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Research Article

DYNAMICS OF *PLANKTOTHRIX AGARDHII* (GOM.) ANAGN. ET KOM. BLOOMS IN POLIMICTIC LAKE LASKOWNICKIE AND GRYLEWSKIE (WIELKOPOLSKA REGION) POLAND

KAROLINA STEFANIAK [*1], MIKOŁAJ KOKOCIŃSKI[2],
BEATA MESSYASZ[1]

[1]*Department of Hydrobiology, Adam Mickiewicz University*
Umultowska 89, 61-614 Poznań, Poland
[*]*e-mail: stefkar@tlen.pl*

[2]*Collegium Polonicum, Adam Mickiewicz University*
Kościuszki 1, 69-100 Słubice, Poland

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Abstract

The blooms of many species of cyanobacteria have been investigated intensively for many years due to their importance from ecological as well as from a water management point of view. Among many potentially toxic species, *Planktothrix agardhii* is one of the best known in shallow and turbid lakes. The water blooms of this cyanobacterium have been observed in nutrient-rich lakes in the Wielkopolska region during summer and early autumn. Moreover, the dynamics of their occurrence seem to be predictable. The composition of phytoplankton communities during *P. agardhii* blooms in two shallow polimictic and highly eutrophic lakes is presented.

INTRODUCTION

Filamentous cyanobacterium *Planktothrix agardhii* (Gom.) (syn. *Oscillatoria agardhii* Gom.) Anagn. et Kom. is characteristic for fertile and shallow lakes around the world (Van Liere and Mur 1980, Zevenboom 1982, Berger 1975, 1984, Nixdorf 1994, Rojo and Alvarez-Cobelas 1994, Romo and Miracle 1995, Rücker *et al.* 1997, Gibson *et al.* 2000, Briand *et al.* 2002). The most abundant populations of this species are noted in late summer or autumn (Skulberg 1978, Van Liere and Mur 1980). *Planktothrix agardhii* seems to prefer warm water (> 20°C, Van Liere and Mur 1980, Berger and Sweers 1988). However, due to its low-temperature tolerance mass occurrences of this species have also been noted in temperatures 6 -16°C (Berger 1989, Dokulil and Teubner 2000). With advanced trophic state it can be found the whole year round (Nixdorf 1994, Van Liere and Mur 1980). One of the main factors responsible for *P. agardhii* dominance in shallow lakes as well as other *Oscillatoriaceae* species is light (Zevenboom and Mur 1980, Romo and Miracle 1994, Montealegre *et al*. 1995, Mur and Schreurs 1995, Havens *et al*. 1998). The increased eutrophication creates much lower irradiance in water, therefore the advantage in phytoplankton community gain species with a low light-energy requirement for growth such as non-N_2-fixing *Cyanobacteria* (Zevenboom and Mur 1980). *Planktothrix agardhii* is therefore considered as a turbulent species (Scheffer *et al.* 1997, Dokulil and Teubner 2000). Water blooms caused by *P. agardhii* are associated worldwide with production of toxins hazardous to animals and humans (Lindholm *et al.* 2002, Luukkainen *et al.* 1993, Keil *et al*. 2002, Wiedner *et al.* 2002). The collapses of cyanobacterial blooms in hypertrophic lakes, characterized by substantial biomass and nutrient oscillations, are very dangerous, leading to catastrophic breakdown of the system's structure and function (Barica 1993).

Water blooms of *P. agardhii* have been noted in many reservoirs in Poland since the early 90's because of progressing eutrophication processes (Gołdyn *et al*. 1997, Messyasz, 1998, Zębek 1998, Stefaniak *et al*. 2003). The aim of this study was to characterize the phytoplankton communities in two shallow hypertrophic lakes of the Wielkopolska region during summer and early autumn in order to estimate frequencies and intensities of *P. agardhii* blooms.

