Oceanological and Hydrobiological Studies
Vol. XXXIV, Supplement 3

Institute of Oceanography (237-246) University of Gdańsk
2005

Research Article

OCCURRENCE OF PICOCYANOBACTERIA DURING A PERMANENT DESMID BLOOM IN A SMALL DYSTROPHIC LAKE

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Key words: picocyanobacteria, phytoplankton, water bloom, dystrophic lake

Abstract

Changes in cell abundance and biomass of cyanobacteria and green algae were investigated in Lake Skrzynka - a small, shallow lake situated in the Wielkopolski National Park (West Poland). On all sampling dates from March to December in 2001, the most numerous green algae were desmids - *Actinotaenium perminutum* (G.S. West) Teiling - which caused a light green water bloom. Abundance of this species varied between 8.2×10^4 and 2.1×10^5 cells ml^{-1}, and biomass between 9.3 and 23.3 mg l^{-1} with peaks in May and October. The abundance of cyanobacteria was characterized by a broader range: from 1.1×10^5 to 2×10^6 cells ml^{-1} with a maximum in March and September, but their biomass was always small in comparison with that of *A. perminutum.* Within cyanobacterial populations, picoplanktonic cells (0.2-2.0 μm) dominated. Solitary spherical cells of *Synechocystis* were the most abundant picocyanobacteria. However, cells in colonial forms, identified mostly as members of the genus *Aphanocapsa* and *Aphanothece,* increased in some months. The negative correlation between picocyanobacteria and *A. perminutum* abundance was not statistically significant.

INTRODUCTION

Algal blooms are becoming more and more common in aquatic habitats. They have been reported for a long time, and in the temperate zone they occur mainly in the warm seasons. The more fertile a water body is, the longer is the duration of algal blooms (Bucka and Wilk-Woźniak 1999). In dystrophic lakes, considered poor in respect of biodiversity, phytoplankton is also quantitatively poor, so water blooms are very infrequent there. Until recently, abundant populations of algae were also rarely observed in the small, dystrophic Lake Skrzynka, which is one of the best-studied lakes in the Wielkopolski National Park (W Poland) (Dąmbska *et al.* 1978, Pełechaty *et al.* 2002). However, during the last decade, large populations of cyanobacteria and green algae have appeared there (Burchardt *et al.* 1998, Szeląg-Wasielewska 1999, Szeląg-Wasielewska and Tomaszewicz 2003, Ciachera-Raduła and Szeląg-Wasielewska 2004). Hence the aim of this study was to identify the taxa characterized by high densities or biomass, and to analyse their seasonal variation.

MATERIAL AND METHODS

Water samples for phytoplankton analysis were taken from the surface layer at one station between March and December in 2001. For sampling, two kinds of bottles attached to a telescopic extension arm were used: 100 ml (for cells <2 μm) and 250 ml (for cells >2 μm). A total of 11 sampling sessions were carried out. The samples were preserved with 25% buffered glutaraldehyde to a final concentration of 1%, or with Lugol's solution.

In the laboratory, picophytoplankton (0.2-2.0 μm) subsamples of 0.5–2 ml each were collected by filtration on black Nuclepore filters of 0.2 μm pore size. Twenty to sixty fields were examined at a magnification of 1500× under an Olympus BX-60 microscope (which was bought by the Foundation for Polish Science, as part of the SUBIN program). When colonial picocyanobacteria were present, lower magnifications were also used (300× or 600×) and a larger surface area of the filter was investigated. Optic filter sets for green and blue excitation were used (MacIsaac and Stockner 1993). APP was classified as prokaryotic or eukaryotic on the basis of autofluorescence colour, cell shape and size, and presence of chloroplasts. Within picocyanobacteria (Pcy), according to Stockner *et al.* (2000), two groups were distinguished: single cells (S-Pcy) and colonies (C-Pcy) with diverse colonial morphology. The identification of picoeukaryotes (E-APP) was based on the shape and location of chloroplast, presence or absence of pyrenoids, and mode of reproduction.

