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PHYCOFLORA IN THE BASIN OF THE ROSNOWSKIE DUŻE LAKE EXPOSED TO ANTHROPOPRESSURE

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ABSTRACT. The studies include a qualitative and quantitative analysis of phytoplankton of the littoral and pelagial zones of the Rosnowskie Duże Lake basin which is exposed to an intensive anthropopressure. On the basis of phycological and physico-chemical water analyses it was found that the studied reservoir undergoes a progressing eutrophication process caused by an increased concentration of nutrients run-off from the catchment area.

Key words: phytoplankton, anthropopressure, eutrophication, littoral, pelagial, green algae

Introduction

The Rosnowskie Duże Lake localized in the north-western part of the Wielkopolski National Park is a non-flowable reservoir of post-glacial origin. Because of the overgrowing process by rush vegetation, the reservoir has been naturally divided into four basins separated by narrow passages.

One of the lake basins lying directly at the motorway Poznań-Wrocław with numerous houses in the Rosnówko village is particularly exposed to anthropopressure. The aquen is subject to distinct effects of living and economic conditions generating water pollutions due to an excessive amount of nutrients running off from the catchment area (**Dąmbska** et **al.** 1981, **Labijak** 1990, **Pańczakowa** 1990, **Siepak** et **al.** 1999). Sewage from the homesteads run off directly into the lake. An additional source of nutrients flowing into the lake are agricultural fields covering 78.5% of the catchment area.

Earlier phycological studies referring to the Rosnowskie Duże Lake were carried out only in the pelagial zone (**Juskowiak** 1978, **Organiściak** 1978, **Dąmbska** et **al.** 1981, **Koczorowska** and **Wetula** 1984, **Abulgasem** 1999, **Alsambany** 1999).

The objective of this study was the investigation of species composition, number of phytoplankton individuals and their biomass in the Rosnowskie Duże Lake basin ex-

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posed to anthropopressure, as well as to make an assassment of the factual ecological condition of that aquen.

Material and methods

The Rosnowskie Duże Lake is a narrow elongated reservoir covering an area of 34.2 ha and its mean depth is 3.9 m (**Szyper** et **al.** 2001) (Fig. 1). Phycological and physico-chemical studies of water carried out in the period 1974-1982 and in the years 1996 and 1997 permitted to qualify the lake to the eutrophic type (**Dąmbska** et **al.** 1981, **Koczorowska** and **Wetula** 1984, **Pańczakowa** and **Szyszka** 1986, **Siepak** 1998, **Pełechaty** et **al.** 2002).

