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Influence of hydrochemical conditions on diatoms in a limnocrenic spring

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Abstract

Studies of epipsammic diatoms in a limnocrenic spring and an analysis of their habitat conditions were carried out between 2003 and 2005. A total of 225 diatom taxa were identified in the studied spring, and high dynamism in the diatom community was observed during the study. Based on the autecology of the identified diatom taxa, determined according to Van Dam et al. 1994, in comparison with the habitat characteristics determined by the physicochemical water analysis, it was established that diatoms belonging to constancy class V are the best for determining conditions in the studied habitat. Correlation analysis of the participation of the dominants and subdominants of consecutive samples with fifteen physicochemical water parameters revealed the relationship between the reactions of thirteen diatom representatives to changing physicochemical parameters despite their narrow range of changeability in the spring.

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INTRODUCTION

Springs are the most valuable feature of landscapes and nature, and they are very sensitive to environmental changes. They are also an interesting subject of hydrobiological and hydrochemical studies as they are characterized by relatively stable environmental conditions (Kawecka and Eloranta 1994).

Piękne Spring, the subject of the current study, is located in the vicinity of Łódź in the Moszczenica River catchment basin (Fig. 1). This is one of more than 100 springs which can be found in the area of Łódź Hills scarp between Zgierz and Brzeziny.

Piękne Spring is alimented by fluvioglacial sediments from the Riss glaciation. It is a perennial, pulsating spring with long-term water exchange in an aquifer drainage.

Diatomological and hydrochemical studies of Piękne Spring were carried out from January 2003 to June 2005. The aims of the study were to determine the influence of hydrochemical conditions on the epipsammic diatom communities in this limnocrenic spring; to determine diatom groups which best characterize, based on autecology and hydrochemical characteristics, habitat conditions; to determine physicochemical factors that influence the dominant and subdominant species in this community.

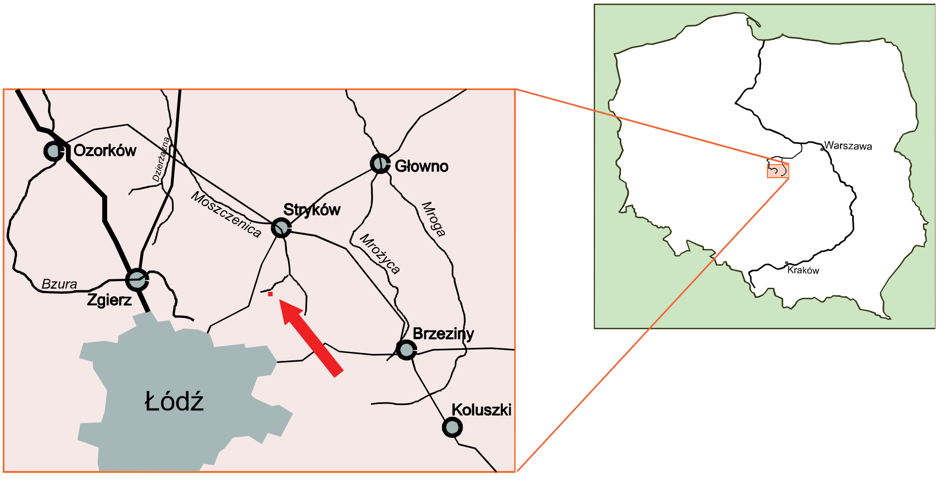

Fig. 1. Location of Piękne Spring.

MATERIALS AND METHODS

Physicochemical properties of the water like temperature, conductivity, pH-reaction, redox potential, and dissolved oxygen, were determined *in situ* monthly. Water chemistry samples were collected once quarterly throughout the year to determine major concentrations of ions, mineral forms of nitrogen and phosphorus, and silica. The dry residue, total hardness, oxidizability, and color of the spring water were also determined. Samples were collected once at the end of the 2004 hydrologic year to determine heavy metals (Cd, Cu, Ni, Pb, Zn, As, Al) and organochloric pesticides.

All of the physicochemical properties and chemical components were determined according to Witczak and Adamczyk (1995). Analyses were conducted at the laboratory of the Geographic Science Faculty of the University of Łódź, and heavy metals and organochloric pesticides were determined at the laboratory of the Polish Geological Institute.

