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AUTOTROPHIC PICOPLANKTON VERSUS TROPHIC STATE OF LAKE WATERS IN NORTH-WESTERN POLAND

AUTOTROFICZNY PIKOPLANKTON A TROFIA WÓD NA PRZYKŁADZIE JEZIOR W PÓŁNOCNO-ZACHODNIEJ POLSCE

This paper is based on results of previous research on the smallest size fraction of phytoplankton, i.e. autotrophic picoplankton (APP), in 24 water bodies in the Pomeranian Lakeland (NW Poland). Abundance, biomass and contribution of APP to total phytoplankton biomass were analysed, as well as correlations of those factors with the trophic state of the lakes. APP communities were composed of prokaryotic organisms, i.e. cyanobacteria, as well as eukaryotic organisms, i.e. chlorophytes. Results from the analysed groups of lakes show that prokaryotic and eukaryotic components of APP need to be considered separately in studies of relationships between APP and trophic state of lakes. Cyanobacteria, which are usually much more abundant, affect those relationships more strongly in neutral and alkaline waters, and are successful in colonizing habitats with a low trophic level. In contrast, picochlorophytes, which tolerate low pH and prefer more fertile habitats, extend the ecological importance of APP in other environments. Thus APP, as a complex group, composed of organisms with diverse requirements, is predisposed to be successful in many types of aquatic habitats.

1. Introduction

The phytoplankton is regarded as a universal and sensitive indicator of changes in aquatic ecosystems. It is found in all types of freshwater habitats, irrespective of their origin, morphometric features, and trophic state. It reacts to even small changes in water quality and nutrient richness, by modifying its biotic structure and intensity of metabolism [2, 3, 8, 9, 10, 21]. Reports on correlations between the taxonomic composition of phytoplankton and water quality or trophic state, supplemented with data on abundance and biomass, are concerned mainly with microplankton and nanoplankton. In contrast, there is little information on the smallest photoautotrophs, termed picophytoplankton or autotrophic picoplankton (APP). It has been reported that APP abundance in freshwater bodies usually ranges from 10^4 to 10^6 cells ml^{-1}, but it tends to increase with increasing trophic state [1, 11, 12, 20]. Despite the high APP densities in phytoplankton, it has been rarely studied in Polish lakes. Most of the published data on APP compared to other size fractions of phytoplankton are concerned with water bodies located in the western part of Poland [19].

This article is focused on APP abundance and biomass in freshwater bodies that differ in trophic state. On the basis of mostly published data from lakes situated in the Pomeranian Lakeland in NW Poland, relationships between trophic state and size of APP communities were analysed. The verified hypothesis was that the importance of APP, i.e. its contribution to total phytoplankton biomass, changes depending on trophic state. More precisely, the aim of this study was to determine if an increase in tropic state is accompanied by an increase in APP abundance and biomass, but a decrease in percent contribution of APP to total phytoplankton biomass. This article is a continuation of three earlier reports presented during International Conferences on Water Supply and Water Quality, concerned with APP in general [15], on a national scale [17], and in detail in a selected Polish water body [18].

2. Study area, materials and methods

The assessment of relationships between APP abundance or biomass and trophic state (expressed here as fresh phytoplankton weight in mg l^{-1}) was performed in two groups of water bodies, of 12 lakes each (Table 1). They are located in the Pomeranian Lakeland and are termed lobelia lakes, because of the characteristic species found in them jointly or separately: *Lobelia dortmanna* L., *Isoëtes lacustris* L., and *Littorella uniflora* (L.) Ascherson [4, 5, 6]. The first group of lakes is situated in the Bytów Lakeland (near Złocieniec and Bytów), and the second in the Kaszuby Lakeland and Łobez Plateau (near Kościerzyna and Łobez).

