata (Kütz.) Schoeman & Archibald [Z,J] |
| A. eutrophilum (Lange-Bert.) Lange-Bert. [Z,J] |
| A. linearoides (Lange-Bert.) Lange-Bert. [J] |
| A. minutissimum var. jaccii (Rabenb.) Lange-Bert. [J] |
| A. minutissimum (Kütz.) Czarnecki var. minutissimum [Z,J] |
| A. pyrenaicum (Hust.) Kobayasi [Z,J] |
| A. saprophilum (Kobayasi & Mayama) Round & Bukht. [Z] |
| Adlafia brockmannii (Hust.) Bruder & Hinz [Z,J] |
| Amphora alpestris Levkov [Z,J] |
E. neogracile
Encyonema caespitosum
Discostella F. pseudoconstruens (Grunow) Lange-Bert. [J]
F. perminuta var. F. parasitica subconstricta Grunow [Z,J]
F. parasitica parasitica (W. Smith) Grunow var. parasitica [Z,J]
F. parasitica var. subconstricta Grunow [Z,J]
F. perminuta (Grunow) Lange-Bert. [J]
F. pseudoconstruens Marciniak [Z]
K. clevei var. bottnica (Cleve) Bukhtiyarova [J]
Kolbesia ploenensis (Hust.) Kingston [Z]
Lemnicola hungarica (Grunow) Round & Basson [Z,J]
Luticola acidoclinata Lange-Bert. [Z,J] R
L. goeppertiana (Bleisch) D.G. Mann [Z]
L. mutica (Kütz.) D.G. Mann [Z,J]
L. nivalis (Ehrenb.) D.G. Mann [J]
L. ventricosa (Kütz.) D.G. Mann [Z]
Mayamaea agrestis (Hust.) Lange-Bert. [J]
Kolpesia ploenensis (Hust.) Kingston [Z]
Lemnicola hungarica (Grunow) Round & Basson [Z,J]
Luticola acidoclinata Lange-Bert. [Z,J] R
L. goeppertiana (Bleisch) D.G. Mann [Z]
L. mutica (Kütz.) D.G. Mann [Z,J]
L. nivalis (Ehrenb.) D.G. Mann [J]
L. ventricosa (Kütz.) D.G. Mann [Z]
Mayamaea agrestis (Hust.) Lange-Bert. [J]
Kolpesia ploenensis (Hust.) Kingston [Z]
Lemnicola hungarica (Grunow) Round & Basson [Z,J]
Luticola acidoclinata Lange-Bert. [Z,J] R
L. goeppertiana (Bleisch) D.G. Mann [Z]
L. mutica (Kütz.) D.G. Mann [Z,J]
L. nivalis (Ehrenb.) D.G. Mann [J]
L. ventricosa (Kütz.) D.G. Mann [Z]
Planothidium frequentissimum (Lange-Bert.) Lange-Bert. [Z,J]

Puncticulata radiosa (Grunow) Håkansson [Z,J]

Reimeria sinuata (Gregory) Kociolek & Stoermer [Z]

Rhoicosphenia abbreviata (Agardh) Lange-Bert. [Z,J]

Rhopalodia gibba (Ehrenb.) O. Müller var. gibba [Z]

Sellaphora americana (Ehrenb.) D.G. Mann [Z,J] R

S. bacillum (Ehrenb.) D.G. Mann [Z,J] V

S. joubaudii (Germain) Aboal [Z,J]

S. laevissima (Kütz.) Mereschkovsky [Z,J]

S. mutatoides Lange-Bert. & Metzeltin [Z]

S. mutata (Krasse) Lange-Bert. [Z]

S. pseudopopula (Krasse) Lange-Bert. [Z,J] E

S. pupula (Kütz.) Mereschkovsky [Z,J]

S. seminulum (Grunow) D.G. Mann [Z,J]

Sellaphora sp. [J]

Simonsoenia delognei (Grunow) Lange-Bert. [Z,J]

Stauroforma exiguiformis (Lange-Bert.) Flower, V.J. Jones & Round [Z] I

Stauroneis acuta W. Smith [Z]

S. amphicephala Kütz. [J]

S. anceps Ehrenb. [Z,J]

S. boricchii (Petersen) Lund [Z,J]

S. gracilior Reichardt [Z,J]

S. gracilis Ehrenb. [Z,J] V
therefore very important to increase in the fertility of water. It is also very important to preserve ecotone zone, especially in a form of woodlots, which can absorb a significant part of nutrients, even before they reach the watercourse. At the site four, which is below the fish ponds, analyzed parameters showed the worst water quality. This section is completely exposed, regulated and devoid of woodlots along both edges. When the studies were conducted, most of the catchment area had sewage system and only lower section of the stream in Białobrzegi could be affected by waste. Currently, the construction of the sewage system in this part of Białobrzegi village has already been completed [Orlik, Obroślak 2005, Raczyńska, Machula 2006].

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