Metalimnetic bloom of *Planktothrix rubescens* in relation to environmental conditions

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**Key words**: *Planktothrix rubescens*, physical-chemical parameters, PAR, chlorophyll *a*, trophy, Łęczna-Włodawa Lake District

**Abstract**

Studies were carried out in the mesotrophic, dimictic Rogóżno Lake of the Łęczna-Włodawa Lakeland (Eastern Poland). The studies were done bi-weekly from May to the end of August, 2006. The aim of this study was to investigate the variability of the metalimnetic population of the Cyanoprokaryota species *Planktothrix rubescens* (DeCand. ex Gom.) Anagn. et Kom. at two depths (6 m and 7 m), where this species was most numerous.

During the study period, the level of *P. rubescens* in the metalimnion fluctuated within a broad range, with a maximum level of 23.7 ind. 10⁶ dm⁻³ (98% of the total number of phytoplankton). The highest abundance peaks of this species always occurred below the euphotic zone in low light conditions with Kₐ values of approx. 1.2. The chlorophyll *a* concentration in the

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metalimnion ranged from 14.4 to 91.7 μg dm⁻³ and was always higher then in the epilimnion. Oxygen concentration in the water was characteristic for heterograde positive with maximum values at a depth of 6 m and exceeding 22 mg dm⁻³ (220%). In the bloom layer (6 m and 7 m), the temperature ranged between 6.5 and 12°C, pH between 7.9–9.0, while water conductivity was 320–370 μS cm⁻¹. The relatively high concentrations of biogenic compounds, especially P–PO₄ (max. 0.101 mg dm⁻³), TP (max. 0.212 mg dm⁻³), N–NH₄ (max. 0.226 mg dm⁻³), and TN:TP ratio of 15–25:1 (at peaks levels) created optimum conditions for the growth of this species.

**INTRODUCTION**

Temperate zone lakes have specific abiotic environmental conditions during the vegetation period (April–October). The thermal stratification of deep water bodies creates specific conditions for phytoplankton growth. During the lake stratification period, *Planktothrix rubescens* (DeCand. ex Gom.) Anagn. et Kom. is usually located in the metalimnion, where the environmental conditions (such as light intensity, water temperature, nutrient distribution) are not as suitable for species growth as in the epilimnion (Konopka 1980, 1982; Reynolds 1984). However, *P. rubescens* has a high affinity for low light conditions since it contains phycoerythrin, which absorbs green light, but as a consequence it is very sensitive to high light levels (Mur, Schreurs 1995). Moreover, this stratifying species has gas vesicles which allow it to fine-tune its buoyancy (Reynolds et al. 1987; Dokulil, Teubner 2000; Lampert, Sommer 2001). This species is a filamentous blue-green algae resistant to grazing by zooplankton, and which is able to produce toxins (Fastner et al. 1995, Jann-Para et al. 2004).

The aim of this study was to investigate variability in the metalimnetic population of cyanoprokaryota species *Planktothrix rubescens* during the vegetation season of 2006, at two depths (6 m and 7 m), where this species was most numerous.

**STUDY AREA AND METHODS**

Studies were carried out in the mesotrophic, dimictic Lake Rogóźno of the Łęczna–Włodawa Lake District (Eastern Poland). Lake Rogóźno is a deep (max depth 25.4 m, mean depth 7.4 m, surface area 57.1 ha) and stratified water body, surrounded by forests, with 38% of the catchment area being characterized by arable land-use (Harasimiuk et al. 1998).

The studies were performed bi-weekly during the vegetation season, from May to the end of August 2006. Water samples for analyses were taken from the pelagial zone (at a depth 20 m, see Fig. 1) of the lake using a Ruttner–type water–sampler (2 dm³ capacity). Samples for biological and physical analyses were collected bi–weekly (for chemical analyses monthly) at depths of 0, 2, 4, 6 and 7 m. The concentration of chlorophyll *a* was determined according to
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a standard method (Nush 1980). Algal levels were determined using an inverted microscope (Zeiss Axiovert 135), according to the Utermöhl method (Vollenweider 1969). For counting, samples were transferred to a settling chamber of 5 ml capacity. At least 100 individuals of the most numerous algae were counted per sample. The phytoplankton species composition was determined using a light microscope (Nikon ECLIPSE E600W) from living and formalin–glycerine mixture–fixed samples.

The physical analysis (temperature, concentration of dissolved oxygen, conductivity, pH, water transparency–SD, and PAR (Photosynthetic Active Radiation)–with a Li–Cor meter (Li–250A) with Li–192SA underwater quantum sensor) was undertaken in situ. On the basis of the PAR measurements, the euphotic zone and attenuation coefficient (K_d) were determined.

