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COMPARISON OF DIATOM COMMUNITIES AT THE NATURAL AND ANTHROPOGENIC CHARACTER STATIONS IN THE LITTORAL ZONE OF THE URBAN LAKE JEZIORAK MAŁY

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Abstract

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Net phytoplankton at the natural and anthropogenic character stations in the littoral zone of the urban lake Jeziorak Mały (Mazurian Lakeland) were studied between April and October of 2002 and 2003. The relationships between selected physicochemical water parameters and numbers of diatoms, coefficients of similarity, dominant taxa and species diversity were analyzed. The anthropogenic stations, separators (A) and the stations with stony-gravel substrates (B), had higher trophy than the natural stations overgrown by vascular plants (C). At stations A and B, the high orthophosphate, silicon and calcium concentrations favoured an increase in the abundance, biomass and species diversity of the diatoms. However at stations C, the high water temperature and low oxygen content could limit the development of diatoms. The largest differentiation (the lowest coefficient of similarity) of their species composition recorded between the stations A and B, which result in the plant periphyton might influence the diatom community.

Key words: differentiation of stations, diatoms, physiochemical water parameters

Introduction

The littoral zones of lakes have wide structural variety with various dynamics of ecological processes and are particularly sensitive to changes in environmental conditions and anthropogenic pressures (Radwan et al., 1998). They can also influence the trophic state of a lake. According to Burchardt (1998), maximal primary productivity in eutrophic water bodies occurs in the littoral zone, which also functions as a biofilter, collecting both water and organisms flowing down from the catchment. Hillbricht-Ilkowska, Pieczyńska (1993) also point out that the littoral zone is an effective filter of pollutants inflowing from the catchment. The effectiveness of stopping invading organisms depends on the diversity of the inhabiting biota, including phytoplankton communities. For this reason, diversity is critical in strongly eutrophicated lakes, which permits the utilization of biogenes by a larger number of species. The differentiation of the littoral zone in time and space, i.e. the number of accessible habitats per surface unit is of great importance for the maintenance of species diversity (Reynolds, 1988; Krebs, 1996).

In the littoral zone, the great majority of phytoplankton are diatoms. As a result of the definable requirements of diatoms, they are often used as indicators of water quality e. g. pollution, salinity levels etc (Kawecka, Eloranta, 1994). Availability of silicon is particularly relevant for diatoms and, in freshwater, can only be absorbed in significant quantities at a high Si:P ratio (Lampert, Sommer, 1996).

The urban lake Jeziorak Mały is an example of a highly eutrophic water body, where the littoral zone is diverse and apart from blue-green algae (Zębek, 2005a, b), the great majority of phytoplankton are diatoms (Zębek, 2007). The aim of the present study was to determine differentiation of diatom communities with relation to physiochemical water parameters at the natural and anthropogenic character stations in the littoral zone of the urban lake Jeziorak Mały, and was conducted during 2002 and 2003.

Research area, material and methods

The urban lake Jeziorak Mały covers a total area of 26 ha (maximum depth 6.4 m; mean depth 3.4 m). For many decades the lake received untreated municipal sewage from the town of Iława. Since 1991, however, effluent has been treated at a local wastewater treatment plant. Work to improve the lake water quality began in 1997 and has been ongoing since that time, including the installation of separators for the pretreatment of storm water influent, and a fountain-based water aeration system.

Samples were collected monthly from April to October 2002 and 2003, at six sites located in the littoral zone of lake Jeziorak Mały. The littoral zone is diverse, with some anthropogenic influences. Sample sites were in three groups:

A. separators – two sites situated at pipe outlets, which drain storm water;
B. stations with stony-gravel substrates – two sites with stones and rubble constructed in 1997;
C. stations overgrown by vascular plants (*Thypetum*, *Phragmitetum*, *Acoretum)* – two sites with no anthropogenic transformation, which have muddy bottoms covered with rotting plant remnants.