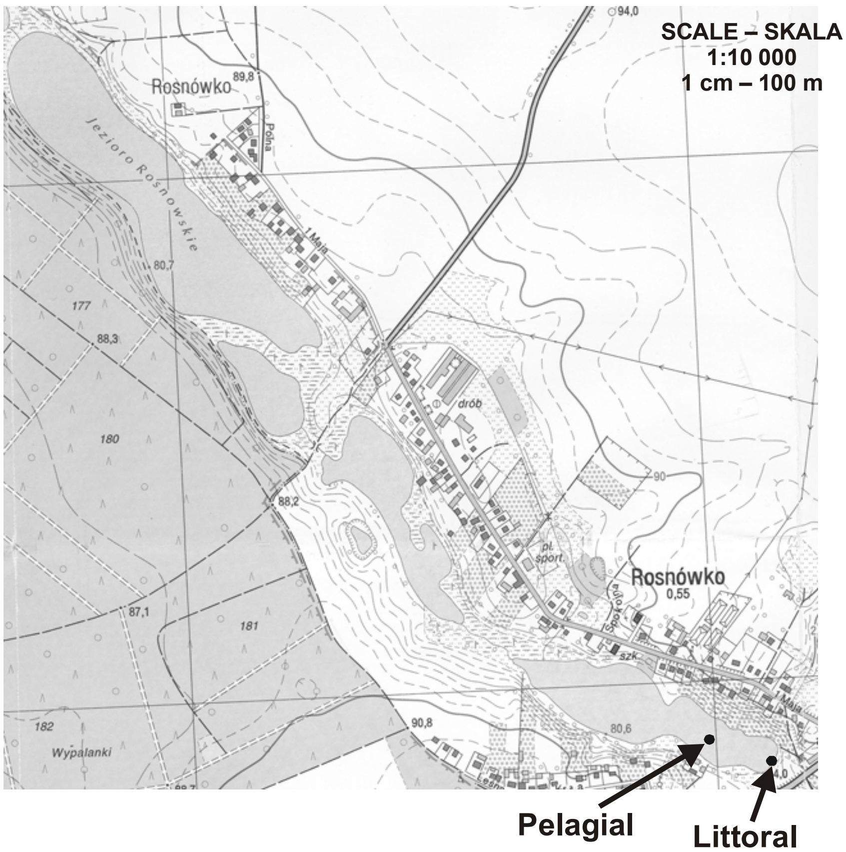

Fig. 1. Location of the studied basin of the Rosnowskie Duże Lake
Ryc. 1. Lokalizacja badanego basenu Jeziora Rosnowskiego Dużego

The area of the studied basin covers 4.4 ha and its maximum depth is 7.8 m. Floristically, the reservoir is the poorest one among the basins of that lake. It was found that it contained only an aggregation with the participation of *Phragmites australis* (Cav.) Trin. ex Steud. and *Typha angustifolia* L. Nymphaeids and elodeids did not develop there at all. Because of thermal water layers, this aquen is defined as an dimictic one (**Kraska** 1993) with a spring and autumn water circulation and summer and winter stagnation of water.

Phycological and physico-chemical analyses of water in the particular lake localities were carried out in the years 2002 and 2003 in the vegetation period of hydromacrophytes. Because of the degree of water vegetation habit development, the obtained data were divided according to the seasons of the year:

– spring – April, May, beginning of June (initial stage of plant development),

– summer – end of June, July, August, beginning of September (optimum development of plants).

In spring, samples were taken for analyses every two weeks, while in summer, sampling was done once a month.

Sampling localities were situated in the littoral zone (locality with narrow-leaved cattail, *Typha angustifolia* L.) and in the pelagial zone of the studied reservoir (Fig. 1).

In the sampling sites, each time the following measurements were carried out: water surface temperature, pH, electrolytic conductivity and the visibility of Secchi disk (in the pelagial zone).

During the whole research period, samples were taken from the surface water layer using a 5 litre bathometer (in the pelagial zone) or 1 litre plastic bottle (in littoral zone). Directly after sampling from the lake, water samples for phycological analyses were fixed in Lugol liquid (J in KJ) and they were preserved in 4% formalin solution.

Parallelly with plankton samples from the particular localities, water samples were taken for analyses of chlorophyll *a.*

Studies of chlorine concentration in water were carried out four times during the total research period: at the beginning of the vegetation season (in April 2002 and in May 2003) and at the beginning of September in the years 2002 and 2003.

Samples for qualitative and quantative analyses of phytoplankton were subjected to sedimentation in measurement cylinders and they were densified to the volume of 10 ml (from 1 litre volume). Qualitative and quantitative analyses of prokaryotic and eucaryotic algae were made using a luminous microscope. Phytoplankton was counted in 64 fields of Fuchs-Rosenthal chamber (chamber parameters: height – 0.2 mm, area of one field – 0.0625 mm^2) with 200 × magnification. Single cells and algae cenobia were regarded as one individual. In case of trichomes, one segment of 100 μm length was regarded as one individual, and in case of a colony form of blue-green algae (*Microcystis*, *Woronichinia*) – the area of 400 μm^2 was accepted as one individual. The biomass value was obtained by the quantitative method multiplying the number of the particular individuals of the particular taxa by their volume (**Kawecka** and **Eloranta** 1994). Volume of algae cells was calculated by comparing their shapes with the known geometrical bodies. The phytoplankton taxa which made 10% and more of the total number in the given sample were regarded as dominants.