MATERIAL AND METHODS

In summer and early autumn in the years 1994 -1995 and 2002 - 2003 two polimictic and nutrient-rich lakes, Laskownickie and Grylewskie, were studied. Both lakes are situated in the northern part of the Wielkopolska region, near the town Wągrowiec (Fig. 1). These lakes have large agricultural catchment areas and are used recreationally in summer. Both reservoirs are very shallow, the mean depth does not exceed 4m. The morphometric data of the lakes investigated are given in Table 1.

Table 1

The morphometric data of the studied lakes.

	Lake Laskownickie	Lake Grylewskie
latitude	52°55,1 '	52°53,4'
longitude	17°16,0'	17°15,1'
area [ha]	19,2	119,1
volume [x 10 ^{3} m^3]	773,8	4329,0
max. depth [m]	7,4	6,5
mean depth [m]	4,0	3,6
max. width [m]	210	350
max. length. [m]	1090	4800

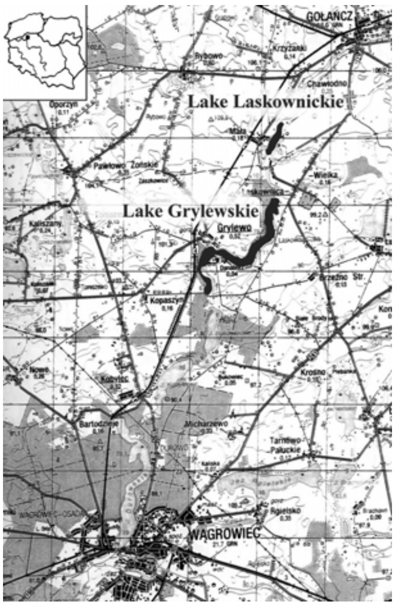

Fig. 1. The localization of the studied lakes.

Water samples for phycological and chemical analyses were collected from the surface layer of the water column of the lakes investigated from July to October, twice a month.

Water samples for phytoplankton analyses (1l volume) were fixed with 4% formaldehyde and Lugol's solution immediately after the sampling and sedimented to the volume 40ml. Individuals were counted in the Fuchs-Rosenthall chamber. Biomass was estimated from the cell numbers and specific volumes (Kawecka and Eloranta 1994). In each case water temperature and visibility in the water column were measured *in situ*. The concentration of chlorophyll *a* was analyzed using the Lorenzen method after acetone extraction (Polish Standard 1986). Concentrations of selected nutrients were assessed by spectrophotometer DR 2010 HACH. The limiting values for the water bloom event were: chlorophyll *a* above 20µg l^{-1} (Neubaeus 1984) and visibility below 1m (Barica 1981). The results were statistically tested using Statistica 6.1 software.

RESULTS

The averaged values of chlorophyll *a* concentrations (between 62 and 109µg l^{-1} in Lake Laskownickie and 64 – 68µg l^{-1} in Lake Grylewskie) and visibility in the water column in the two investigated lakes indicated the phenomenon of the water bloom in each investigated season (Messyasz 1999, Stefaniak 2005).

