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Research Article

ECOLOGICAL CHARACTERIZATION OF DIATOM COMMUNITIES IN THE WISŁOK RIVER WITH APPLICATION OF THEIR INDICATORY ROLE TO THE EVALUATION OF WATER QUALITY

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ABSTRACT
Research conducted in 2007–2008 on eight sites designated along the Wisłok River showed great diatoms diversity – indicated a total of 401 diatom taxa. *Achnathidium pyrenaicum*, *A. minutissimum* var. *minutissimum*, *Navicula gregaria*, *N. lanceolata*, *Amphora pediculus*, *Cyclotella meneghiniana*, *Gomphonema olivaceum* var. *olivaceum*, *Nitzschia dissipata* ssp. *dissipata* were most frequent. Based on diatomaceous indices IPS, GDI and TDI has been shown that the upper part of Wisłok had a high and good ecological status. However, the middle and lower section of river was characterized by moderate and poor ecological status, on the base of the IPS and GDI indices (III and IV class). TDI value indicated bad water quality (V class) in the middle and lower section.

Keywords: Bacillariophyceae diatoms; ecology; indices IPS, GDI, TDI; Wisłok River.

INTRODUCTION

Diatoms (Bacillariophyceae) are a specialized group, settling in different types of ecosystems worldwide, for example fresh and salt waters, wet soils, rocks, ice and snow. They are sensitive to many environmental factors, which is why they, especially the benthic species are applied as indicators of changes taking place in the environment and to assess water quality [Siemińska 1964, Lange-Bertalot 1978, 1979a,b Hofmann 1994, Van Dam et al. 1994, Prygiel, Coste 1999, Rakowska 2001]. Water quality is also assessed using computer software (i.a. OMNIDIA) containing ecological and taxonomic data, and providing indicative values of the diatoms [CEMAGREF 1982, Coste, Ayphassorho 1991, Lecointe et al. 1993, Kelly, Whitton 1995, Eloranta, Kwandrans 1996, Kwandrans et al. 1998, Kwandrans 1999].

Many algological studies on benthic diatoms have been conducted in the area of southern Poland. Recently, they have mainly involved the Carpathian Mountains (including the Tatra Mountains, which have featured in about 230 different studies) and the Krakowsko-Częstochowska Upland [Kawecka 1996, 2012, Wojtal 2009]. No algological studies have 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, using their indicative role, in the Wisłok River basin [Noga 2012], in other currents in the Podkarpacie Province [Noga, Siry 2010, Tambor, Noga 2011, Pajączek et al. 2012, Noga et al. 2012a,b, 2013] and on soil diatoms [Stanek-Tarkowska, Noga 2012a,b].

The aim of the work was to present the ecological characteristics of diatom communities, as well as their application and the usage of diatom indices to assess the water quality of the Wisłok River.

STUDY AREA

The Wisłok River is the largest left-bank tributary of the San River (about 220 km long) – Figure 1. It springs from the Kanasiówka Mountain (823 m a.s.l.) in the Beskid Niski Mountains near the border between Poland and Slovakia. It flows through seven geographical mesoregions located within the Western Carpathian Mountains [Kondracki 2001]. Hence the catchment area of the Wisłok River is characterized by a high differentiation of landscape. The river flows from the area of the Beskid Niski, running further through the Bukowskie Foothills (Pogórze Bukowskie) and the Jasielsko-Krośnieńska Valley (Kotlina Jasielsko-Krośniewska). The riverbed constitutes a border between the Strzyżowskie Foothills (Pogórze Strzyżowskie) and the Dynowskie Foothills (Pogórze Dynowskie). The lower reaches of the river run through the Rzeszowskie Foothills (Pogórze Rzeszowskie) and the river empties into the San River on the territory of the Subcarpathian Proglacial Valley (Pradolina Podkarpacka). The upper course of the Wisłok River runs through mountainous and forested lands (where only a small degree of environmental transformation can be found), and in the middle and lower sections the river drains areas of industrial and agricultural characters.

A significant part of the catchment area is protected within the Jaśliska Landscape Park and the Czarnorzecko-Strzyżowski Landscape Park. The river's mountainous section ends in an artificial water body, the Besko Reservoir, with a concrete dam in Sienawa. Another reservoir, in the city of Rzeszów (Rzeszów Reservoir) was created to ensure a water supply, flood protection and recreation. The waters of the Wisłok River are used for both communal and industrial purposes. The river is also a receiver of sewage from agricultural areas, which are brought into the river directly or through running currents.