Analysis of chlorophyll *a* concentration was made by acetonic method. In the calculation of chlorophyll *a* concentration, the formulae of **Strickland** and **Parson** (1972) were applied with the consideration of **Lorenzen's** modification (1967).

The trophic state of the lake was determined on the basis of Trophic State Index (TSI) in logarithmic transformation of **Carlson** (1977) calculated for chlorophyll *a* concentration and for the visibility of Secchi disk.

In order to define the taxonomic differentiation of phytoplankton in the particular localities, the species diversity coefficient of Shannon-Wiener (**Krebs** 1996) was applied. To identify the evenness of the particular algae species in the sample, the evenness coefficient (**Krebs** 1996) was used.

Results

In result of a detailed analysis of phycological samples taken from the investigated basin of the Rosnowskie Duże Lake, a total of 120 taxa were identified (Table 1). Green algae constituted the most dominating taxonomic group of phytoplankton (51 species). A significant number was also represented by diatoms (34 taxa) and blue-green algae (15 species). No major differences between the study years were found in the number of taxa in the particular systematic groups of algae (Table 1). In reference to the investigated zones (littoral and pelagial), in the total study period, the qualitative phytoplankton structure showed the domination of green algae. In further sequence, there were diatoms and blue-green algae. The total number of taxa was higher in the summer period in both studied localities in comparison with the spring period.

Table 1

Number of taxa in particular systematic groups
Liczba taksonów z poszczególnych grup systematycznych

Taxonomic group Grupa systematyczna	Number of taxa in 2002 Liczba taksonów w 2002 roku	Number of taxa in 2003 Liczba taksonów w 2003 roku	Number of taxa in all investigated seasons Liczba taksonów w całym okresie badawczym
Chlorophyta (Green algae – Zielenice)	45	46	51
Bacillariophyceae (Diatoms – Okrzemki)	30	25	34
Cyanoprokaryota (Blue-green algae – Sinice)	15	12	15
Euglenophyta (Euglenophytes – Eugleniny)	5	6	7
Cryptophyceae (Cryptomonads – Kryptofity)	4	6	6
Dinophyceae (Dinoflagellates – Bruzdnice)	4	4	5
Chrysophyceae (Chrysophytes – Złotowiciowce)	2	2	2
Total – Suma	105	101	120

On the basis of quantitative analysis, it was found that the total number and the biomass of the phytoplankton were subject to significant temporal oscillations.

In 2002, in early spring, both localities showed the domination of diatoms and chrysophytes (Fig. 2). In the studied lake zones, the culmination of the total number and of the biomass occurred in late spring (on the 10th of June 2002). It was connected with the bloom of blue-green algae *Planktothrix agardhii* (Gom.) Anagn. et Kom. and *Limnothrix redeke*i (Van Goor) Meffert. Significantly higher numbers and biomasses of blue-green algae occurred in the littoral zone (number: 23 946 indiv./ml; biomass: 14.82 mg/l) than in the pelagial zone (number: 8034 indiv./ml; biomass: 7.73 mg/l). After the bloom of blue-green algae in the littoral zone, there followed a sudden drop in the total number and in the biomass of phytoplankton. On the other hand, in pelagial, a high number and biomass was maintained until the end of June (Fig. 2). In summer (on the 8th of August 2002) the smallest total number of phytoplankton was recorded in both sampling localities (130 indiv./ml in littoral and 1352 indiv./ml in pelagial). At the end of the vegetation season (the 9th of September 2002), a significant increase of the total number of algae cells was observed (mainly in pelagial) connected with the increased participation of blue-green algae (Fig. 2). In case of total phytoplankton biomass in the summer season in the littoral zone, no great oscillations were recorded and the values were maintained on a low level for a long time (Fig. 2). Green algae were the dominating group. On the 9th of September 2002, there followed an increase of the value of total biomass in littoral (4.86 ml/l) toghether with a sudden increase of dinoflagellates (2.28 mg/l).