Phytoplankton cells larger than 2.0 μm were analysed with an inverted microscope after sedimentation in settling chambers, according to the method of Wetzel and Likens (1991) at magnifications 40, 150 and 600×. Abundance of organisms was expressed as the number of cells per 1ml. The biovolume of each species was calculated on the basis of cell shape, size, and number, while their biomass was expressed as wet weight. Biomass was estimated assuming that the volume of 10^6 μm^3 is equivalent to 1μg.

Site description

Lake Skrzynka is situated near the city of Poznań, in the south-eastern part of the Poznań Lakeland. The Wielkopolska National Park (NP) was created in this area in 1957. Lake Skrzynka lies in the centre of the Wielkopolska NP, in the Górecko-Budzyński Channel, between the Buk-Mosina Esker and the morainic plateau. It is the smallest lake of the Wielkopolska NP (area 1.7 ha, volume $2.4 \cdot 10^4$ m^3, maximum length 237 m, maximum width 90 m), quite shallow (maximum depth 2.9 m, mean depth 1.43 m), and located at the highest altitude (65.4 m above sea level). *Sphagnum* mosses form dense mats floating on the lake surface along its margins. The catchment area of Lake Skrzynka covers 78 ha, including 62 ha of woodland, 11.2 ha of grassland, 4.5 ha of cultivated fields, and 0.3 ha of built-up areas. There are no point sources of pollution in the direct catchment, but the lake is affected by pollution from diffuse and dispersed sources (Szyper and Gołdyn 2002).

In Lake Skrzynka no typical thermal stratification is observed (Brzęk 1948, Dąmbska *et al.* 1978, Klimaszyk *et al.* 2002). A review of hydrochemical data on this lake (Siepak *et al*. 1999) shows that during the last 50 years, water transparency ranged from 0.8 to 2.4 m, pH from 6.0 to 8.41, colour from 5 to 24 mg Pt·l^{-1}, oxydability from 9.4 to 32.5 mg $O_2 \cdot l^{-1}$, whereas in the 1990's total phosphorus content in the pelagic zone ranged from 0.05 to 0.25 mg $PO_4 \cdot l^{-1}$.

RESULTS

Within cyanobacterial populations, picoplanktonic cells dominated (Fig. 1, 2). Densities and biomass of picocyanobacteria varied widely, from 1.07×10^5 to 1.96×10^6 cells ml^{-1} (mean 6.9×10^5 cells ml^{-1}) and from 0.06 to 1.07 mg l^{-1} (mean 0.31mg l^{-1}), respectively. The highest value was recorded at the beginning of this study, *i.e.* in late March, but afterwards it dramatically decreased to 2.9×10^5 cells ml^{-1} in mid-April. Another peak of abundance of cyanobacteria was observed in late September: 1.7×10^6 cells ml^{-1}. It must be emphasized that their mean abundance in the first half of the year (7.8×10^5 cells ml^{-1}) was slightly higher than in the second half (5.9×10^5 cells ml^{-1}). Solitary spherical cells of

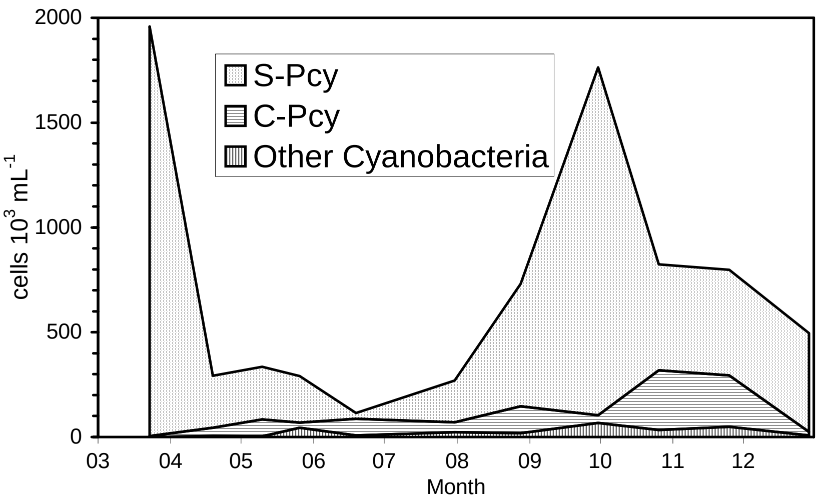

Fig. 1. Abundance of Cyanobacteria groups: Single-celled picocyanobacteria (S-Pcy), colonial picocyanobacteria (C-Pcy) and other Cyanobacteria in Lake Skrzynka from March to December 2001.