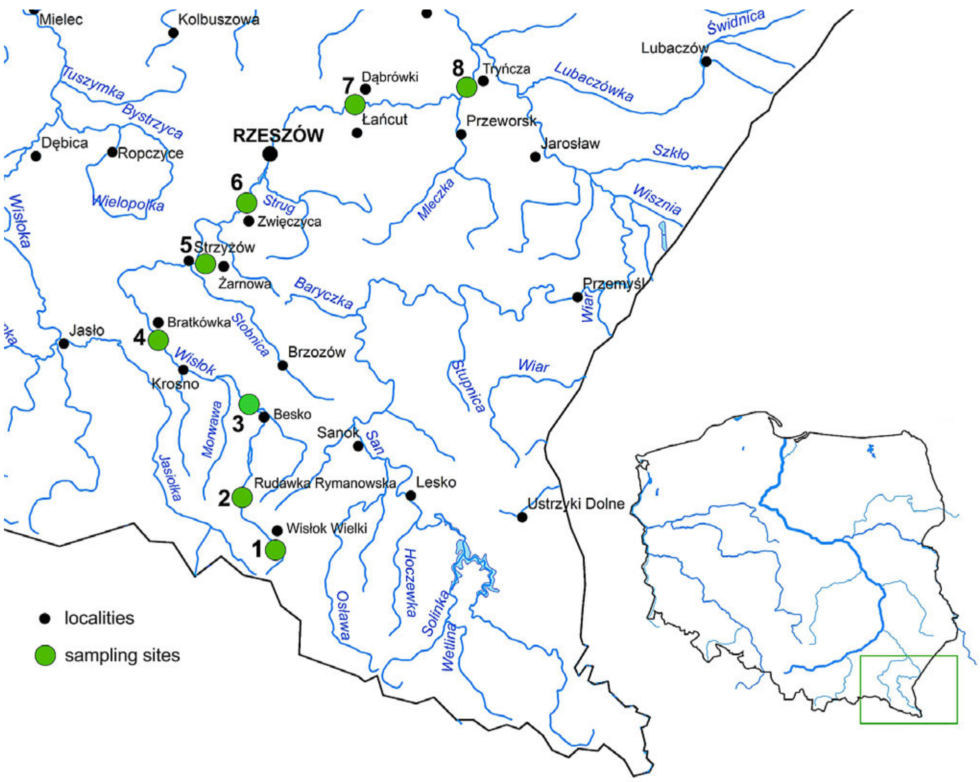

Fig. 1. Location of sampling sites (1–8) at Wisłok River

MATERIALS AND METHODS

Materials for studies were collected from eight study sites on the Wisłok River in 2007–2008 from all available habitats: rocks, sediments and aquatic macrophytes (Fig. 1).

The collected material was preserved in a 4% solution of formalin. 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 next it was rinsed in a centrifuge (at 2500 revol./min). 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 using the "Nikon 80i" light microscope, according to keys: Krammer, Lange-Bertalot [1986–1991], Lange-Bertalot [1993, 2001], Krammer [2000, 2002, 2003], Hofmann et al. [2011].

The number of diatoms was obtained by counting all species in randomly selected microscopic fields of view, up to a total of 400 valves. Species whose participation in a given community was 5% or more were classified as the most numerous.

Diatom classification with the aid of ecological indicators was presented using the list of Van Dam et al. [1994]. The following indicators were taken into consideration: pH, saprobity and trophic state.

In order to calculate diatomaceous indices, the computer program OMNIDIA (version 4.2) was used, which also contains ecological and taxonomic data [Lecointe et al. 1993, Prygiel, Coste 1993].

The analysis of diatom communities was conducted in order to determine the ecological status of the Wisłok River. The results were presented using selected diatomaceous indices, for which a range of ecological classes of water qualities and the ecological status conforming to them was outlined by mutual agreement, according to Dumnicka et al. [2006] (Table 1).

Table 1. Definitions and thresholds of diatom indices

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).

The indices of organic pollution: IPS – Specific Pollution Sensitivity Index [CEMAGREF 1982] and GDI – Generic Diatom Index [Coste, Ayphassorho 1991] (based on genus) are scaled from 1 to 10 (when water quality increases there is an increase in the value of the indicator). The TDI – Trophic Diatom Index [Kelly, Whitton 1995] is scaled from 1 to 100 (the higher the value, the higher the trophy of water). The percentage participation of species characteristic for organic pollution (PT) must be taken into account during the interpretation of the TDI index. There is a possibility of organic pollution with a participation of above 20% of PT.