In 2003, the quantitative structure of phytoplankton ranged differently than in the previous year (Fig. 3) In the spring, in littoral, there dominated cryptomonads, while in the pelagial, green algae and cryptomonads were in the majority. The highest total number of algae plankton in pelagial (22 568 indiv./ml) occurred on the 12th of May 2003 and it was associated with a great number of green algae cells (20 956 indiv./ml). In summer, on the 23rd of June 2003, there was the summit of the total number (20 475 indiv./ml) and of the biomass (33.79 mg/l) of phytoplankton in the littoral, and also of the highest biomass values (20.94 mg/l) in pelagial. In both lake zones, the dominating group in that time consisted of green algae. In July, a sudden drop in the total number and in the biomass of the phytoplankton was recorded in the whole lake basin, and an increase was found in the participation of diatoms, dinoflagellates and chrysophytes in comparison with the June period (Fig. 3).

In the analysis of phytoplankton dominants structure, great differences were found between the particular years of studies, as well as between the seasons (in spring and in summer; Table 2). Some distinguished dominating species dominated only in 2002 in both studied localities. They included *Limnothrix redekei* (Van Goor) Meffert, *Planktothrix agardhii* (Gom.) Anagn. et Kom., *Cyclotella distinguenda* Hustedt and *Stephanodiscus parvus* Stoermer et. Hakansson). Some other dominants dominated only in 2003; they included: *Chlamydomonas globosa* Snow, *Scenedesmus ecornis* (Ehrenb.) Chodat, *Tetraedron triangulare* Koršikov, *Chroomonas acuta* Utermöhl and *Cryptomonas erosa* Ehr. From the spacial point of view, the differences in the dominant structure were less distinct. *Achnanthes flexella* (Kűtz.) Grun., *Coelastrum astroideum* De Notaris, *Kirchneriella contorta* (Schmidle) Bohlin, *Stauarastrum pseudotetracerum* (Nord.) W. et G.S. West and *Dinobryon bavaricum* Imhoff dominated only in littoral, while *Crucigenia tetrapedia* (Kirchner) W. et G.S. West, *Tetraedron minimum* (A.. Braun) Hansgirg and *Cyclotella radiosa* (Grun.) Lemm. were dominating exclusively in pelagial.