The samples were collected with a 10 l calibrated bucket (20l at each site), filtered through a no. 30 plankton net, and preserved in Lugol's solution followed by a 4% formaldehyde solution. A total of 62 samples were collected. The following physicochemical water parameters were determined: temperature (°C), oxygen content (mg O_2 l^{-1}) (using an HI 9143 oxygen meter), electrolytic conductivity (μS cm^{-1}) (using a CONMET 1 conductometer), and orthophosphate (mg PO_4 l^{-1}), silicon (mg Si l^{-1}) and calcium (mg Ca l^{-1}) concentrations (using a NOVA 400 spectrophotometer).

Diatom samples were prepared following standard procedures, as described by Battarbee (1979). The diatoms were mounted onto slides using Naphrax. Qualitative and quantitative determinations of diatoms were performed with an Eclipse 800 optical microscope at 20x, 40x, 60x and 100x magnifications, under oil immersion. Diatom identification was aided by the following works of Krammer, Lange-Bertalot (1986, 1988, 1991a, b). The specimens were counted in a 1 ml plankton chamber. Diatom biomass was calculated for biovolume by comparing algae to their geometrical shapes (Rott, 1981). Abundance and biomass of diatoms were given per 1l.

To verify the representativeness of the experimental materials collected, the following characteristics of the sets examined were calculated: standard deviation, coefficient of variation, median, modal value and coefficient of asymmetry representing distribution skewness. The Pearson correlation coefficient was applied in order to determine the statistical significance of relationships between physiochemical water parameters and the numbers of diatoms. These relationships are presented in the form of straight line regression equations (Guilford, 1964). Calculations to statistical analysis be leanings on individual observations (N = 62). In the analysis, means were applied that represented the sum of the numbers of individuals or biomass at the particular stations (A, B and C) in the littoral zone divided by the number of measurements. Shannon-Weaver species diversity index for the diatoms and Jaccard similarity coefficient between the species composition of diatoms at the stations A, B and C were analyzed (Shannon, Weaver 1949; Jaccard, 1912). The similarity between the species composition of diatoms shows also the dendrogram of Euclidean distances (STATISTICA version 8).

Results

General characteristics of the diatom communities

In the 2002–2003 period in the littoral zone of lake Jeziorak Mały, the mean abundance of diatoms was reached 3655 indiv. l^{-1} and the mean biomass was 74.10 x 10^{-4} mg l^{-1} at mean water temperature of 18.5 °C, oxygen content of 7.83 mg O_2 l^{-1}, electrolytic conductivity of 386 μS cm^{-1}, orthophosphates of 0.48 mg PO_4 l^{-1}, calcium of 101 mg Ca $l^{-1}$and silicon of 0.83 mg Si l^{-1} (Table 1). The standard deviations were lower than the arithmetic means for the abundance and biomass of diatoms, water temperature, oxygen content, electrolytic conductivity, calcium and silicon concentrations and higher – for orthophosphates. The

T a b l e 1. Characteristics of datasets in terms of representativeness of the experimental material collected in lake Jeziorak Mały in the years 2002 and 2003 (N = 62).

Variable	Mean (X)	Standard deviation (ð)	Coefficient of variation (V) %	Median (Me)	Modal value (Mo)	Coefficient of asymmetry (As)
abundance of diatoms (indiv. l^{-1})	3655	3636	99.48	2121	-	+
biomass of diatoms ($x10^{-4}$mg l^{-1})	74.10	71.83	96.94	47.75	-	+
water temperature (°C)	18.5	4.1	22.16	19.05	20.7	-0.54
oxygen content (mg O_2 l^{-1})	7.83	4.37	55.81	7.08	8.01	-0.04
electrolytic conductivity (μS cm^{-1})	386	172	44.56	345	330	+0.32
orthophosphates (mg PO_4 l^{-1})	0.48	0.81	168.75	0.26	0.23	+0.31
calcium (mg Ca l^{-1})	101	86	85.15	71	160	-0.69
silicon (mg Si l^{-1})	0.83	0.66	79.52	0.63	0.66	+0.26