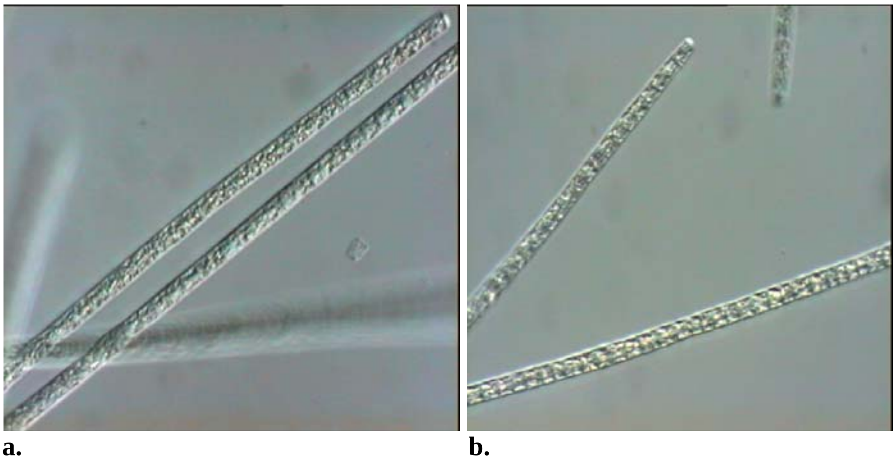

Fig. 2. *Planktothrix agardhii:* a - in Lake Laskownickie, b – in Lake Grylewskie; magnification 10 x 100.

The structure of phytoplankton communities during blooms in Lake Laskownickie

The phytoplankton of Lake Laskownickie in 1994 was dominated by *Cyanobacteria* and *Cryptophyta* during the whole study period from July to September. The averaged contributions of these groups ranged from 49 to 67%

and from 14 to 19%, respectively. The dominant species in each investigated month were *P. agardhii*, *Limnothrix redekei* and *Cryptomonas rostrata* Troitzkaja emend. I. Kiselev. In contrast, during the water bloom in Lake Laskownickie in 1995 *Cyanobacteria* reached above 85% in total phytoplankton biomass in each investigated month. The most abundant species in the phytoplankton community was *P. agardhii* (Fig. 2a), which formed almost a monoculture (Messyasz 1999). During the bloom in 2002, *Cyanobacteria* contributed above 75% of total phytoplankton biomass. In July the most abundant species were *Cyanobacteria P. agardhii* and *Aphanizomenon flos-aquae* (L.) Ralfs ex Bornet et Flahault. In August, *P. agardhii* reached dominance, while in September this cyanobacterium co-dominated with *Anabaena flos-aquae* (Lyngb.) Bréb. ex Bornet et Flahault. The development of *Cyanobacteria* in Lake Laskownickie during the bloom in 2003 was similar to that in 2002. The averaged contribution of blue-greens ranged from 73 to 91% during the whole study period. In July 2003 *P. agardhii* co-dominated with *Anabaena flos-aquae* and *Aphanizomenon flos-aquae*. In August, September and October *P. agardhii* was the most abundant species in the phytoplankton community of Lake Laskownickie. Moreover, in September and October *Cryptomonas reflexa* (Marss.) Skuja was also very abundant.

The structure of phytoplankton communities during blooms in Lake Grylewskie

Lake Grylewskie in July 1994 was dominated by *Cyanobacteria* and dinoflagellates. Their averaged contributions in total biomass concentration of phytoplankton amounted to 37 and 17%, respectively. The dominant species in the phytoplankton community were *P. agardhii*, *Limnothrix redekei* (Van Goor) Meff. and *Peridinium inconspicuum* Lemm. In August, *Cyanobacteria* (39%) and *Cryptophyta* (37%) co-dominated. The most abundant species was *Cryptomonas rostrata* Troitzkaja emend. I. Kiselev. *Cyanobacteria* reached 68% of total phytoplankton biomass in September and the dominants were *P. agardhii* and *C. rostrata* again. The dominance of *Cyanobacteria* in Lake Grylewskie in the year 1995 was evident in each month studied. The contribution of blue-greens in total phytoplankton biomass ranged from 47% in July to 88% in September. The only dominant was *P. agardhii* and no other subdominant species in biomass concentration was detected (Messyasz 1999).