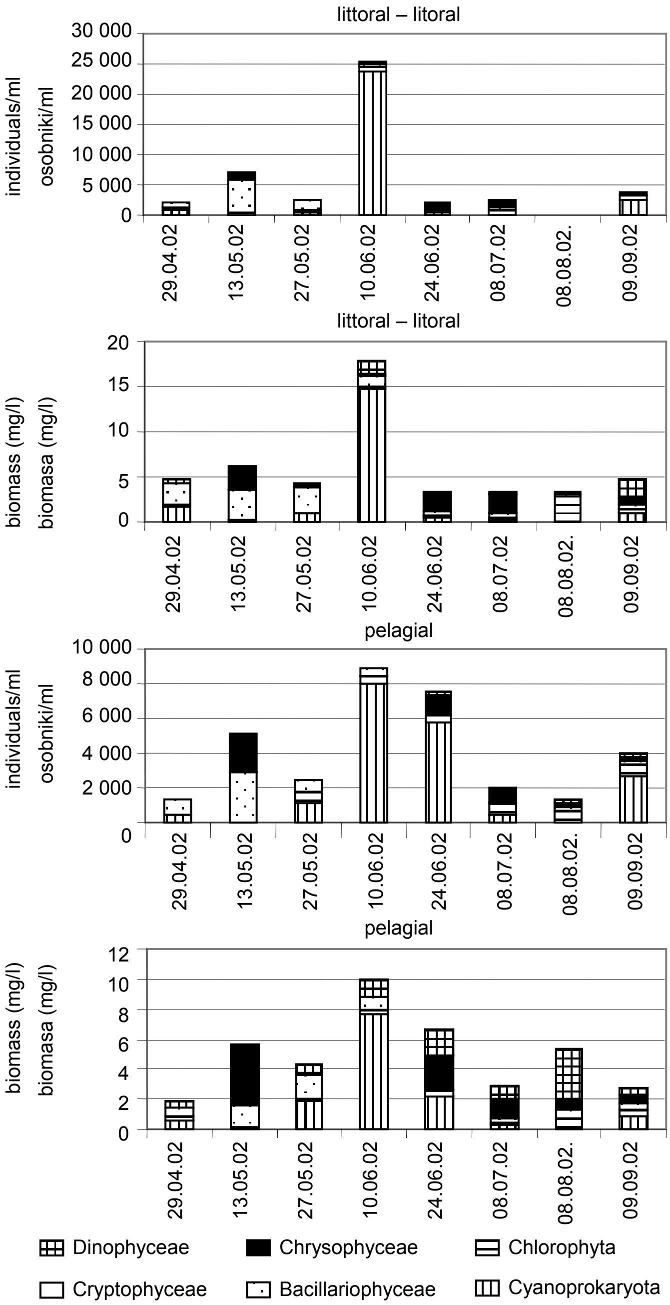

Fig. 2. Number of individuals and biomass of phytoplankton in the littoral and pelagial zones in the studied basin of the Rosnowskie Duże Lake in 2002
Ryc. 2. Liczba osobników i biomasa fitoplanktonu w strefie litoralu i pelagialu badanego basenu Jeziora Rosnowskiego Dużego w 2002 roku