The chemical analysis of soluble nutrients (N–NH_4, N–NO_3, P–PO_4) and total values (TN and TP) were estimated in a laboratory using colorimetric methods (Hermanowicz et al. 1999).

![Fig. 1. Location of sampling site on the bathymetric plan of Lake Rogoźno.](image)
RESULTS

The thermal stratification of Lake Rogóżno was observed from April to October, but three typical thermal layers: epilimnion, metalimnion, and hypolimnion, formed between May and September. This situation made it possible for the Cyanoprokaryota species (e.g. Planktothrix rubescens) to bloom in the thermocline layer.

During the stratification period (May to September), the concentration of dissolved oxygen (DO) in the metalimnion was at its highest level, and ranged from 10.5 (at the beginning of May) to 22.5 mg dm⁻³ (at the peak level - June). The maximal concentration of DO in the epilimnion never exceeded 10.3 mg dm⁻³ and was always lower then in the metalimnion. Consequently, the oxygen curve was of the type known as heterograde positive, with a permanent anoxia in the hypolimnion (from 9 m to the bottom).

The physical-chemical values varied between all studied periods (Table 1). The pH of the epilimnion (0–4 m) ranged from 8.32 to 8.65, and from 7.84 to 8.98 in the metalimnion. In most periods, the conductivity was a little higher in the metalimnion than in the epilimnion, and varied between 320 and 370 μS cm⁻¹.

<table>
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<th>N-NO₃</th>
<th>N-NH₄</th>
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*epilimnion-average values from the 0, 2 and 4 m
The chemical analysis showed an elevated concentration of biogenic compounds, especially the total fractions (TN and TP) in the metalimnion, when two maximal peaks of phytoplankton levels were noted (19 June at 6 m and 13 July at 7 m). The concentration of soluble nutrients (N–NH₄, N–NO₃, P–PO₄) was similar in the epilimnion and metalimnion (Table 1).

Light is a very important factor for phytoplankton growth. During the investigation the Secchi Disk (SD) values fluctuated in a broad range from 1.4 to 4.1 m (Fig. 2), but the euphotic zone estimated from the PAR was almost stable and came up to 5 m or a maximum 6 m, because of algal bloom in the metalimnion. The attenuation coefficient (Kₐ) at the bloom layer (6 m and 7 m), when the maximum peaks of abundance were observed was high, at approx. 1.2.

During the studies, 59 species belonging to seven phytoplankton groups were indicated, but only five groups (Cyanoprokaryota, Cryptophyceae, Dinophyceae, Bacillariophyceae and Chlorophyta) reached a significant number (Fig. 3). The main phytoplankton group was Cyanoprokaryota, whose percentage share in the total phytoplankton was at times above 95% (in the 6–7 m metalimnion) due to the metalimnetic bloom of *Planktothrix rubescens* (Fig. 2). The highest differentiation of phytoplankton was noted in the epilimnion (0, 2 and 4 m), where *P. rubescens* was absent. Only in May (at the beginning of thermal stratification) was this species present in the epilimnion.

![Fig. 2. Changes in abundance of *Planktothrix rubescens* in the epilimnion and bloom layer (6 and 7 m), and visibility of Secchi Disk for all studied periods.](image-url)
As a result of this the Cyanoprokaryota group achieved a high percentage share of the total levels of phytoplankton (over 60%, see Fig. 3), and then in the following weeks this group had a small share (below 20%). Other systematic groups (Cryptophyceae, Dinophyceae, Bacillariophyceae and Chlorophyta) were observed, generally in the epilimnion and sometimes achieving as much as 60% of the total number of phytoplankton. However, in later weeks (25.07, 07.08 and 24.08) these groups achieved higher proportions of the metalimnion (6 and 7 m) following the end of *Planktothrix rubescens* blooming (Fig. 3).

The total number of phytoplankton was highly variable in the water column. In the epilimnion (0, 2 and 4 m) it was low and ranged from 0.18 to 2.5 ind. 10^6 dm^-3, but in the metalimnion it was repeatedly higher due to the presence of *Planktothrix rubescens* and ranged from 1.9 to 23.9 ind. 10^6 dm^-3.