coefficients of variations for abundance and biomass of diatoms, expressed as a standard deviation to arithmetic mean ratio, were high and ranged from 99.48 to 96.94%. Among physicochemical parameters the high variation was noted for orthophosphate, calcium and silicon concentrations (168.75, 85.15 and 79.52%, respectively), and the low for water temperature (22.16%). In the absence of recurring numbers and biomass of diatoms not specified the modal values. However, in this case, the means were higher than the medians, suggesting that the coefficients of asymmetry were positively. Data distributions, determined by the coefficient of asymmetry, were moderately positively skewed for the abundance of biomass of diatoms, electrolytic conductivity, orthophosphate and silicon concentrations, and moderately negatively skewed for the other variables (water temperature, oxygen content and calcium concentration). Data distributions were close normal only for oxygen content (As = -0.04) (Table 1). Thus, it was assumed that data distributions and variation are close to normal and monomodal (Guilford, 1964).

Relationships between the abundance of diatoms and water physicochemical parameters

According to the objective of the study, the relation between the abundance of diatoms and selected water physicochemical parameters were analyzed. For the purposes of a detailed analysis of these relations, data were grouped according to water temperature ranges (Fig. 1). To this aim, the ranges of water temperature were marked on an axis of ordinates, which was subordinated by using the mean abundance of diatoms. The highest abundance diatoms reached in a temperature range of 15.0 to 17.5 °C. The mean abundance of diatoms in this temperature range was 6975 indiv.l^{-1} at water temperature of 16.5 °C – the value was accepted as border. Then data of abundance of diatoms and physicochemical water parameters were divided into two groups according to border temperature

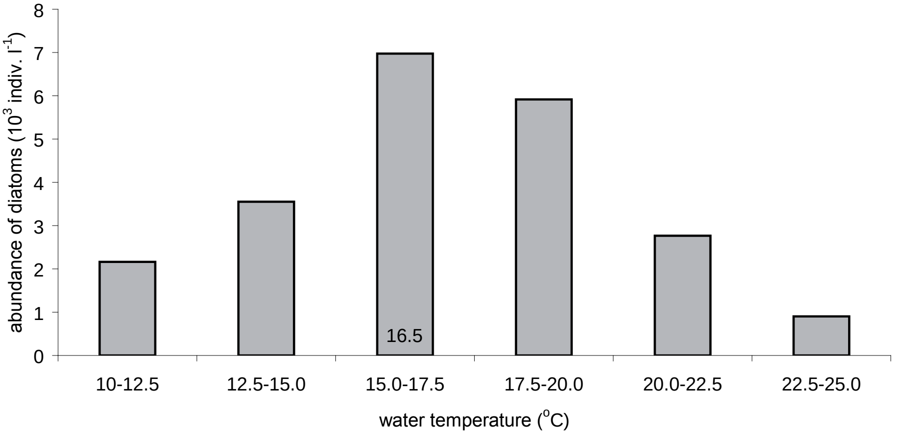

Fig. 1. Mean abundance of diatoms in various water temperature ranges in the littoral zone of lake Jeziorak Mały (means of the years 2002 and 2003).

– from 10.0 to 17.5 °C and from 17.6 to 25.0 °C (Fig. 1). On this basis, two data samples were collected and the Pearson correlation coefficients between the abundance of diatoms and water temperature, oxygen content, electrolytic conductivity, orthophosphate, calcium and silicon concentrations were calculated. In the temperature ranges which followed an increase in the abundance of diatoms (from 10.0 to 17.5 °C) in comparison from second range of water temperature, the coefficients of correlation were higher and statistically significant between water temperature, calcium and silicon concentrations and the abundance of diatoms (r = 0.6884, r = -0.4142 and r = -0.3981, respectively) (Table. 2). In the water temperature range, the equations of line regression, suggest that an increase in water temperature by 1 °C as followed by an increase in the abundance of diatoms by 1154 indiv. l^{-1}. However, a decrease in calcium concentration by 1mg Ca l^{-1} was accompanied by

T a b l e 2. Pearson correlation coefficients (r) between physiochemical water parameters and the abundance of diatoms, calculated in two water temperature ranges in the littoral zone of lake Jeziorak Mały in 2002 and 2003.