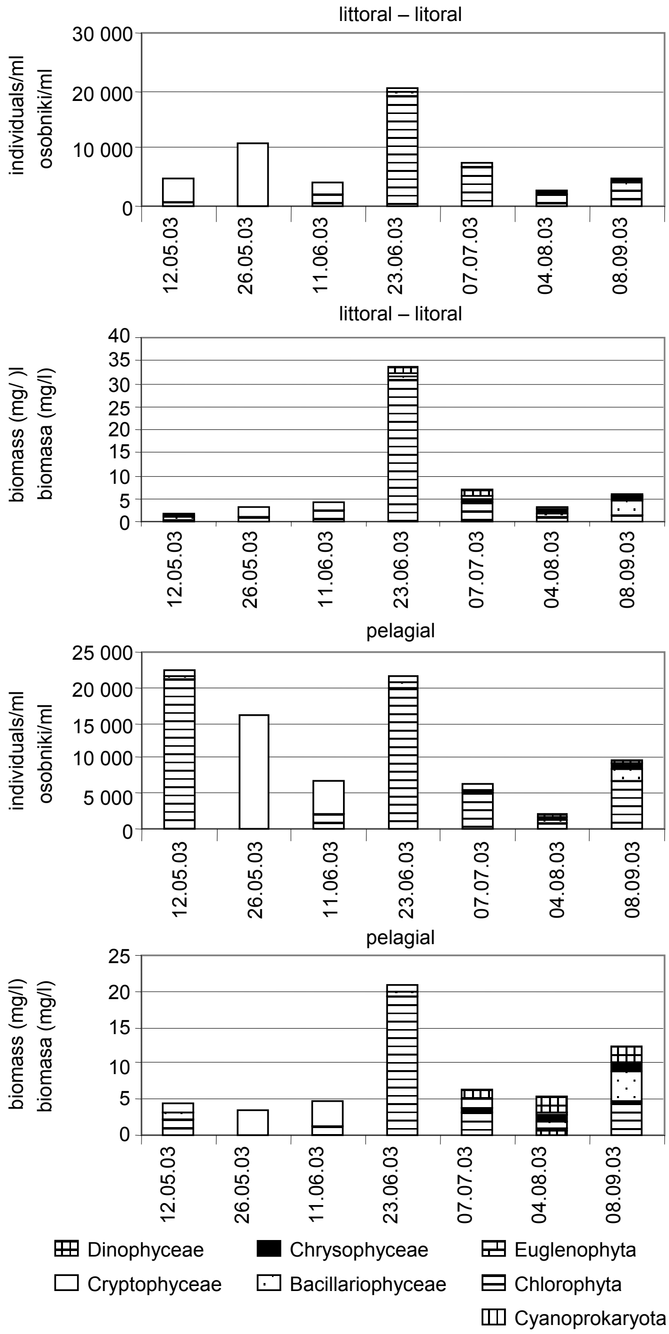

Fig. 3. Number of individuals and biomass of phytoplankton in the littoral and pelagial zones in the studied basin of the Rosnowskie Duże Lake in 2003
Ryc. 3. Liczba osobników i biomasa fitoplanktonu w strefie litoralu i pelagialu badanego basenu Jeziora Rosnowskiego Dużego w 2003 roku

Table 2

The structure of phytoplankton dominants in the particular stations of the Rosnowskie Duże Lake
Struktura dominantów fitoplanktonu na poszczególnych stanowiskach Jeziora Rosnowskiego Dużego

Station Stanowi-sko	2002		2003	
	spring wiosna	summer lato	spring wiosna	summer lato
Littoral Litoral	*Limnothrix redekei* *Planktothrix agardhii* *Achnanthes flexella* *Cyclotella distinguenda* *Fragilaria ulna* var. *acus* *Stephanodiscus parvus* *Dinobryon divergens*	*Limnothrix redekei* *Planktothrix agardhii* *Coelastrum astroideum* *Kirchneriella contorta* *Staurastrum pseudotetracerum* *Achnanthes flexella* *Fragilaria ulna* var. *acus* *Dinobryon divergens*	*Scenedesmus ecornis* *Tetraedron triangulare* *Chroomonas acuta* *Cryptomonas erosa*	*Chlamydomonas globosa* *Kirchneriella contorta* *Scenedesmus ecornis* *Tetraedron triangulare* *Fragilaria ulna* var. *acus* *Dinobryon bavaricum* *Dinobryon divergens*
Pelagial Pelagial	*Limnothrix redekei* *Planktothrix agardhii* *Tetraedron minimum* *Cyclotella distinguenda* *Cyclotella radiosa* *Stephanodiscus parvus* *Dinobryon divergens*	*Limnothrix redekei* *Crucigenia tetrapedia* *Fragilaria ulna* var. *acus* *Dinobryon divergens*	*Chlamydomonas globosa* *Scenedesmus ecornis* *Tetraedron triangulare* *Chroomonas acuta* *Cryptomonas erosa*	*Chlamydomonas globosa* *Scenedesmus ecornis* *Tetraedron triangulare* *Fragilaria ulna* var. *acus* *Dinobryon divergens*

In the study period, the values of Shannon-Wiener coefficient in littoral ranged between 1.49 and 3.37, while in pelagial, they were between 1.38 and 3.37. The evenness coefficient values in littoral oscillated between 0.27 and 0.65, and in pelagial, they were between 0.26 and 0.6.

Calculated trophy index for chlorophyll *a* concentration and for the visibility of Secchi disk showed that the Rosnowskie Duże Lake had a eutrophic character. The highest value of chlorophyll *a* concentration (36 $\mu g/dm^3$) was found in pelagial on the 27th of May 2002.

Water reaction in the lake did not show any distinct spacial or temporal changes. During the total period of studies. the pH vallues oscillated between 7.6 and 8.3.

The values of electrolytic conductivity were subject to high temporal oscillations. The range of changes in this parameter in littoral was 390-841 µs/cm, and in pelagial: 385-332 µs/cm. The highest values in both studied localities occurred on the 26th of May 2003.

Chlorine concentration in water was similar in both locations in the period of studies amounting to 83-103 mg Cl/l in littoral and 93-99 mg Cl/l in pelagial.