Algological samples were collected once monthly. The qualitative and quantitative analysis of epipsammic diatoms was performed based on permanent slides. The diatoms were identified according to Krammer (2000, 2002, 2003), Krammer and Lange-Bertalot (1986, 1988, 1991a, b), Lange-Bertalot (2001), Lange-Bertalot and Metzeltin (1996), Werum and Lange-Bertalot (2004). In each sample, 500 valves were counted. The following issues were considered in the analysis of the diatom communities:

- quantitative differentiation was expressed as the participation percentage of individual species; participation exceeding 5% - dominant species, 2-5% - subdominants, 1-2% - influents, below 1% - accessory and alien species;
- occurrence constancy according to the five-grade Braun-Blanquet scale: 81%-100% (class V), 61%-80% (class IV), 41%-60% (class III), 21%-40% (class II) and 1%-20% (class I);
- the Sørensen similarity index was calculated for diatom communities in individual samples.

The environmental conditions of the studied spring were determined based on information on diatom autecology in the Omnidia 4.1 database and according to Van Dam et al. (1994).

STATISTICA version 6.0 was used for the statistical analysis of the data.

RESULTS

The spring's niche is circular in shape, with a diameter of 1.2 m and a 0.40 m maximum depth. The bottom of the niche is sandy. The mean yield of the spring was 0.9 l s^{-1} (Q_{max} 1.0 l s^{-1}, Q_{min} 0.6 l s^{-1}). The mean water retention time in the niche was 541 sec ~ 9 min.

The high hydrological stability of the studied spring influences its hydrochemical conditions. Water outflow into the spring niche has low total mineralization (256 mg l^{-1} ± 12 mg l^{-1}), medium hardness (3.05 mval l^{-1} ± 0.97 mval l^{-1}), and weak alkaline reaction (7.51 ± 0.21). According to Szczukariew-Prikłoński, the hydrochemical type was $HCO_3 – SO_4 – Ca$, and the oxidizability of spring water was 2.28 mg O_2 l^{-1} ± 0.8 mg O_2 l^{-1}.

Changeability in the majority of the physicochemical properties was low at a variability coefficient of less than 10%. Some elements, like ammonia, nitrate, phosphate, and oxidizability were more changeable with a maximum v.c. of 40% in the case of phosphate.

A total of 225 diatom taxa were determined in 29 samples collected. The number of identified diatom taxa in the various samples ranged from 52 to 111. Most of the identified taxa (133) belonged to constancy classes I and II (59.1%). There were 32 constant species (class V) in the diatom communities of the studied spring (14.2%), whereas 34 belonged to class IV (15.1%) and 26 were from class III (11.6%).

The dominant and subdominant species in the studied spring that belonged to constancy class V were: *Achnanthidium minutissimum* (Kützing) Czarnecki, *Amphora pediculus* (Kützing) Grunow, *Am. inariensis* Krammer (AINA), *Am. ovalis* (Kützing) Kützing (AOVA), *Encyonema silesiacum* (Bleisch) Mann (ESLE), *Eolimna minima* (Grunow) Lange-Bertalot (EOMI), *Fragilaria pinnata* Ehrenberg (FPIN), *Gomphonema parvulum* (Kützing) Kützing (GPAR), *Hippodonta costulata* (Grunow) Lange-Bertalot, Metzeltin et Witkowski (HCOS), *Navicula antonii* Lange-Bertalot (NANT), *N. gregaria* Donkin (NGRE), *N. protracta* (Grunow) Cleve (NPRO), *N. seminulum* Grunow (NSEM), *Karayevia clevei* (Grunow in Cleve & Grunow) Round & Bukhtiyarova (KCLE), *Planothidium dubium* (Grunow) Round & Bukhtiyarova (PTDU), *Pl. frequentissimum* (Lange-Bertalot) Lange-Bertalot (PLFR), *Pl. lanceolatum* (Brebisson) Lange-Bertalot (PTLA), *Pl. rostratum* (Oestrup) Lange-Bertalot (PRST).

The Sorensen similarity index of diatom communities among all the samples was calculated. A similarity diagram was made; this illustrates changes in the diatom community appearance throughout the study and Euclidean distances were measured using Simple Linkage rules (Fig. 2).

The indicator value for pH, salinity, nitrogen uptake metabolism, oxygen saturation, trophic state, saprobity, and moisture was attributed to the diatom taxa identified. Based on the preceding, the habitat requirements of diatoms belonging to particular constancy classes expressed as the percentage of taxa were determined (Table 1).