In Lake Grylewskie in July and August 2002 the most abundant groups of phytoplankton were *Cyanobacteria* and *Cryptophyta*. They contributed above 80% of total phytoplankton biomass together. In July and August *P. agardhii* and two species of *Cryptophyta*, *Cryptomonas reflexa* and *C. erosa* Ehr. co-dominated. Moreover, in July *Ceratium hirundinella* (O. F. Müll.) Dujardin (of the *Dinophyta* group) was also very abundant. In September and October 2002 the contribution of *Cyanobacteria* amounted to above 75% of the total phytoplankton biomass. The only dominant in the phytoplankton community was *P. agardhii* (Fig. 2b). The dominance of *Cyanobacteria* in the year 2003 was better expressed that in previous years. The contribution of blue-greens in total phytoplankton biomass ranged from 76 to 96% during the whole period studied. In July and August 2003 two *Cyanobacteria*, *P. agardhii* and *Aphanizomenon flos-aquae* reached dominance. In September and October, as in the year 2002, the only dominant was *P. agardhii*.

Table 2

Selected averaged parameters of phytoplankton communities in Lake Laskownickie. J– July; A- August; S- September; O- October.

	1994**			**1995****			**2002***			**2003***			
Lake Laskownickie	**J**	**A**	**S**	**J**	**A**	**S**	**J**	**A**	**S**	**J**	**A**	**S**	**O**
Total biomass [mg l^{-1}]	70.077	10.521	72.370	14.791	40.028	35.973	28.00	41.47	17.40	43.83	46.69	55.90	12.31
Phytoplankton abundance [ind. ml^{-1}]	49108	9112	53694	12738	32046	27612	17000	23370	8354	31475	25858	32022	7777
P. agardhii abundance [ind. ml^{-1}]	29077	3440	32663	9359	30135	24353	5325	11745	3395	12050	17063	22310	4803

*Stefaniak, 2005
** Messyasz, 1999

Table 3

Selected averaged parameters of phytoplankton communities in Lake Grylewskie. J– July; A- August; S- September; O- October.

Lake Grylewskie	**1994****			**1995****			**2002***				**2003***			
	J	**A**	**S**	**J**	**A**	**S**	**J**	**A**	**S**	**O**	**J**	**A**	**S**	**O**
Total biomass [mg l^{-1}]	33.97	25.49	55.07	16.50	34.30	31.33	12.25	23.01	32.37	28.77	28.77	26.42	38.18	48.34
Phytoplankton abundance [ind. ml^{-1}]	22610	17485	37011	14775	28884	24647	13210	27082	31773	23320	26689	23806	26296	31420
P .agardhii abundance [ind. ml^{-1}]	10738	4073	21034	5052	20372	21798	1040	3565	10350	13500	7800	8242	17690	26415

*Stefaniak, 2005
** Messyasz, 1999

Although the abundance of *P. agardhii* was lower in the years 2002 – 2003 than in the years 1994 -1995 in both the lakes (Table 2 and 3), statistically significant differences in abundance of this cyanobacterium between the years studied were not found. (Fig. 3a, 4a). Furthermore, there were no statistically significant differences in the total abundance of phytoplankton and total phytoplankton biomass between the years 1994 – 2003 in each investigated lake (Fig. 3bc, 4bc).

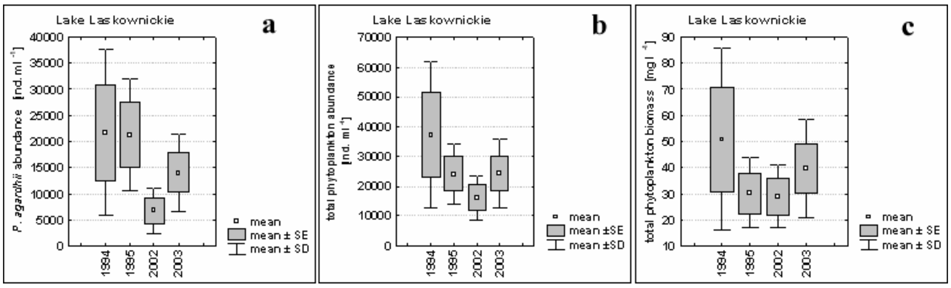

Fig. 3. Statistical analyses of quantitative parameters of phytoplankton communities in Lake Laskownickie between the years studied: a. average abundance of *P. agardhii* (Kruskal-Wallis ANOVA; H_3=3,55; N=13; p=0,31); b. average abundance of phytoplankton (ANOVA; N= 13; F = 1,07; p=0,41); average phytoplankton biomass (ANOVA; N=13; F=0,67; p=0,59). (Messyasz 1999, Stefaniak 2005)