Discussion

Phycological studies carried out in the basin of the Rosnowskie Duże Lake showed that the number of phytoplankton taxa was significantly smaller than in the earlier years (**Juskowiak** 1978, **Organiściak** 1978, **Dąmbska** et **al.** 1981, **Koczorowska** and **Wetula** 1984, **Abulgasem** 1999, **Alsambany** 1999). The impoverishment of phycoflora caused by the increase of water eutrophication (**Sayer** and **Roberts** 2001) which was confirmed by physico-chemical analyses (small visibility of Sacchi disk, high concentration of chlorophyll *a*, high values of electrolytic conductivity and high concentration of chlorine). Analyses carried out in the years 2002 and 2003 showed an increase of orthosoluble phosphates, ammonia nitrogen, nitrate nitrogen, ions of potassium, sodium, calcium and chlorine in comparison with the earlier years of studies (**Celewicz**-**Gołdyn** 2005). A high fertility of water was testified also by significant participation of green algae (42.5%) in the qualitative structure of phytoplankton in the vegetation period (**Gajdus** 1998), as well as the high values of the total quantity and biomass of algae. Low values of Shannon-Wiener species diversity and the evenness coefficient in the investigated localities also indicated a high water fertility. **Stoyneva** (1998) reported that in eutrophic waters, species diversity and the values of evenness were comparatively low.

The main reason of a high trophy level in the lake was the high inflow of organic matter from homesteads situated on the lake bank, as well as (although in a smaller degree) the feeding of fish by anglers. Furthermore, a significant thickness of bottom sediments favoured an intensive activation of nutrients from the bottom (**Krogerus** and **Ekholm** 2003, **Selig** 2003). Together with the increased nutrient concentration, the phytoplankton biomass increased as well (**William** and **Moss** 2003) and thereby the chlorophyll *a* content was higher.

In result of eutrophication, there followed a mass development of blue-green algae (*Planktothrix agardhii* (Gom.) Anagn. et Kom. and *Limnothrix redekei* (Van Goor) Meffert) observed on the 10th of June 2002. Such early significant development of blue-green algae was probably caused by a quick warming up of the lake water after the winter period and by a high intensification of nutrients (mainly of ammonia nitrogen). **Rücker** et **al.** (1997) reported that a mass development of *Limnothrix redekei* (Van Goor) Meffert usually occurred in spring and autumn, while that of *Planktothrix agardhii* (Gom.) Anagn. et Kom. – in summer.

An intensive development of *Limnothrix redekei* (Van Goor) Meffert occurred with an increase of temperature (**Rojo** and **Cobelas** 1994). Blue-green algae prefer waters rich in nitrogen compounds (**Sivonen** 1990) and particularly in ammonia nitrogen (**Tõnno** and **Nõges** 2003). Mass development of the above mentioned blue-green algae is characteristic of shallow eutrophic waters (**Briand** et **al.** 2002, **Wiedner** et **al.** 2002, **Pouličkova** et **al.** 2004). Bloom of blue-green algae being a testimony of a high concentration of nutrients in the lake (strong eutrophication of water) is an undesired consequence of anthropopressure (**Nixdorf** 1994, **Hodgkiss** and **Lu** 2004). Optimum conditions for the development of blue-green algae (next to a high nutient content in water and an adequately high temperature) include also water stagnation and weak intensity of solar radiation. In the period of blue-green algae bloom, in the Rosnowskie Duże Lake, there was a high cloudiness and a weak wind. Blue-green algae represent a group which is not very attractive to be consumed by zooplankton (**Schriver** et **al.** 1995, **Janse** et **al.**

1998) and these algae are able to adjust the level of their abiding in water depth (**Hašler** and **Pouličkova** 2003). That is why they frequently form blooms in lakes with a high trophy.