Tab. 1. Alphabetical list of analysed water bodies

Tab. 1. Alfabetyczne zestawienie uwzględnionych zbiorników wodnych

No.	Lake name	Surface[1] area (ha)	Max. depth[1] (m)	Thermal[1] layer	Period	References
First group of 12 lakes						
1	Bobięcińskie Małe	33.3	4.0	E	Summer (August 1993, 1994)	[14]
2	Borzytuchom III	9.6	4.5	E, M		
3	Ciemniak	8.0	7.8	E, M		
4	Cietrzewie Małe	3.5	7.5	E, M		
5	Krasne	28.0	5.5	E		
6	Leśniówek Mały	1.6	5.0	E, M		
7	Linowskie	10.5	3.5	E		
8	Lubienieckie Duże	13.0	4.0	E, M		

No.	Lake name	Surface[1] area (ha)	Max. depth[1] (m)	Thermal[1] layer	Period	References
9	Lubienieckie Małe	3.3	5.8	E, M		
10	Nierybno	9.0	5.2	E		
11	Nowoparszczenickie	2.3	4.9	E		
12	Sękacz	15.0	4.0	E		
Second group of 12 lakes						
1	Chełm	7.4	2.0	E	Summer (August 1996)	[16]
2	Dobrogoszcz	49.0	6.2	E, M		
3	Drzędno	8.7	3.0	E		
4	Głęboczko	6.1	7.5	E, M		
5	Kaliska	7.0	2.1	E		
6	Oczko Małe	1.0	5.1	E		
7	Morskie Oko	4.9	19.2	E, M, H		
8	Oczko Wielkie	3.6	10.0	E, M, H		
9	Okno	14.0	2.1	E		
10	Pławno	47.5	5.5	E		
11	Święte	50.0	6.4	E, M		
12	Zakrzewie	12.5	16	E, M, H		

[1] according to Kraska et al. [4, 5]; E = epilimnion; M = metalimnion; H = hypolimnion

This article is partly based on published results from papers by Szeląg-Wasielewska [14], and Szeląg-Wasielewska and Fyda [16], supplemented with detailed unpublished data. Depth-integrated water samples were collected once (in August) from each lake, at its deepest part, from each of the thermal layer (with 1m interval). Thus the number of integrated samples from each lake equalled the number of thermal layers in August. Detailed information on the methods of collection of water samples and their microscopic analysis can be found in the above-mentioned publications. Statistical analysis of the results included the calculation of linear correlation coefficients. STATISTICA 5.5 software was used for the analysis.

3. Results and discussion

In the first group of lakes, which differed in trophic state (reflected in the range of total phytoplankton biomass: 0.2–35 mg l^{-1}) and in morphometric features, but were generally shallow (no deeper than 8 m) and small (1.6–33 ha), no significant correlation was found between APP abundance (in cells ml^{-1}) or biomass and trophic state (r=-0.02, p=0.936; r=0.402, p=0.098) (Fig. 1).