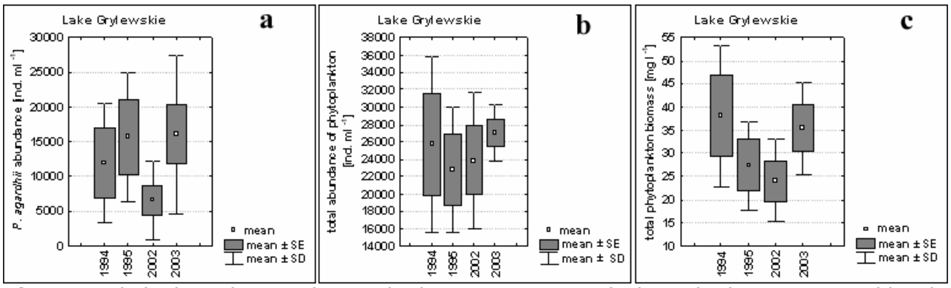

Fig.4. Statistical analyses of quantitative parameters of phytoplankton communities in Lake Grylewskie between years studied: a. average abundance of *P. agardhii* (Kruskal-Wallis ANOVA; H_3=2,67; N=14; p=0,45); b. average abundance of phytoplankton (ANOVA; N= 14; F = 0,24; p=0,86); average phytoplankton biomass (ANOVA; N=14; F=1,31; p=0,32). (Messyasz 1999, Stefaniak 2005)

The characteristics of physico-chemical parameters of water in both the lakes

The mean value of ammonium nitrogen was three times higher in Lake Laskownickie in the years 1994 -1995 (1.41 mg N l^{-1}) than in the years 2002 - 2003 (0.53 mg N l^{-1}). In contrast, the mean value of orthophosphates was two times lower in this lake in the years 1994 - 1995 (0.33 mg PO4 l^{-1}) than in the years 2002 - 2003 (0.625 mg PO4 l^{-1}). A similar phenomenon was observed in Lake Grylewskie (Fig. 5). Moreover, the disproportion in concentration of orthophosphates between the years 1994 – 1995 and 2002 – 2003 in Lake Grylewskie was even more pronounced.

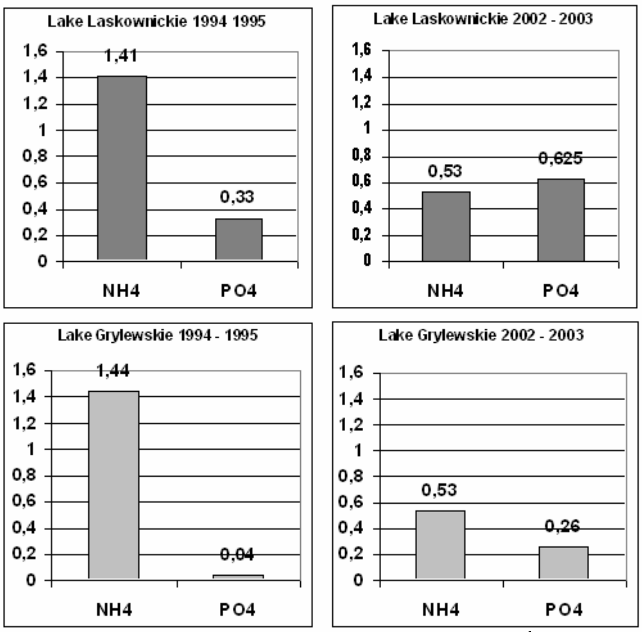

Fig. 5. Average values of ammonium nitrogen [mg N l^{-1}] and orthophosphates [mg PO_4 l^{-1}] in Lake Laskownickie and Grylewskie in the years 1994 – 1995 and 2002 – 2003.