A high number of *P. rubescens* was noted in the metalimnion, sometimes even exceeding 90% of the total number of phytoplankton. Only in May, when the SD value was low (1.4 m), was this taxon present in the epilimnion (levels of about 1.0 ind. 10^6 dm^-3). In the following weeks (June to August) this species did not occur in the upper water layer due to the raised irradiance (Fig. 2).
Two high abundance peaks of *P. rubescens* occurred in the metalimnion at a depth of 6 m and 7 m (Fig. 3). The first peak was observed on 19 June at 6 m (23.6 ind. 10^6 dm^-3, 157.3 mg dm^-3 of biomass value), when the SD visibility was about 2.1 m. In the following month (13 July), when the SD value had increased (4.1 m), a second abundance peak was observed at 7 m (13.0 ind. 10^6 dm^-3, 86.6 mg dm^-3 of biomass value). After the maximal peaks, the number of this cyanoprokaryota decreased, to the range 0.5 to 4.1 ind. 10^6 dm^-3.

The chlorophyll *a* values were related to the phytoplankton peaks. In the epilimnion these values were low and ranged from 2.0 to 13.6 μg dm^-3, but in the metalimnion the values were high and ranged from 17.0 to 91.7 μg dm^-3 (Fig. 4).

**DISCUSSION**

*Planktothrix rubescens* is a metalimnetic species which lives at low temperatures (between 7 and 14ºC) and very low light intensities (even below 0.01% of the surface light intensity) and it is sensitive to high light levels (Konopka 1980, 1982; Reynolds 1984; Mur, Schreurs 1995). This was the first time that the bloom for this species had been observed in Rogóźno Lake. It was present at depths of 6 m and 7 m (metalimnion layer), where the PAR values

![Fig. 4. Changes in concentration of chlorophyll *a* [μg dm^-3] in epilimnion and bloom layers (6 and 7 m).](image-url)
were always below 1% of the surface irradiance (PAR = 0.15–4.5 μmol s\(^{-1}\) m\(^{-2}\)). When the SD increased and the euphotic zone reached 6 m (July, Fig. 2), *P. rubescens* migrated downward to the 7 m layer, where light conditions were more suitable for its growth (below 1%). The same situation was observed in other European freshwater lakes by Walsby et al. (2001) in Lake Zürich, Messyasz et al. (2003) in Lake Holzmar, and Legnani et al. (2005) in Lake Pusiano.

Walsby et al. (2001) indicated high attenuation coefficients (K\(_d\)) in the metalimnion of Lake Zürich, evidently due to light absorption by the *Planktothrix rubescens* layer. Moreover, it indicated a high linear relationship between K\(_d\) and filament concentration. Simultaneously, high values of K\(_d\) approx. 1.2 were ascertained in the metalimnion of Lake Rogóźno during the highest peaks of abundance.

*P. rubescens* can dominate at low levels of biogenic compounds (Dokulil, Teubner 2000). The chemical analysis showed that the levels of the dissolved fractions were low in the epilimnion and metalimnion until the first abundance peak in the metalimnion began. The elevated concentration of these fractions was ascertained, but just after the maximal peaks of abundance. The highest values of total fractions (TN, TP) corresponded with the highest peaks of abundance. Additionally, the TN:TP ratio was low (15-25:1) during the peak density of *P. rubescens* (June and July), which is optimum for lakes with a Cyanoprokaryota dominance (Smith 1983, Havens et al. 2003).

In the bloom layer, elevated values of pH (7.9–9.0) were ascertained. In this situation Cyanoprokaryota species have a high affinity to bind CO\(_2\), and as a consequence, they exhibit faster growth (Kawecka, Eloranta 1994). Moreover, the high density of *Planktothrix rubescens* with high values of chlorophyll \(a\) proved that this species is able to produce plenty of oxygen in the metalimnion. This accounts for the high values of dissolved oxygen noted in this water layer, which is characteristic of a heterograde positive curve.

Rogóźno Lake is difficult to classify in terms of the right trophic level. According to the OECD (1982) classification, many of the environmental conditions such as high values of nutrients (mean TP above 0.1 mg dm\(^{-3}\), mean TN above 2.6 mg dm\(^{-3}\)), high abundance of phytoplankton (mean 5.98 ind. 10\(^6\) dm\(^{-3}\) and consequently high concentration of chlorophyll \(a\) (mean value 49 μg dm\(^{-3}\)) in the metalimnion indicate that this is eutrophic lake. However, at the same time, the abundance of phytoplankton in the epilimnion was low (mean 0.94 ind. 10\(^6\) dm\(^{-3}\), the mean concentration of chlorophyll \(a\) was 7.0 μg dm\(^{-3}\) and the SD values (average 2.95 m) were characteristic for a mesotrophic lake. Thus, this lake has been characterized as a meso-eutrophic water body with a high tendency for eutrophy due to the significant domination of the filamentous Cyanoprocaryota species in the metalimnion.
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