RESULTS

The waters of the Wisłok River are characterized by an alkaline reaction (6.6–8.6) and medium to higher values of conductivity, especially in the middle and lower courses. Other chemical parameters, including BOD_5, COD, N_{NH4}–N, N_{NO3}–N, also indicate increased values in the middle and lower sections of the river (Table 2).

401 diatoms taxa were identified in eight determined study sites along the current of the river. A full list of taxa, containing and singling out endangered and rare taxa, was published in 2012 [Noga 2012]. *Achnathidium pyrenaicum* and *A. minutissimum* var. *minutissimum* developed the most numerously in the upper course of the Wisłok River (study sites number 1–3), and *Cocconeis pediculus*, *Diatoma moniliformis* and *Encyonema minutum* developed in small numbers. The middle and lower sections of the river (study sites 4–8) were characterized by numerous developments of *Navicula gregaria* and *N. lanceolata*, which dominated on all studied sites during most of the research seasons. *Amphora pediculus*, *Cyclotella meneghiniana*, *Gomphonema olivaceum* var. *olivaceum* and *Nitzschia dissipata* ssp. *dissipata* also developed numerously (Table 3).

The ecological preferences of diatom communities in terms of pH, saprobity and trophic state were characterized using the Van Dam et al. classification system [1994]. Classification based on pH showed that alkaliphilous diatoms

Table 2. Physico-chemical parameters on studied sites in the Wisłok River (July 2007 – May 2008)

Site	1	2	3	4	5	6	7	8
	Wisłok Wielki	Rudawka Rymanowska	Besko	Bratkówka	Żarnowa	Zwięczyca	Dąbrówki	Tryńcza
Temperature [°C]	4.8–19.7	5.3–26.5	4.2–26.0	5.0–22.1	3.8–24.2	4.1–25.4	3.7–24.4	3.9–24.9
pH	7.3–8.1	7.4–8.4	7.5–8.2	6.6–7.8	8.0–8.4	8–8.5	7.7–8.5	7.8–8.6
Conductivity [µS cm $^{-1}$]	212–327	165–410	299–322	410–553	460–500	467–492	454–514	420–531
BOD_5 [mg O_2 L $^{-1}$]	0.9–1.5	0.7–2.1	0.9–2.3	1.6–3.8	1.1–2.3	1.9–7.0	2.3–6.0	1.7–13.0
COD [mg O_2 L $^{-1}$]	<10.0–12.6	<10.0–22.1	10.6–13.4	12.7–26.2	13.7–28.7	<10.0–44.8	14.0–48.4	<10.0–63.0
N_{NH4} – N [mg L $^{-1}$]	<0.1–0.37	0.08–0.11	0.09–0.14	>0.1–1.75	0.163–0.7	0.27–1.21	0.22–1.14	0.38–0.95
N_{NO2} – N [mg L $^{-1}$]	0.004–0.01	<0.01–0.004	0.006–0.02	0.02–0.05	0.016–0.04	0.02–0.07	0.03–0.06	0.01–0.06
N_{NO3} – N [mg L $^{-1}$]	<0.2–0.71	0.124–0.93	0.53–1.23	1.17–2.4	1.31–2.02	1.11–2.11	0.88–2.45	0.22–2.25
PO_4 – P [mg L $^{-1}$]	<0.05–0.06	<0.05	<0.05	0.09–0.44	0.01–0.39	0.12–0.31	0.08–0.22	<0.05–0.18
Total P [mg L $^{-1}$]	<0.02–0.06	<0.05	<0.05	0.05–0.21	0.07–0.17	0.08–0.18	0.09–0.26	0.15–0.26
Ca [mg L $^{-1}$]	35.0–54.0	50.0–62.7	47.7–50.0	64.1–76.0	69.0–76.0	72.0–75.0	67.0–76.0	61.0–82.0