DISCUSSION

High concentrations of nutrients together with mechanical disturbances of the water column caused by wind action seemed to be the major factors which favored *Planktothrix agardhii* blooms in the studied lakes. Lakes Laskownickie and Grylewskie are very shallow reservoirs (Tab. 1) in which permanent mixing plays an important role in establishing the phytoplankton communities. In literature, lakes with a dominance of filamentous *Cyanobacteria* from the genus *Planktothrix* or *Limnothrix* are described as '*Oscillatoriaceae'* lakes (Rücker *et al.* 1997). They are characterized by low average depth (< 3 m) and low visibility (< 0.3 m).

Although the dominance of *Planktothrix agardhii* was less developed in both Lake Laskownickie and Lake Grylewskie in the years 2002 – 2003 than in the years 1994 – 1995 (Table 2 and 3), the dynamics of blooms of this cyanobacterium seemed to be similar in the following years in each lake. Pliński (2004) stated that the intense blooms of *Cyanobacteria*, which are the effects of environmental disturbances, have been fixed in the biocenotical structure as a new homeostatic quality in the ecosystem. Such a phenomenon could be considered in Lake Laskownickie and Grylewskie. The results of statistical analyses of quantitative parameters of phytoplankton communities in both the lakes confirmed this hypothesis (Figures 3 and 4). There were no statistical differences in either abundance of *P. agardhii* or in total abundance of phytoplankton and total phytoplankton biomass between the years 1994 – 2003 in each investigated lake. This may suggest that water blooms of *P. agardhii* can be quite well predicted in these lakes. This phenomenon can be considered as stability of the system. It is noted that equilibria with a dominance of *Cyanobacteria* tend to be a monoculture in the community and show stable seasonal dynamics (Holzmann 1993). However, Scheffer *et al*. (2003) suggested that even if we knew exactly the rules that govern the phytoplankton community, the time course of the community remains unpredictable. We can never precisely determine the current state and even if we could, the slightest perturbation (meteorological events) has huge effects in the long term. Weather related disturbances are also thought to be important in keeping algal communities diverse and dynamic (Padisák *et al.* 1993). The stability of the phytoplankton communities in Lake Laskownickie and Grylewskie during *P. agardhii* dominance was confirmed by the presence of the same subdominant species in each lake during the following seasons.

The highest abundance of *P. agardhii* (in the years 1994 – 1995) was associated with the lowest averaged concentration of orthophosphate and extremely high values of ammonium nitrogen in both studied lakes. (Fig. 5, Tab. 2 and 3). It is well known that *P. agardhii* requires high concentrations of orthophosphate in the water (Zevenboom *et al*. 1982). The lowest values of this nutrient during the dense water bloom suggested that developed populations of *P. agardhii* in each investigated lake exhausted the whole available phosphorus. A similar phenomenon was also observed by Rojo and Alvarez Cobelas (1994) during intensive growth of *P. agardhii* in hypertrophic Lake El Porcal. The presence of high values of ammonium nitrogen in summer is considered to be a favorable factor for the growth and development of *P. agardhii* in the surface water column (Walsby and Klemer 1974, Klemer 1976, Gibson *et al.* 2000). Changes in proportion of ammonium nitrogen between the years studied in Lake Laskownickie as well as in Grylewskie could be related to changes in economic activities in the catchment areas of these lakes. Since 1998 a sewage-treatment plant has been working in Gołańcz (Messyasz, personal communication).

Due to the possibility of toxin production by cyanobacterium *P. agardhii***,** further monitoring of shallow and fertile reservoirs of the Wielkopolska region has been planned with special regard to estimating the frequencies and intensities of *P. agardhii* blooms.

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