The conditions prevailing in the studied spring that were determined based on the habitat preferences of diatoms belonging mainly to constancy class V

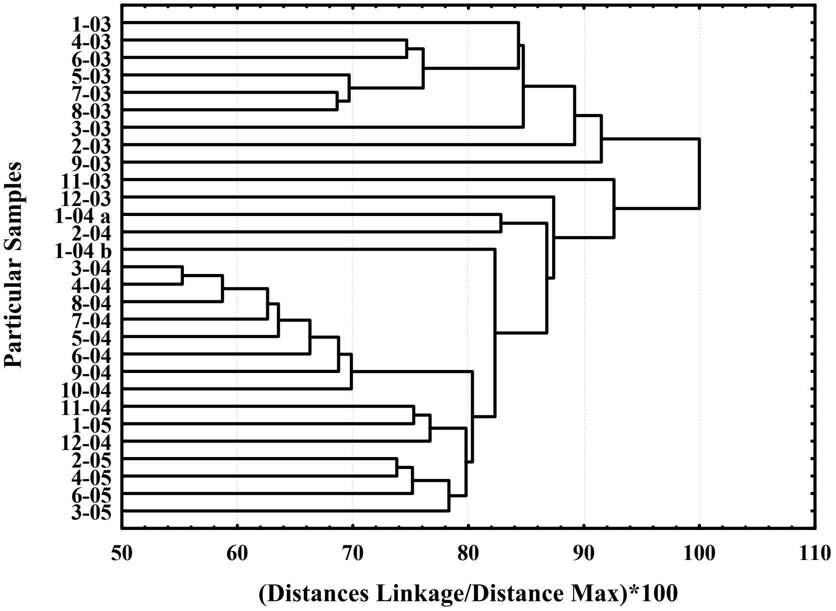

Fig. 2. Diagram of the similarities between the various samples of the Piękne Spring diatom communities (Euclidean distances were measured using Single Linkage rules).

were confirmed by hydrochemical analysis. In the case of oxygen saturation, only the range indicated by diatoms that belonged to constancy class V was confirmed by physicochemical water studies.

The correlation analyses performed indicated that there were essential connections among fifteen spring water physicochemical parameters and the thirteen dominant and subdominant diatom species belonging to constancy class V (Table 2).

The most correlations were revealed for *Eolimna minima* (EOMI), *Fragilaria pinnata* (FPIN), and *Planothidium dubium* (PTDU), where changes in diatom participation percentage were related to TDI values and concentrations of HCO_3^- and SiO_2, NO_3^- and NO_2^-. The first three of these parameters were characterized by low general variability throughout the study. The *Eolimna minima* (EOMI) participation in the diatom communities increased along with TDI and the concentration of HCO_3^- and SiO_2 components (Fig. 3a-c), which was contrary to that of *Fragilaria pinnata* (FPIN) and *Planothidium dubium* (PTDU) whose roles in analogical situations were diminished (Fig. 3d).

Table 1

Ecological preferences of the identified diatom taxa belonging to particular constancy classes