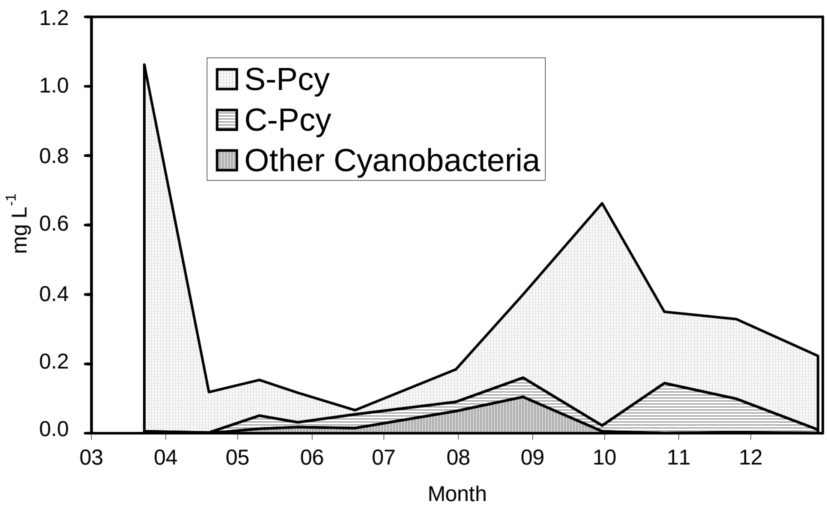

Fig. 2. Biomass of Cyanobacteria groups: Single-celled picocyanobacteria (S-Pcy), colonial picocyanobacteria (C-Pcy) and other Cyanobacteria in Lake Skrzynka from March to December 2001.

Synechocystis were the most abundant picocyanobacteria and their contribution ranged from 25.7 to 99.8% (mean 78.7%). However, cells in colonial forms, identified mostly as members of the genera *Aphanocapsa* and *Aphanothece,* increased in some months. Larger cyanobacterial cells, whose size exceeded 2 μm, were infrequent, and their contribution to the total cyanobacteria abundance did not exceed 15% (mean 4.6%). Their contribution to the total cyanobacteria biomass was obviously higher and amounted to 35% (mean 9.8%), and the highest biomass was reached by *Microcystis* and *Woronichinia* species.

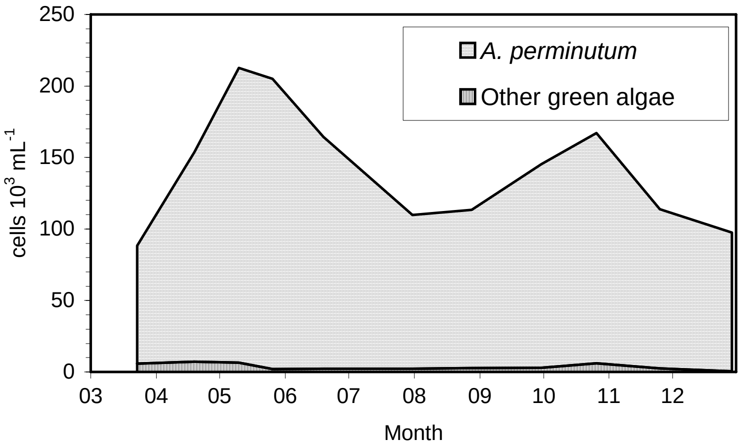

Fig. 3. Abundance of *Actinotaenium perminutum* and other green algae in Lake Skrzynka from March to December 2001.