	10.0–17.5 °C N = 25	17.6 – 25.0 °C N = 37
water temperature (°C)	0.6884*	-0.4345
oxygen content (mg O_2 l^{-1})	0.1943	-0.0133
electrolytic conductivity (µS cm^{-1})	-0.0899	0.0665
orthophosphates (mg PO_4 l^{-1})	-0.3028	0.2354
calcium (mg Ca l^{-1})	-0.4142*	0.0530
silicon (mg Si l^{-1})	-0.3981*	0.0845
* - statistically significant correlation coefficients		

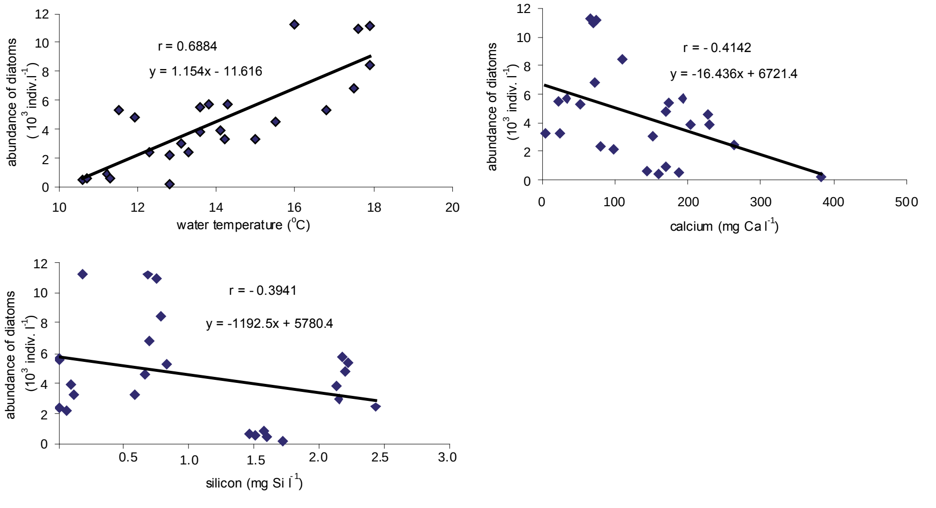

Fig. 2. Relationships between water physiochemical parameters and the abundance of diatoms in a water temperature range of 10.0 to 17.5 °C in the littoral zone of lake Jeziorak Mały in the years 2002 and 2003.

an increase in the abundance by 16 indiv. l^{-1} and a decrease in silicon concentration by 1 mg Si l^{-1} was accompanied by an increase in the abundance by 1192 indiv. l^{-1} (Fig. 2).

Comparison of diatom communities and physicochemical water parameters at the natural and anthropogenic character stations in the littoral zone

In lake Jeziorak Mały in the years 2002 and 2003, the proportion of diatoms in the total abundance of phytoplankton was from 16.12% at the stations with stony-gravel substrates (B) to 19.65% at the stations with separators (A), and in the total biomass from 8.09% (A) to 11.39% (B). The highest mean abundance of diatoms (3958 indiv. l^{-1}) was noted at the highest oxygen content (8.01 mg O_2 l^{-1}), electrolytic conductivity (412 µS cm^{-1}), calcium and silicon concentrations (115 mg Ca l^{-1} and 0.83 mg Si l^{-1}, respectively) at the stations A. The lowest mean abundance of diatoms (3484 indiv. l^{-1}) was recorded at the highest mean water temperature (19.4 °C) at the natural stations overgrown by vascular plants (C). However, the highest mean biomass of diatoms (76.30 x 10^{-4} mg l^{-1}) was recorded at the highest orthophosphate concentration (0.59 mg PO_4 l^{-1}) at stations B and the lowest mean biomass (68.79 x 10^{-4} mg l^{-1}) at stations C (Table 3).