Table 3. The characteristic of sampling sites, including dominant species

Site	Description	Dominants
1 Wisłok Wielki	Width: 2–4 m. Depth: 0.1–0.2 m. Insolation: medium (partial shadowed by decidous trees). Bottom: stony, in summer covered by *Cladophora* sp., single-family houses and outbuildings in the immediate vicinity of the river. Current: rapid	*Achnathidium pyrenaicum, A. minutissimum* var. *minutissimum, Amphora pediculus, Cocconeis pediculus, C. placentula* var. *lineata, Encyonema ventricosum, Gomphonema olivaceum* var. *olivaceum, Navicula lanceolata, N. reichardtiana, Nitzschia dissipata* ssp. *dissipata, Rhoicosphenia abbreviata*
2 Rudawka Rymanowska	Width: ok. 20 m. Depth: 0.1–0.5 m. Insolation: high. Bottom: stony, with big boulders in bed, surrounded by mixed forest. Current: rapid	*Achnathidium pyrenaicum, A. minutissimum* var. *minutissimum, Cymbella excisa, Diatoma moniliformis, Encyonema ventricosum, Encyonopsis microcephala, Gomphonema olivaceum* var. *olivaceum, Navicula reichardtiana, Nitzschia dissipata* ssp. *dissipata*
3 Besko	Width: ok. 25 m. Depth: 0.3–0.5 m Insolation: high. Bottom: stony with big boulders in bed covered by mosses and *Cladophora* sp., site near to road, single-family houses around. Current: rapid	*Achnathidium pyrenaicum, A. minutissimum* var. *minutissimum, Cocconeis pediculus, Diatoma moniliformis, Encyonema ventricosum*
4 Bratkówka	Width: 10–15 m. Depth: 0.4–0.8 m Insolation: high. Bottom: stony, with a small amount of sand and silt near shore, stones intensively covered by *Cladophora* sp. and *Myriophyllum* sp. Current: calm	*Amphora pediculus, Cocconeis placentula* var. *lineata, Cyclotella meneghiniana, Gomphonema olivaceum* var. *olivaceum, Navicula capitatoradiata, N. gregaria, N. lanceolata, N. reichardtiana, Nitzschia dissipata* ssp. *dissipata, Rhoicosphenia abbreviata*
5 Żarnowa	Width: ok. 25 m. Depth: 0.2–0.5 m (near shore) Insolation: high. Bottom: stony, silted near shore, stones covered by *Cladophora* sp. in summer, meadows and grasslands in the immediate vicinity. Current: calm	*Amphora pediculus, Cocconeis placentula* var. *lineata, Cyclotella meneghiniana, Gomphonema olivaceum* var. *olivaceum, Navicula capitatoradiata, N. gregaria, N. lanceolata, N. reichardtiana, Nitzschia dissipata* ssp. *dissipata*
6 Zwięczyca	Width: ok. 20–30 m. Depth: 0.2–0.3 m (near shore) Insolation: high. Bottom: intensively silted near shore and covered by rushes. Stagnant water	*Amphora pediculus, Cocconeis placentula* var. *lineata, Cyclotella meneghiniana, Gomphonema olivaceum* var. *olivaceum, Navicula gregaria, N. lanceolata, N. reichardtiana, Nitzschia dissipata* ssp. *dissipata, Sellephora seminulum*
7 Dąbrówki	Width: 15–25 m. Depth: 0.2–1.0 m Insolation: high. Bottom: stony with big boulders in bed, covered by Chlorophyta (maliny *Cladophora* sp.), fallow lands and bush scrub in the vicinity of river. Current: rapid	*Amphora pediculus, Cyclotella atomus, Cyclotella meneghiniana, Navicula lanceolata, Nitzschia dissipata* ssp. *dissipata*
8 Tryńcza	Width: 15–25 m. Depth: from 0.5 (near shore) to 1.0–2.5 m. Insolation: high. Bottom: stony, silted near shore, station near road. Current: calm	*Amphora pediculus, Cyclotella atomus, Cyclotella meneghiniana, Navicula capitatoradiata, N. gregaria, N. lanceolata*

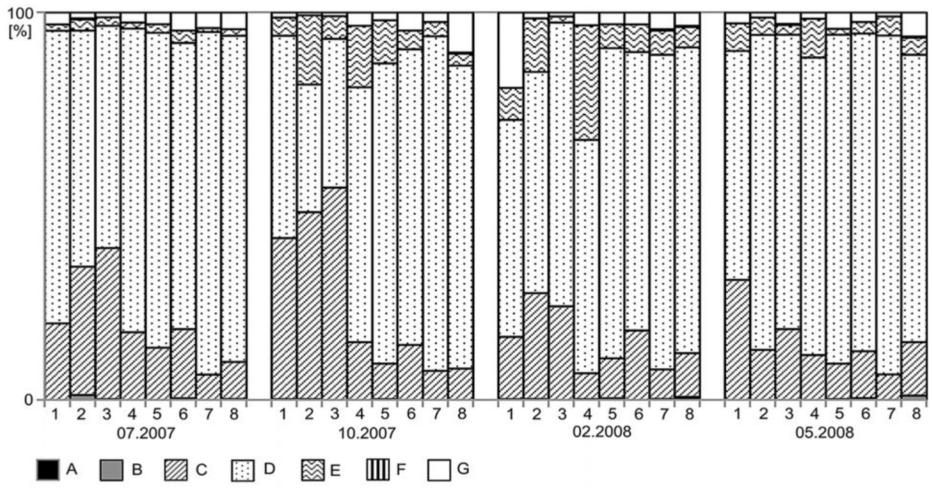

Fig. 2. Classification of ecological indicator values (according to Van Dam et al. 1994). pH range: A – acidobiontic, B – acidophilous, C – neutral, D – alkaliphilous, E – alkalibiontic, F – indifferent, no apparent optimum, G – unknown. Sampling sites: 1–8