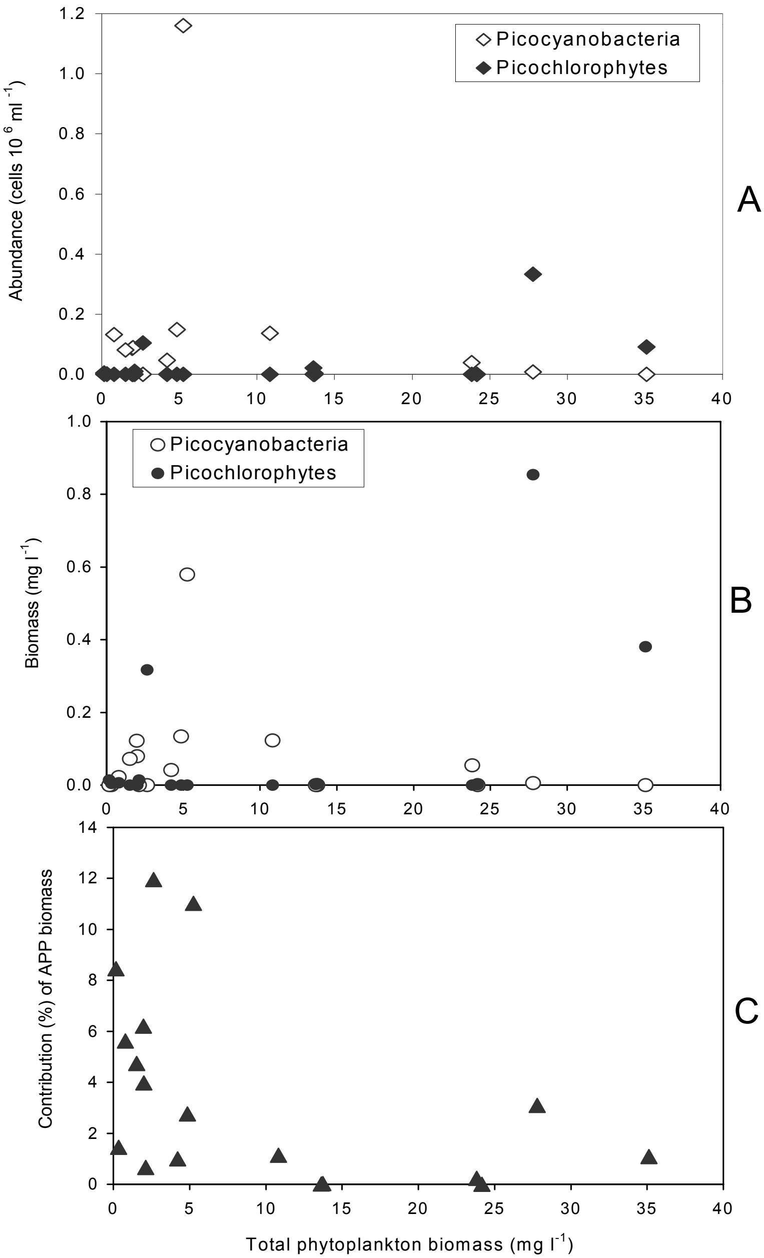

Fig. 1. *Abundance (A), biomass (B) and contribution (C) of autotrophic picoplankton (APP) to total phytoplankton biomass in the first group of lakes plotted against total phytoplankton biomass*

Rys. 1. *Liczebność (A), biomasa (B) i udział (C) autotroficznego pikoplanktonu (APP) w ogólnej biomasie fitoplanktonu w pierwszej grupie jezior w stosunku do ogólnej biomasy fitoplanktonu*

Prokaryotic and eukaryotic components of APP reacted differently to changes in total phytoplankton biomass. The abundance and biomass of prokaryotic APP, i.e. cyanobacteria, decreased with increasing trophic state, but the correlations were not significant ($r=-0.17$, $p=0.499$; $r=-0.21$, $p=0.409$). In contrast, the abundance and biomass of eukaryotic APP, i.e. chlorophytes, increased and the correlations were significant at $p=0.035$ ($r=0.50$) and $p=0.019$ ($r=0.55$), respectively. The contribution of APP to total phytoplankton biomass was significantly and negatively correlated with total phytoplankton biomass: $r=-0.47$, $p=0.049$ [14]. The negative correlation confirms the predictions made by Stockner [11] about a lower relative contribution of APP to total phytoplankton biomass in eutrophic freshwater bodies.

In comparison with larger size fractions of phytoplankton, APP biomass was small. It ranged from nearly 0.001 to 0.86 mg l^{-1}, which on average accounted for only 3.5% of total phytoplankton biomass (Table 2). Lakes with more abundant picochlorophytes were characterized by a high total phytoplankton biomass, absence or low abundance of picocyanoacteria, and acidic water. Total phytoplankton biomass in those lakes was determined mainly by microplanktonic phytoflagellates, from the classes Dinophyceae, Raphidophyceae and Chrysophyceae [14], while water pH did not exceed 6 [4, 5, 6]. This confirms the observations made by Stockner and Shortreed [13], that low pH eliminates picocyanobacteria, and can favour the growth of picochlorophytes.

Tab. 2. Autotrophic picoplankton (APP) in two groups of lakes. Values in parentheses are means

Tab. 2. Autotroficzny pikoplankton (APP) w dwu grupach jezior. Wartości w nawiasach przedstawiają średnie.

Group of lakes	Total phyto-plankton biomass (mg l^{-1})	APP				Contribution (%) of APP to total phytoplank-ton biomass
		Abundance (10^3 cells ml^{-1})			Biomass (mg l^{-1})	
		Total	Pico-cyanobacteria	Pico-chlorophytes		
First	0.2–35 (9.7)	0.32–1160 (139)	0.0–1160 (107)	0.0–333 (32)	0.0007–0.86 (0.16)	0.003–12 (3.5)
Second	1.0–21.2 (3.5)	0.71–2850 (404)	0.71–2850 (400)	0–61 (3.6)	0.001–1.54 (0.27)	0.03–56 (10.0)

In the second group of lobelia lakes, which were also studied in August but several years later, mean APP abundance and contribution of APP to total phytoplankton biomass were 2–3 times higher than in the earlier studied group of lakes (Table 2). APP biomass was positively and significantly correlated ($r=0.61$, $p=0.004$) with total phytoplankton biomass. This positive correlation results from the fact that the highest APP biomass was recorded only in one lake with the highest total phytoplankton biomass (Fig. 2). Elimination of data from that lake resulted in a negative and non-significant correlation ($r=-0.01$, $p=0.974$, $n=19$).