Table 3. Mean abundance and biomass of diatoms and physiochemical water parameters at the particular stations in the littoral zone of lake Jeziorak Mały (means of the years 2002 and 2003).

Variable	Stations A	Stations B	Stations C
abundance of diatoms (indiv. l^{-1})	3958	3557	3484
proportion of diatoms in the total abundance of phytoplankton (%)	19.65	16.12	16.63
biomass of diatoms (10^{-4} mg l^{-1})	75.88	76.30	68.79
proportion of diatoms in the total biomass of phytoplankton (%)	8.09	11.39	8.63
water temperature (°C)	18.0	17.9	19.4
oxygen content (mg O_2 l^{-1})	8.01	7.55	7.66
electrolytic conductivity (µS cm^{-1})	0.412	388	333
orthophosphates (mg PO_4 l^{-1})	115	0.59	0.34
calcium (mg Ca l^{-1})	0.83	91	80
silicon (mg Si l^{-1})	18.0	0.82	0.71

Notes: stations A – separators; stations B – with stony-gravel substrates; stations C – natural overgrown by vascular plants.

In lake Jeziorak Mały, the species diversity from the diatom community at the particular stations in the littoral zone was analyzed to calculate the Shannon-Weaver index. The highest index (3.851 bit $indiv.^{-1}$) was noted at the lowest number of taxa (45) at stations B, and the lowest diversity index (3.577 bit $indiv.^{-1}$) at the taxa number of 48 at stations C (Table 4). The highest Jaccard similarity coefficient of the diatom species composition at the particular stations was noted between stations A and C (81%), and the lowest one between stations A and B – 69% (Table 5).

T a b l e 4. Shannon-Weaver species diversity indices for diatoms at the stations in the littoral zone of lake Jeziorak Mały (means of the years 2002 and 2003).

	Stations A	Stations B	Stations C
species diversity index (bit indiv^{-1})	3.629	3.851	3.577
number of taxa	48	45	48

Notes: stations A – separators; stations B – with stony-gravel substrates; stations C – natural overgrown by vascular plants.

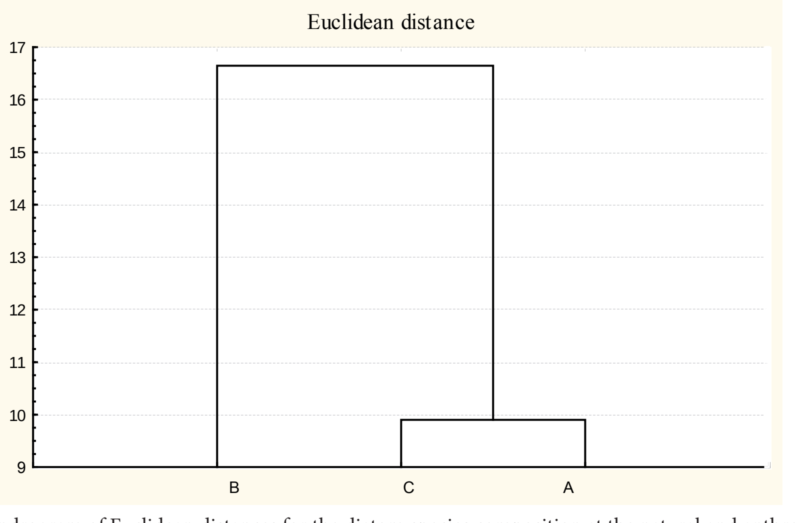

Fig. 3. Dendrogram of Euclidean distances for the diatom species composition at the natural and anthropogenic character stations in the littoral zone of the lake Jeziorak Mały in the years 2002 and 2003.

T a b l e 5. Jaccard similarity coefficients of the diatom species composition between the particular stations in the litoral zone of the lake Jeziorak Mały (means of the years 2002 and 2003).

	Stations B	Stations C
stations A	0.69	0.81
stations B		0.75

Notes: stations A – separators; stations B – with stony-gravel substrates; stations C – natural overgrown by vascular plants.