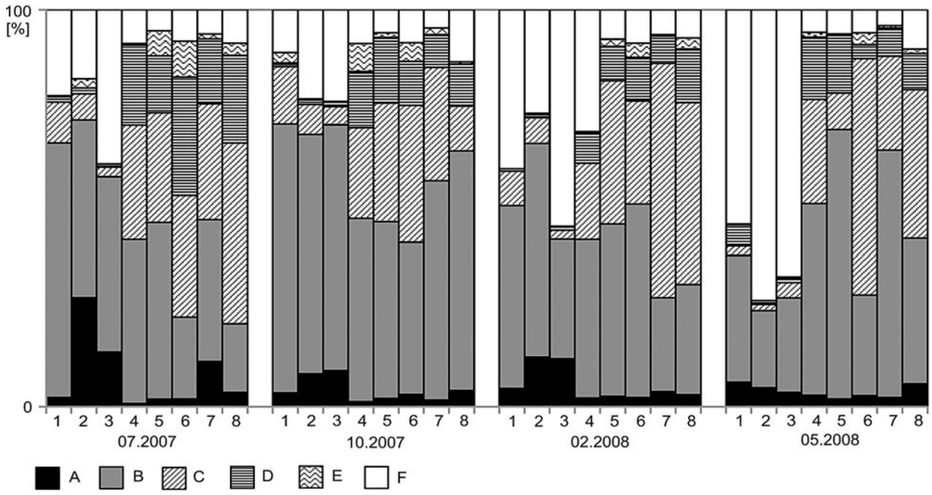

Fig. 3. Classification of ecological indicator values (according to Van Dam et al. 1994). Saprobity range: A – oligosaprobous, B – β-mesosaprobous, C – α-mesosaprobous, D – α-meso-polysaprobous, E – polysaprobous, F – unknown. Sampling sites: 1–8

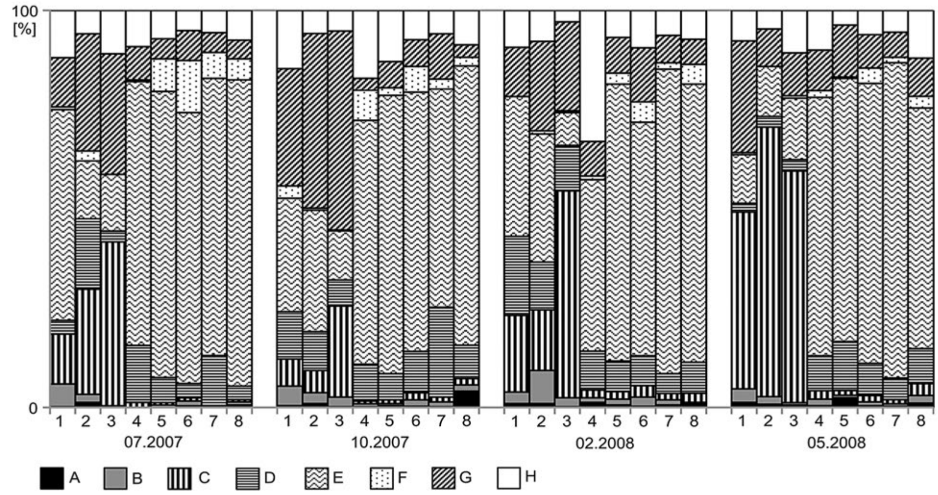

Fig. 4. Classification of ecological indicator values (according to Van Dam et al. 1994). Trophic state range: A – oligotraphentic, B – oligo-mesotraphentic, C – mesotraphentic, D – meso-eutraphentic, E – eutraphentic, F – hypereutraphentic, G – oligo- to eutraphentic, H – unknown. Sampling sites: 1–8

were definitely dominant along the whole length of the Wisłok River, whereas the lower section of the river is characterized by higher participation of circumneutral diatoms, especially during autumn season (Fig. 2). The taxa β-mesosaprobous (II class) dominated on the Wisłok River in terms of saprobity, especially in the upper section. The participation of taxa α-mesosaprobous (III class) increased in the middle and lower currents (Fig. 3). In all research seasons, eutraphentic taxa developed the most numerously in the middle and lower currents of the river. The upper section was characterized by the numerous presence of mesotraphentic (i.a. spring) and oligo- to eutraphentic diatoms (Fig. 4).