Ecological indicator value	class V	class IV	class III	class II	class I
pH					
acidobiontic (1) optimal occurrence at pH <5.5	0	0	4.50%	0	0
acidophilous (2) mainly occurring at pH <7.0	0	0	9.10%	10%	10.90%
circumneutral (3) mainly occurring at pH values of about 7.0	28%	40.70%	**45.50%**	37.50%	**50%**
alkaliphilous (4) mainly occurring at pH >7.0	**68%**	**55.60%**	40.90%	**45%**	28.20%
alkalibiontic (5) exclusively occurring at pH >7.0	4%	3.70%	0	7.50%	12.90%
indifferent (6) no apparent optimum	0	0	0	0	0
Salinity					
fresh (1) <0.2‰	0	7.10%	22.70%	19.50%	20%
fresh brackish (2) <0.9‰	**92.60%**	**89.30%**	**72.70%**	**70.70%**	**66%**
brackish fresh (3) 0.9-1.8‰	7.40%	3.60%	4.60%	9.80%	14%
brackish (4) 1.8-9.0‰	0	0	0	0	0
Nitrogen uptake metabolism					
nitrogen-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen (1)	9.50%	22.70%	41.20%	43.20%	**45.90%**
nitrogen-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen (2)	**81%**	**63.60%**	**52.90%**	**48.70%**	**45.90%**
facultatively nitrogen-heterotrophic taxa, needing periodically elevated concentrations of organically bound nitrogen (3)	9.50%	4.60%	5.90%	8.10%	5.50%
obligately nitrogen-heterotrophic taxa, needing continuously elevated concentrations of organically bound nitrogen (4)	0	9.90%	0	0	2.70%
Oxygen requirements					
continuously high (about 100% saturation) (1)	19.10%	**43.50%**	**50%**	**46.20%**	**38.40%**
fairly high (above 75% saturation) (2)	**33.30%**	26.10%	22.20%	23.10%	30.80%
moderate (above 50% saturation) (3)	**33.30%**	21.70%	22.20%	25.50%	20.50%
low (above 30% saturation) (4)	14.30%	8.70%	5.60%	5.10%	7.70%
very low (about 10% saturation) (5)	0	0	0	0	2.60%
Saprobity					
oligosaprobous (1)	4.40%	20%	22.20%	36.80%	30.30%
β-mesosaprobous (2)	**56.50%**	**60%**	**50%**	**39.50%**	**46.50%**
α-mesosaprobous (3)	26.10%	12%	16.70%	18.40%	11.60%
α-meso-/polysaprobous (4)	13%	4%	5.60%	5.30%	11.60%
polysaprobous (5)	0	4%	5.50%	0	0
Trophic state					
oligotraphentic (1)	4.60%	4.40%	0	5.30%	4.70%
oligo-mesotraphentic (2)	4.50%	4.40%	17.70%	10.50%	18.60%
mesotraphentic (3)	0	8.70%	17.70%	13.20%	16.30%
meso-eutraphentic (4)	18.20%	13%	**23.50%**	21%	9.30%
eutraphentic (5)	**50%**	**39.10%**	**23.50%**	**28.90%**	**39.50%**
hypereutraphentic (6)	0	4.30%	0	5.30%	0
oligo- to eutraphentic (hypereutraphentic) (7)	22.70%	26.10%	17.60%	15.80%	11.60%
Moisture					
never, or only rarely, occurring outside water bodies (1)	21.70%	7.40%	4.80%	21.10%	25%
mainly occurring in water bodies, sometimes on wet places (2)	21.70%	7.40%	14.30%	**38.90%**	27.30%
mainly occurring in water bodies, also rather regularly on wet and moist places (3)	**52.20%**	**51.90%**	**42.80%**	34.20%	**29.60%**
mainly occurring on wet and moist or temporarily dry places (4)	4.40%	33.30%	38.10%	15.80%	13.60%
nearly exclusively occurring outside water bodies (5)	0	0	0	0	4.50%

According to the number of significant correlations between physicochemical water parameters and particular dominant and subdominant diatoms species, it can be inferred that the most important hydrochemical features are those which were characterized by low variability and concentrations.

Table 2

Correlation relationships between dominant and subdominant species and physicochemical parameters of Piękne Spring waters (n=10, α ≥ 0.05)