A confirmation of this fact is the dendrogram of similarity, which shows the smallest Euclidean distance between stations A and C, and largest – between stations A and B (Fig. 3).

In the littoral zone in lake Jeziorak Mały, in the domination of *Fragilaria delicatissima* (W. Smith) Lange-Bertalot in total abundance of diatoms at all stations was noted. The proportion of this species in the total abundance of diatoms ranged from 21.59% at the stations with stony-gravel substrates (B) to 34.52% at the stations overgrown by vascular plants (C). Accompanying species included *Stephanodiscus hantzchii* Grunow (Cleve & Grunow) at the stations with separators (A), *Fragilaria capucina* Desmazieres at stations B and *Fragilaria crotonensis* Kitton at stations C. In the case of biomass, the genus *Rhizosolenia* Ehrenberg sp. dominated at stations A and C (33.87 and 35.40% of the total biomass of diatoms, respectively), and *Melosira varians* Agardh at stations B (21.59% of the total biomass of diatoms). Accompanying taxa included *Fragilaria delicatissima* at stations A and C and *Rhizosolenia* sp. at stations B (Table 6).

Table 6. Dominant diatom taxa in the abundance and biomass at the particular stations in the littoral zone of lake Jeziorak Mały (means of the years 2002 and 2003).

Variable	Stations A	Stations B	Stations C
abundance	*F. delicatissima* 31.46% *S. hantzchii* 9.09%	*F. delicatissima* 21.59% *F. capucina* 16.03%	*F. delicatissima* 34.52% *F. crotonensis* 12.28%
biomass	*Rhizosolenia* sp. 33.87% *F. delicatissima* 10.19%	*M. arians* 21.59% *Rhizosolenia* sp. 20.19%	*Rhizosolenia* sp. 35.40% *F. delicatissima* 11.29%

Notes: stations A – separators; stations B – with stony-gravel substrates; stations C – natural overgrown by vascular plants.

Discussion

In urban lakes, such as Jeziorak Mały, the littoral zone is an effective filter of pollutants inflowing from the catchment. According to Guzkowska, Gasse (1990a) urban catchments differ from vegetated catchments in that a large proportion of urban surfaces are impermeable. Consequently, most of the rainfall falling on an urban area reaches surface water bodies in the form of overland flow whereas in vegetated catchments interception of the rainfall results in a slow percolation into water courses. Percolation under natural conditions results in a steady but relatively low concentration of nutrients being discharged into receiving waterbodies over time. Runoff entering surface waterbodies from impermeable surfaces, on the other hand, contains high concentrations of nutrients which are washed into the drainage system within a few hours of a storm (Guzkowska, Gasse, 1990a). The littoral zones of such lakes can be transformed anthropogenically, which results in new habitats being created for animals and plants, including algae (with a large group of diatoms both quantitatively and qualitatively).

The development of diatoms in shallow eutrophic lakes, e.g. lake Jeziorak Mały, may be affected by a variety of factors, including water temperature, oxygen content, electrolytic conductivity, phosphorus, calcium and silicon concentrations (Reynolds, 1984; Guzkowska, Gassse, 1990a; Krebs, 1996). In lake Jeziorak Mały, the relationships between the abundance of diatoms and selected water physicochemical parameters were observed. During growth of the diatoms in water with a temperature range of 10.0 to 17.5 °C, the coefficients of correlation were negative and statistically significant between their abundance and silicon and calcium concentrations (Table 2, Fig. 2). Laugaste et al. (1996) reported a relationship between diatom biomass and silicon concentration at a water temperature of 10°C. According to Dokulil, Padisak (1994), a statistically significant relationship was observed between the total abundance of phytoplankton and water phosphorus concentration ($r^2 = 0.70$) in spring, when the phytoplankton was dominated by diatoms. Further, Huszar, Caracao (1998) recorded a statistically significant correlation between diatom biomass and water temperature ($r = -0.30$); and between diatom biomass and phosphorus content ($r = 0.20$). This may suggest that the in lake Jeziorak Mały, the diatoms could contribute to reducing calcium and silicon concentrations in water. Water temperature may be the factor determining the quantity and rate of taking these biogenic elements by diatoms. In this case was from 10.0 to 17.5 °C. However, in a temperature range of 17.6 to 25.0 °C, decreased the abundance of diatoms and the phytoplankton was dominated by blue-greens, which can compete for resources of phosphorus with other algae (Zębek, 2005a, b).