The values of diatomaceous indices in the upper course of the Wisłok River indicated waters of good and very good quality (second and first class) corresponding to a good and a high ecological status. Only study site number one was characterized by worse water quality (especially according to TDI index values). Values of diatomaceous indices in the upper course of the river differed slightly in all research seasons. Also, a small participation of taxa resistant to organic pollution (PT=1.0–7.7%) was noted. The middle and lower sections of the Wisłok River were characterized by worse water quality – third and fourth class when based on the IPS and GDI indexes and fifth class according to the TDI index. Moreover, the participation of taxa resistant to organic pollution increased to even above 50% on some study sites (Table 4).

DISCUSSION

Waters of the Wisłok River in their middle and lower sections were characterized by an alklaine reaction (6.6–8.6), average to increased values of conductivity and BOD_5, COD, N_{NH4}–N and N_{NO3}–N. Similar values of conductivity were noted in the lower section of the Wisłoka River [Augustyn et al. 2012]. Other studied currents on the territory of the Podkarpacie Province also have increased values of some chemical parameters. The small Matysówka stream, running through Rzeszów, was characterized by a higher content of ammonium nitrogen, phosphates and other nitrate concentrations, which are similar to the Wisłok River [Noga et al. 2013]. The catchment area of the Wisłok River is a receiver of various types of pollution (sewage, surface flows from farming lands, wild rubbish dumps, etc.) and it is distinguished from others by an increased content of organic

Table 4. The values of diatomaceous indices IPS, GDI, TDI and %PT calculated for individual sites in the Wisłok River (1–8) in four studied seasons

07.2007				
Site	IPS	GDI	TDI	%PT
1	16.8	13.5	62.7	5.7
2	16.9	15.6	33.8	5.8
3	18.8	16.4	36.0	1.6
4	12.3	11.2	66.4	18.1
5	11.2	10.1	80.4	17.9
6	8.8	10.9	76.3	19.4
7	11.0	12.1	82.5	7.1
8	8.5	12.1	80.0	9.5
Average	13.04	12.74	64.76	10.64
10.2007				
Site	IPS	GDI	TDI	%PT
1	16.1	13.4	66.4	7.7
2	17.0	16.4	36.1	1.0
3	18.5	16.3	37.4	2.1
4	12.3	10.1	90.5	24.5
5	12.6	10.3	91.0	16.5
6	11.4	10.6	79.5	27.7
7	13.8	11.6	89.2	18.2
8	13.4	10.4	86.7	6.9
Average	14.38	12.38	72.1	13.07
02.2008				
Site	IPS	GDI	TDI	%PT
1	15.6	12.3	65.4	2.9
2	17.0	15.4	46.8	2.0
3	18.6	16.7	29.4	2.4
4	11.4	12.0	84.7	11.1
5	12.9	11.3	81.1	28.4
6	12.6	11.2	75.7	20.1
7	13.1	12.1	85.4	50.5
8	11.9	11.5	82.3	36.5
Average	14.13	12.81	68.85	19.23
05.2008				
Site	IPS	GDI	TDI	%PT
1	18.4	16.5	36.8	1.3
2	19.1	17.1	30.3	1.3
3	18.5	16.3	37.3	3.3
4	14.0	12.0	87.9	33.0
5	14.4	10.6	89.1	9.0
6	11.8	11.2	85.8	56.4
7	13.6	10.4	90.7	19.4
8	13.1	11.8	77.8	30.0
Average	15.36	13.23	66.96	19.21

Ecological status IPS, GDI, TDI	high	good	moderate	poor	bad

pollution and biogenic compounds [WIOŚ 2009]. The character of the catchment area, the type of surface and the good oxygenation connected with it result in the fact that the water quality of the Wisłok River is better, in comparison to small currents within its catchment area.

The alkaline character of the water of the Wisłok River is also reflected in the ecological preferences of the species of diatoms occurred in it. A dominant group were alkaliphilous diatoms (mainly occurring at pH>7), taking into consideration the water reaction, among which *Achnanthidium pyrenaicum* occurred frequently. It is considered as an alkaliphil species [Van Dam et al. 1994, Lange-Bertalot, Steindorf 1996], whereas according to Hofmann [1994] it has a pH towards neutral. Circumneutral diatoms, mainly occurring at pH – values of about 7 [Van Dam et al. 1994], developed numerously in the upper section of the river.