In spring, in both years of studies, a high quantitative participation of algae representing the life strategy of "r" type (small size with a quick growth rate) connected with unstable existence conditions were recorded. These algae included among others diatoms from *Cyclotella* and *Stephanodiscus* genera and cryptophytes (in 2003, they included *Chroomonas acuta* Utermöhl and *Cryptomonas erosa* Ehr.). According to the assumptions of the seasonal succession model PEG for eutrophic lakes (**Temponeras** et **al.** 2000, **Lampert** and **Sommer** 1996), the domination of small cryptomonads and diatoms from Centrales order is a phenomenon characteristic of the spring period. Furthermore, a high participation of diatoms in spring season is connected with the mixing of water (**Lung'ayia** et **al.** 2000, **Hubble** and **Harper** 2002), Diatoms belonging to Centrales order (among others from *Cyclotella* and *Stephanodiscus* genera) have a higher requirement for phosphorus than diatoms from Pennales order (**Bucka** et **al.** 1993). A high concentration of soluble orthophosphates in the Rosnowskie Duże Lake favoured the development of *Cyclotella distinguenda* Hustedt, *Cyclotella radiosa* (Grun.) Lemm. and *Stephanodiscus parvus* Stoermer et Hakansson.

In the summer season, one could expect that in the quantitative structure of plankton, there dominated forms with big cell sizes (representing the "K" type of life strategy) being typical of summer stagnation period (**Kawecka** and **Eloranta** 1994). However, in that time, in the Rosnowskie Lake, one could mainly observe the dominance of small green algae (*Chlamydomonas globosa* Snow, *Crucigenia tetrapedia* (Kirchner) W. et G.S. West., *Kirchneriella contorta* (Schmidle) Bohlin, *Tetraedron triangulare* Koršikov), being characteristic of the initial succession stages. Numerous occurrence of organisms representing the r type of life strategy in the summer period confirms the changing and unstable environmental conditions. A high quantitative participation of dinoflagellate (*Peridinum cinctum* (O.F. Müll.) Ehr. and *Peridinopsis elpatiewskyi* (Ostenfeld) Bourrelly in the period of late summer testified a high content of nutritive components.

Conclusions

Phycological and physico-chemical analyses of water carried out in the basin of the Rosnowskie Duże Lake have confirmed that the studied aquen is subject to a strong anthropopressure.

Observations revealed there a progressing eutrophication process caused by a growing load of nutritive elements running off from homesteads of the Rosnówko village. The results of that unfavourable process include among others the drop of phytoplankton species diversity, a great quantity and biomass of algae and blue-green algae blooms.

It is necessary to continue hydrobiological studies in the Rosnowskie Duże Lake in order to observe the further tendencies of changes taking place in that aquen. In connection with the necessity to protect the reservoir against the progressing eutrophication process involving its shallowing and overgrowing, it is necessary to cut off the inflow of nutrients from the catchment area.

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FYKOFLORA BASENU JEZIORA ROSNOWSKIEGO DUŻEGO PODDANEGO ANTROPOPRESJI

S t r e s z c z e n i e

Badania fykologiczne prowadzono w basenie Jeziora Rosnowskiego Dużego (w Wielkopolskim Parku Narodowym) poddanym dużej presji antropogenicznej, w sezonie wegetacyjnym, w latach 2002 i 2003.

Celem badań było określenie składu gatunkowego, liczebności i biomasy fitoplanktonu w basenie Jeziora Rosnowskiego Dużego oraz próba oceny aktualnego stanu ekologicznego tego akwenu.

Próby do badań fykologicznych i fizyczno-chemicznych pobierano z warstwy powierzchniowej wody, ze strefy litoralu i pelagialu.

Duże wartości koncentracji chlorofilu *a* oraz mała widzialność krążka Secchiego wskazywały na eutrofię zbiornika.

W wyniku przeprowadzonych badań w Jeziorze Rosnowskim Dużym stwierdzono obecność 120 taksonów fitoplanktonu, wśród których dominowały zielenice. Wzrost wartości przewodnictwa elektrolitycznego i stężenia biogenów, spadek różnorodności gatunkowej fitoplanktonu, duża liczebność i biomasa glonów oraz zakwity sinic *Limnothrix redekei* i *Planktothrix agardhii* wskazywały na postępujący proces eutrofizacji jeziora.

Główną przyczyną wysokiego poziomu trofii w jeziorze jest duży dopływ materii organicznej z gospodarstw domowych położonych nad brzegiem jeziora.

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