In lake Jeziorak Mały, the proportion of diatoms in the total abundance of phytoplankton was from 16.12% at the stations with stony-gravel substrates (B) to 19.65% at the stations with separators (A) and from 8.09% (A) to 11.39% (B) of the total biomass of phytoplankton (Table 3). Rengefors et al. (2003) reported a lower proportion of diatoms in the total biomass of phytoplankton of 3 to 9% in a mesotrophic lake. However, Romo, Miracle (1994) noted a higher proportion of diatoms (35% in the total biomass of phytoplankton and 40% in the total abundance of phytoplankton) in a shallow eutrophic lake. The results of this study, and data from literature, indicate that the proportion of diatoms in the total abundance and biomass of phytoplankton in lake Jeziorak Mały were somewhat lower than that noted in eutrophic lakes. This situation could have been caused by a great abundance of blue-green algae (up to 90% of the total abundance of phytoplankton) (Zębek, 2005a, b), which could indicate a polytrophic lake. The diatoms reached a highest abundance, but lower biomasses, at stations A compared to stations B. This situation could have been caused by a larger abundance of diatom species of small biomass of an individual (e.g. *Fragilaria leptostauron var. martyi* (Heribaud) Lange-Bertalot, *Navicula capitata* Ehrenberg, *Stephanodiscus hantzschii* Grunow (Cleve & Grunow) in comparison to the remaining stations.

According to Guzkowska, Gasse (1990b), water from the catchment flows through the separators could influence the trophy state of urban lakes. The storm waters often are dirtied and can change the chemical composition of the water. Gervais et al. (1999) reported electrolytic conductivity of 490−590 μS cm^{-1} and calcium concentrations of 65−119 mg Ca l^{-1} in a shallow eutrophic lake. However, in an urban lake electrolytic conductivity of 660 to 890 μS cm^{-1}, calcium concentration levels of 109 to180 mg Ca l^{-1}, orthophosphate concentration of 0.08 mg PO_4 l^{-1} and silicon content of 13.4 mg Si l^{-1} have been reported (Guzkowska, Gasse, 1990b). In lake Jeziorak Mały, these water physicochemical parameters were different at the particular stations (Table 3) and better conditions for the development of diatoms (the highest oxygen content, electrolytic conductivity, calcium and silicon concentrations) were at the anthropogenic stations (A and B) than the natural stations (C), which was confirmed by the high mean abundance and biomass of diatoms. However, the high water temperature and low oxygen content could have limited the development of diatoms at the stations overgrown by vascular plants (C).

An indicator of characteristic of phytoplankton communities, including diatoms, in lakes may be species diversity, i.e. relative abundance of particular species (Kawecka, Eloranta, 1994). In lake Jeziorak Mały, the highest Shannon-Weaver index for diatoms was noted at the stations with stony-gravel substrates (B) and the lowest index at the stations overgrown by vascular plants (C) at the number of taxa of 45 and 48, respectively (Table 4). Heinonen (1980) reported Shannon-Weaver index calculations for phytoplankton that ranged from 3.46 to 3.60 bit $indiv.^{-1}$ for 94 species in a eutrophic lake; however, in a hypertrophic lake this figure was 3.03 bit $indiv.^{-1}$ for 92 species. Eloranta (1986) also recorded an index level of 2.76 bit $indiv.^{-1}$ in a eutrophic lake. This may suggest that, in lake Jeziorak Mały, environmental conditions at the anthropogenic stations (A and B), with high calcium, silicon and orthophosphate concentrations are more favourable for an increase in the species diversity of diatoms than at the natural stations (C).