Diatoms characteristic for β-mesosaprobous waters, belonging to the second class of quality, predominated on the majority of the study sites. The most numerous group in the middle and lower sections made up *α*-mesosaprobous taxa (third class), especially on the study sites number 6 in Zwięczyca and 8 in Tryńcza. A considerable share of diatoms belonging to an unknown category was noted in the study sites in the upper course of the river in connection with the numerous development of *Achnanthidium pyrenaicum*, which was not taken into consideration in the classification system according to Van Dam et al. [1994].

With reference to diatom requirements in relation to trophy, mesotraphentic, oligo- and eutraphentic taxa, that is those with a wide spectrum of occurence, predominated in the upper course of the Wisłok River. *Achnanthidium minutissimum* var. *minutissimum*, which has a wide ecological amplitude and develops from oligo- to eutrophic conditions [Krammer, Lange-Bertalot 1986–1991], occurred numerously. The middle and lower sections of the river (study sites 4–8) were characterized by the most numerous occurrence of eutraphentic diatoms, which prefer very fertile waters. *Navicula lanceolata* and *N. gregaria*, which are found as halophilic taxa, were the most frequently dominants. *Navicula lanceolata* is one of the most frequently occurring taxa in different types of water ecosystem. It develops best in mesotrophic and eutrophic waters [Krammer, Lange-Bertalot 1986–1991, Van Dam et al. 1994, Lange-Bertalot, Steindorf 1996, Hofmann et al. 2011, Kawecka 2012].

Diatom communities in the Wisłok River indicate similar ecological preferences regarding pH, saprobity and trophy in comparison to other studied currents on the territory of the Podkarpacie Province [Noga, Siry 2010, Tambor, Noga 2011, Bernat, Noga 2012, Pajączek et al. 2012].

Studies conducted in 2007–2008 indicated a huge species richness of diatoms in the Wisłok River. The occurrence of more than 400 taxa was noted on eight study sites [Noga 2012]. Other studied inflows of the Wisłok River are characterized by a huge species richness, for example Matysówka – 271 taxa, Mleczka – 277 taxa, Morwawa – 244 taxa and Różanka – 202 taxa [Pajączek et al. 2012, Noga et al. 2013].

The analysis of the structure of diatom communities was also applied in order to determine the ecological status of the Wisłok River. Based on the IPS [CEMAGREF 1982], GDI [Coste, Ayphassorho 1991] and TDI [Kelly, Whitton 1995] diatomaceous indicess, the upper section of the Wisłok River had a high or good ecological status. A moderate and poor ecological status was noted on study site number one, based on the GDI and TDI indices. The first study site, in the Wisłok Wielki, was located close to the neighbourhood of residential houses and outbuildings. The surrounding area is not connected to a sewage system and that is probably why household and farming sewage is directly channelled into the river.

The middle and lower sections of the River Wisłok were characterized by a moderate and poor ecological status, based on the IPS and GDI diatomaceous indices (third and fourth class). TDI index values indicated bad water quality (fifth class). The participation of taxa resistant to organic pollution (PT) increased, even to >50% on some studying sites. An increase of PT values above 40% might prove huge organic pollution and cause an increase in eutrophication [Kelly, Whitton 1995, Kelly et al. 2001].

The IPS and GDI indices are found to be the most reliable to assess the ecological state of rivers on the territory of Poland. The TDI index decreases the quality of the studied waters considerably, as in other rivers and streams in Poland [Kwandrans et al. 1998, 1999, Kawecka et al. 1999, Dumnicka et al. 2006, Szczepocka 2007, Szczepocka, Szulc 2009, Rakowska, Szczepocka 2011, Noga et al. 2013, Noga et al. – in press]. The IPS index also works well in assessment of water qualities on the territory of Central Europe [Blanco et al. 2007].