In the study period the most abundant species of green algae was the desmid *Actinotaenium perminutum* (G.S. West) Teiling, which caused a light-green water bloom. The abundance of this species varied between 82×10^3 and 206×10^3 cells ml^{-1}, (Fig. 3) and biomass between 9.3 and 23.3 mg l^{-1}, with peaks in May and October. Its biomass was high throughout the study period and only in March it did not exceed 10 mg l^{-1}. It peaked in May, when it reached ca. 23 mg l^{-1}. Even in December it approached 11 mg l^{-1}, although water temperature was only 1ºC then. All other desmid taxa were much less abundant; the most frequent among them were: *Teilingia excavata* (Ralfs) Bourrelly (ca. 1800 cells ml^{-1}), *Staurastrum spp*. (ca. 90 cells ml^{-1}) and *Closterium acutum var. variabile* (ca. 60 cells ml^{-1}). Their mean contribution to total desmid abundance and biomass was only 0.2 and 0.4%, respectively.

Correlations between picocyanobacteria and *A. perminutum*, both in terms of biomass (r= - 0.507, p=0.11) and abundance (r= - 0.459, p=0.16), were negative but insignificant. However, the highest abundance and biomass of picocyanobacteria coincided with the lowest abundance and biomass of *A. perminutum* (Fig. 4, 5).

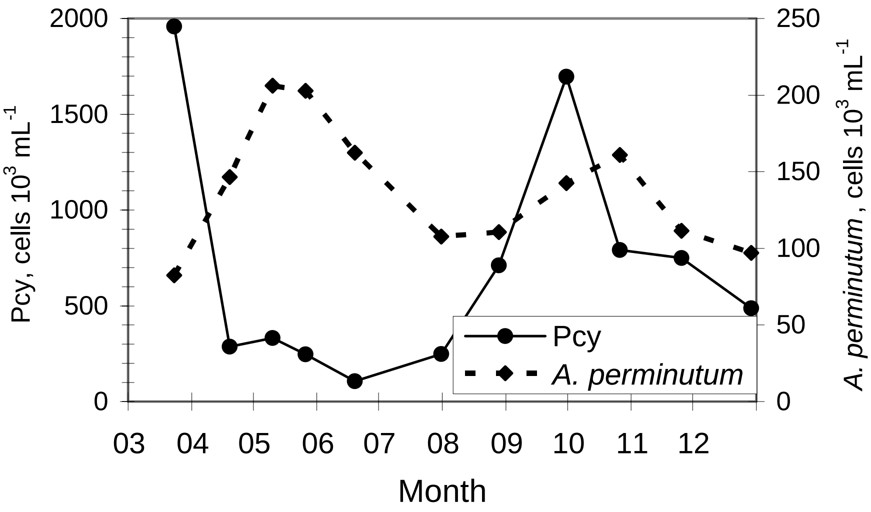

Fig. 4. Abundance of picocyanobacteria (Pcy, solid line) and *Actinotaenium perminutum* (*A. perminutum,* broken line) in Lake Skrzynka from March to December 2001.

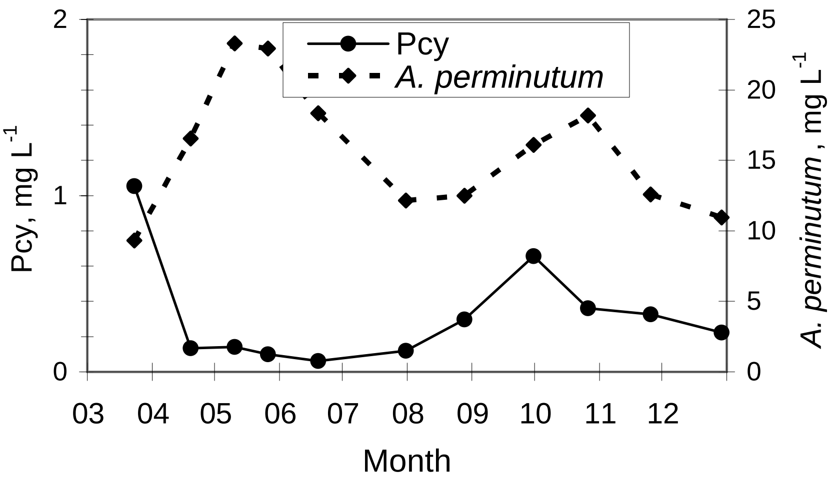

Fig. 5. Biomass of picocyanobacteria (Pcy, solid line) and *Actinotaenium perminutum* (*A. perminutum,* broken line) in Lake Skrzynka from March to December 2001.