In lake Jeziorak Mały, dominant diatom taxa (*Fragilaria delicatissima*, *Stephanodiscu hantzschii, Fragilaria capucina, Rhizosolenia* sp. and *Melosira varians*) (Table 5) were typical of variety trophy of water (Van Dam et al., 1994) and preferred other environmental conditions (Zębek, 2007). Van Dam et al. (1994) classified *Fragilaria delicatissima* and *F. capucina* as mesotrophic species. Poulickova et al. (2004) recorded domination of *F. delicatissima* in the littoral zone of a mesotrophic lake. Reynolds (1984) classified *Stephanodiscus* sp. as eutrophic and hypertrophic genus and Van Dam et al. (1994) *S. hantzschii* as hypertrophic species. Guzkowska, Gasse (1990b) reported *S. hantzschii* in the group of diatoms which are typical of nutrient-rich waters. Padisak et al. (2003) noted the presence of this species at the level of 7% and was a species accompanying others in a small eutrophic lake. A great abundance of *Rhizosolenia* sp. has been recorded in a variety of water bodies, both oligotrophic and eutrophic. Van Dam et al. (1994) classified this genus as mesotrophic, and Reynolds (1984) and Burns et al. (1997) as oligotrophic. High biomass of *Rhizosolenia* sp. has been reported in a small mesotrophic lake (Danilov, Ekelund, 2001). Van Dam et al. (1994) classified *Melosira varians* as eutrophic species. Celekli, Kulkoyluoglu (2006) reported domination of the species in the littoral zone of eutrophic lake and Guzkowska, Gasse (1990a) as a species accompanying others diatoms at the high phosphorus concentration. Both the results of this study and data from literature indicate that in lake Jeziorak Mały in the years 2002 and 2003, both dominant and accompanying species were typical of eutrophic water, from less fertile (*Fragilaria delicatissima*, *Rhizosolenia* sp.) to nutrient-rich waters (*Stephanodiscus hantzschii*). In the case of an abundance of diatoms, the dominant species did not differ in the particular stations in the littoral zone. Among the accompanying species, a high proportion of *S. hantzschii* was recorded (which prefer nutrient-rich waters) at the stations with separators. This situation could have been caused by water from the catchment flowing through the separators, especially after torrential rains, which could contain nutrients. In the case of biomass, at the stations with stony-gravel substrates, the domination of *Melosira varians* was noted which prefer more nutrient-rich waters than the genus *Rhizosolenia* sp. High orthophosphate concentrations at these stations could favour the development of this species.

The similarity coefficients enabled the comparison of features of diatom communities between the natural and anthropogenic character stations in the littoral zone of the lake Jeziorak Mały. The largest similarity of the diatom species composition was noted between stations A (separators) and C (natural overgrown by vascular plants) and the smallest similarity between stations A and B (with stony-gravel substrates) (Table 5, Fig. 3), which could results the differentiation between the dominant diatom taxa, especially at stations B. At these stations dominated species *Fragilaria capucina* and *Melosira varians,* which has been reported as a component of plant periphyton (Kuczyńska-Kippen et al., 2004). This may suggest that the plant periphyton might influence the differentiation of diatom species composition at these stations (Zębek, 2009), it also illuminated the Euclidean distances (Fig. 3) especially as applied to stations A.

Conclusion

The littoral zones of shallow lakes with small surfaces and classified as polytrophic, are usually overgrown by macrophytes (reeds, sweet flag, bulrush). However, the littoral zone of lake Jeziorak Mały was anthropogenically transformed with the installation of separators and the piling up of stones and gravel. Such construction caused a change in the environmental conditions, confirming that are indeed differences in physiochemical water parameters. The variation of these conditions favoured an increase in the abundance and biomass of diatoms; appearance of the diatom taxa which prefer both poor (*Rhizosolenia* sp., *Fragilaria delicatissima*) and nutrient-rich waters *(Stephanodiscus hantzschii*, *Melosira varians*); and an increase in the species diversity. However, the piling up of stones increased quantity of habitats for plant periphyton, which could influence the differentiation of diatom species composition.

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