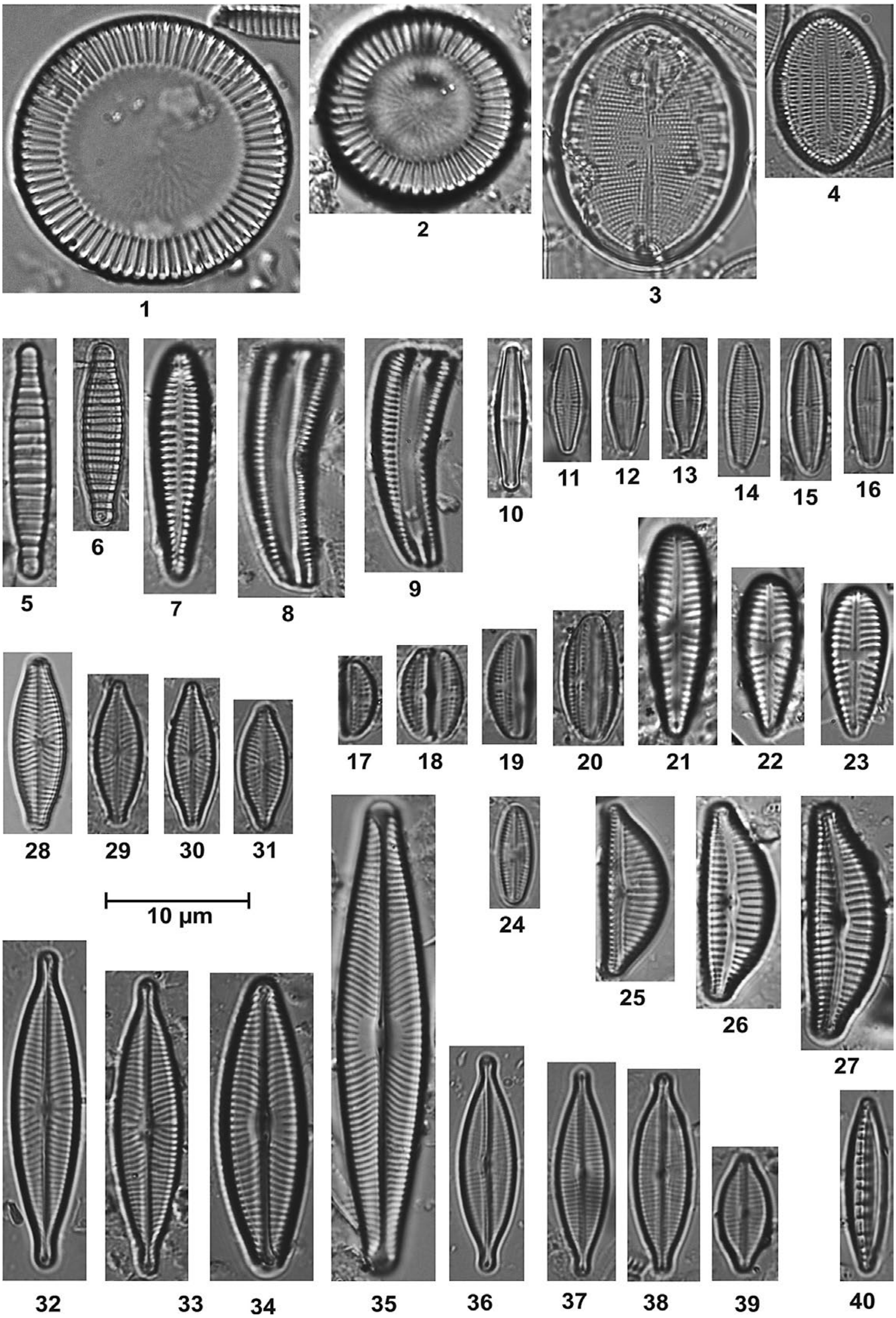

Plate I. Selected dominant diatoms taxa in the Wisłok River: 1–2 ***Cyclotella meneghiniana*** Kütz., 3 ***Cocconeis pediculus*** Ehrenb., 4 ***C. placentula*** var. ***lineata*** (Ehrenb.) Van Heurck, 5–6 Diatoma moniliformis Kütz., 7–9 ***Rhoicosphenia abbreviata*** (Ag.) Lange-Bert., 10–13 ***Achnanthidium minutissimum*** (Kütz.) Czarnecki var. ***minutissimum***, 14–16 ***A. pyrenaicum*** (Grunow) Round & Bukht., 17–20 ***Amphora pediculus*** (Kütz.) Grunow, 21–23 ***Gomphonema olivaceum*** (Hornemann) Bréb. var. ***olivaceum***, 24 ***Sellaphora seminulum*** (Grunow) D.G. Mann, 25 ***Encyonema ventricosum*** (Agardh) Grunow, 26–27 ***Cymbella excisa*** Kütz., 28–31 ***Navicula reichardtiana*** Lange-Bert., 32–33 ***N. capitatoradiata*** Germain, 34–35 ***N. lanceolata*** (Ag.) Kütz., 36–39 ***N. gregaria*** Donkin, 40 ***Nitzschia dissipata*** (Kütz.) Grunow ssp. ***dissipata***.

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