Physicochemical parameters	KCLE	AINA	AOVA	EOMI	FPIN	GPAR	HCOS	NPRO	NSEM	PTDU	PLFR	PTLA	PRST
Ca^{2+}	n	n	n	n	n	n	n	-0.87	n	n	n	n	-0.81
Mg^{2+}	n	n	n	n	n	n	n	n	n	n	n	n	n
Na^{+}	n	n	n	n	n	n	n	n	n	n	n	n	n
K^{+}	n	n	n	n	n	n	n	n	n	n	n	n	n
NH_4^{+}	n	n	n	n	n	n	n	n	n	n	n	n	n
Cl^{-}	0.84	n	n	n	n	n	n	n	n	n	n	n	n
HCO_3^{-}	n	n	n	0.99	-0.95	n	n	n	n	-0.94	n	n	n
SO_4^{2-}	n	n	n	n	n	n	n	n	n		n	n	n
NO_3^{-}	n	n	n	n	n	n	n	n	n	-0.81	n	n	n
NO_2^{-}	n	n	n	n	0.81	n	n	n	n	n	n	n	n
PO_4^{3-}	n	n	n	n		n	n	-0.95	n	n	n	-0.86	n
SiO_2	n	n	n	0.91	-0.82	n	n	n	n	-0.94	n	n	n
TDI	n	n	n	0.88	-0.98	0.84	n	n	n	-0.93	n	n	n
Dry Residue	n	n	n	n	n	n	n	n	n	n	n	n	n
Oxidizability	n	n	n	n	n	n	n	n	n	n	n	n	n
Total Hardness	n	n	0.88	n	n	n	0.83	n	n	n	0.93	n	n
Color of water	n	n	n	n	n	n	n	n	0.86	n	n	n	n
Temperature	n	-0.82	n	n	n	n	n	n	n	n	n	n	n
Electroconductivity	n	n	n	n	n	n	n	n	n	n	n	n	n
pH reaction	n	0.94	n	n	n	n	n	n	n	n	n	n	n
Redox	n	n	n	n	n	n	n	n	n	n	n	n	n
O_2 [%]	0.87	n	n	n	n	n	n	n	n	n	n	n	n
O_2 [$mg \cdot L^{-1}$]	n	n	n	n	n	n	n	n	n	n	n	n	n
Carbonate hardness	n	n	n	0.99	-0.95	n	n	n	n	-0.94	n	n	n
Non-carbonate hardness	n	n	n	n	n	n	n	n	-0.94	n	n	n	n

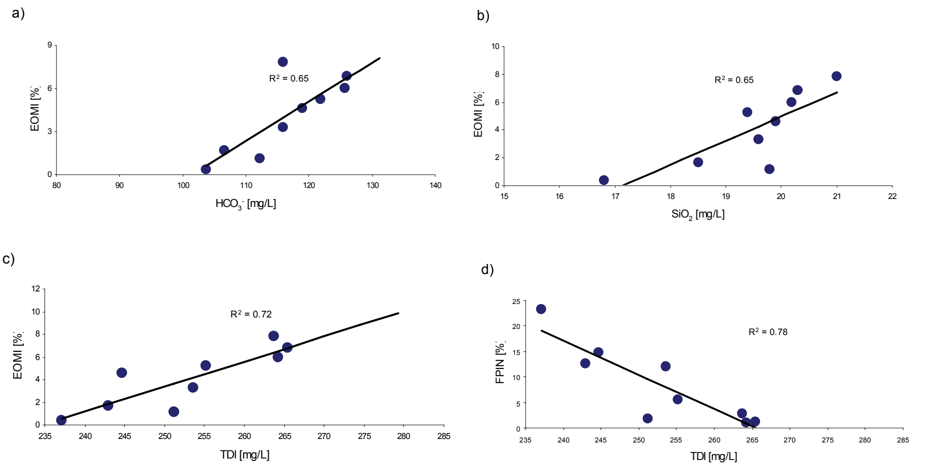

Fig. 3. Relationships between the percentage of diatom community participation and hydrochemical properties of the spring water: a) *Eolimna minima* and HCO_3^-, b) *Eolimna minima* and SiO_2, c) *Eolimna minima* and TDI, d) *Fragilaria pinnata* and TDI.

CONCLUSIONS

The studied diatom community was characterized by exceptional species richness, as exemplified by the high number of taxa identified (225). To date, the highest number of diatom taxa determined in Polish springs was 175 in a limestone spring in the Warta river valley (Żelazna-Wieczorek and Mamińska 2006) and 152 in a karst limnocren spring (Rakowska 1996).

Considerable dynamics in diatom species variety and the share of particular taxa in the composition of the diatom community in particular samples was revealed.

In comparison with other habitats, the low variability in environmental conditions in the studied spring resulted in relatively significant changes in diatom diversity in the spring. Hydrochemical features affect the occurrence of the following dominant and subdominant species (constancy class V): *Planothidium dubium*, *Pl. frequentissimum*, *Pl. lanceolatum*, *Pl. rostratum*, *Eolimna minima*, *Fragilaria pinnata*, *Karayevia clevei, Amphora inariensis*, *Am. ovalis*, *Navicula protracta*, *N. seminulum*, *Hippodonta costulata*, *Gomphonema parvulum*.

The hydrochemical conditions of the water were described based on autecological features of the species determined in the studied spring. These concurred with the results obtained from the hydrochemical analyses of water with regard to pH and salinity. However, oxygen saturation could be assessed only in case of species belonging to constancy class V.

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