DISCUSSION

Research conducted during the last few years in the dystrophic Lake Skrzynka has showed that phytoplankton biomass is very high there in some periods, mainly due to the desmid *A. perminutum* (Szeląg-Wasielewska 2003). Earlier research on the phytoplankton of Lake Skrzynka – started in 1929 (Smoluchowska-Jaroszewska 1937) and later conducted in 1954 (Krawiecowa 1957), 1974 and 1975 (Wiktor 1976, Dąmbska *et al.*1978), 1981 and 1982 (Pańczak and Szyszka 1986), 1995 (Szeląg-Wasielewska 1999) and 1996 (Messyasz 2000) – did not detect the presence of *A. perminutum*. This species was found in the study lake as late as in July 1999 in an occasional water sample. Before, this species had been recorded in Poland only once, in Lower Silesia (Szeląg-Wasielewska and Tomaszewicz 2003). It occurs in many European countries, also in Africa and Asia and South America, but is rarely recorded in Central Europe (Růžička 1981). Perhaps it could have been overlooked because of its small size and delicate cell walls. Specimens of *A. perminutum* from Lake Skrzynka were relatively small, as their cells were shorter than reported earlier, while cell width was at the lower limit of the range found in the literature (Szeląg-Wasielewska and Tomaszewicz 2003). Thus, the use of plankton nets with mesh size of about 50 μm during collection of water samples, as in most of the other studies of the phytoplankton of Lake Skrzynka (Dąmbska *et al.* 1978) could be the reason why the species was not reported from the lake previously.

The maximum density of picocyanobacteria in Lake Skrzynka was 10 times as high as that of *A. perminutum*, while the mean for picocyanobacteria was about 5 times as high as for *A. perminutum.* This does not confirm the common belief that in dystrophic lakes cyanobacteria are less numerous than desmids. Nevertheless, in terms of biomass, cyanobacteria reached only 1/50 of the biomass of desmids. It must be noted that high densities of picocyanobacteria in Lake Skrzynka were also recorded earlier, *e.g.* in the mid 1990s their mean abundance was about 3 times higher (Szeląg-Wasielewska 1999), and in the year 2000 it was 30% higher (Szeląg-Wasielewska 2004) than in this study. The intensive growth of picocyanobacteria in the study lake may be associated with the nearly neutral water pH. Stockner and Shortreed (1991) found in dystrophic Canadian lakes that picocyanobacteria are eliminated when water pH decreases to below 6.

Among both cyanobacteria and desmids, small-sized cells prevailed: pico- and nanoplanktonic, respectively. Such small organisms are characterized by a high rate of food utilization and fast reproduction, leading to the appearance of numerous new generations (Happey-Wood 1988). The negative correlation (although insignificant at α=0.05) between the size of the population of *A. perminutum* and of picocyanobacteria suggests that they have different environmental requirements and/or are differently grazed by consumers. The desmid, because of its larger size and gelatinous coat, is certainly – in contrast to picocyanobacteria – unavailable to many small consumers, such as small-sized flagellates and ciliates. For this reason, the biomass produced by them is maintained for a longer time in seston, enriching the detritus food chain, or is sedimented, enriching the pool of bottom sediments. Colonial picocyanobacteria appear to have adaptive strategies for more efficient nutrient recycling during periods of scarcity, or anti-predator mechanisms (Stockner *et al.* 2000).

The high or very high abundance of phytoplankton throughout the study period may attest to disturbance of the earlier balance in the aquatic-terrestrial system of Lake Skrzynka. Within its catchment there is no direct source of pollution, so the gradual eutrophication of the lake may be due to periodical changes in water level, resulting in an increased supply of nutrients from the catchment. A similar situation was described by Hutorowicz *et al*. (1999), who discussed the functioning of dystrophic lakes in Wigry National Park (NE Poland).

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