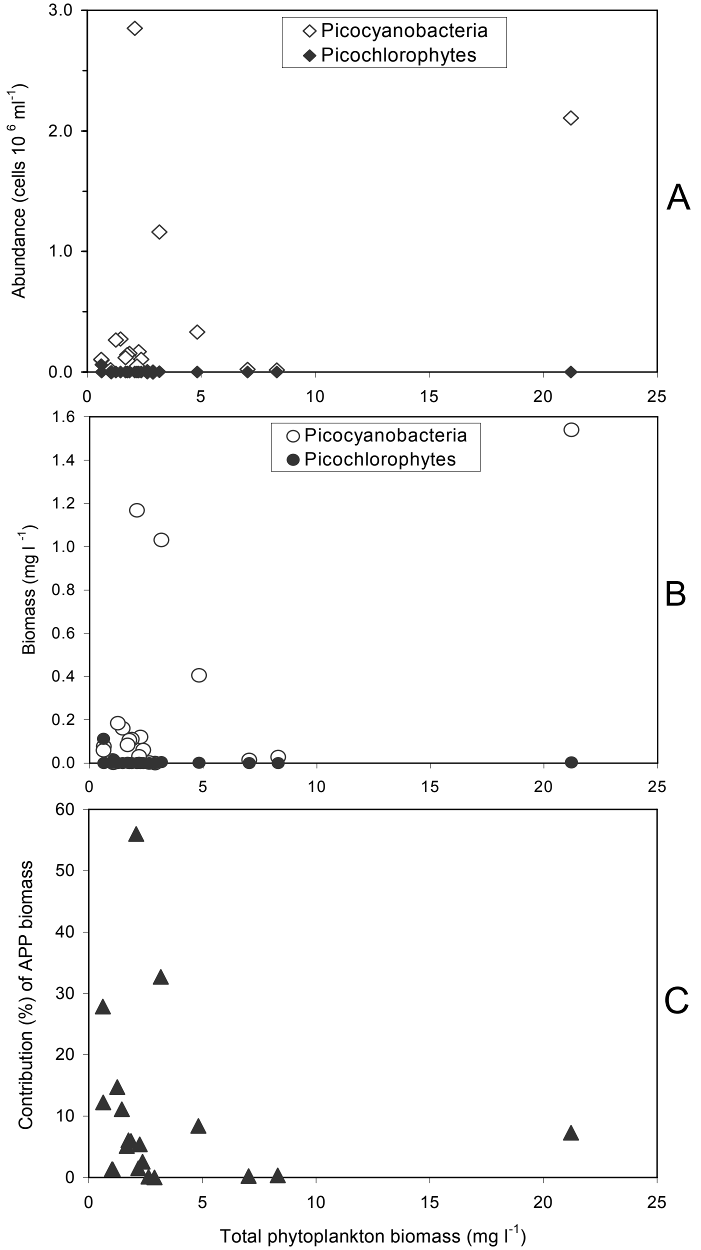

Fig.2. *Abundance (A), biomass (B) and contribution (C) of autotrophic picoplankton (APP) to total phytoplankton biomass (C) in the second group of lakes plotted against total phytoplankton biomass*

Rys.2. *Liczebność (A), biomasa (B) i udział (C) autotroficznego pikoplanktonu (APP) w ogólnej biomasie fitoplanktonu w drugiej grupie jezior w stosunku do ogólnej biomasy fitoplanktonu*

Mean abundance of picochlorophytes in that group of lakes was nearly 9-fold lower than in the first group, while mean abundance of picocyanobacteria was nearly 4-fold higher. In ¼ of water samples, picochlorophytes were not detected, while picocyanobacteria were present in all water samples, which was undoubtedly at least partly due to the neutral or slightly alkaline water pH. Data from Kraska et al. [4] show that water pH during sampling varied between 5.8 and 7.6, and only in three lakes it did not exceed 6.0. Like in the first group of lakes, prokaryotic and eukaryotic components of APP reacted differently to changes in total phytoplankton biomass. The abundance and biomass of picocyanobacteria increased with increasing trophic state, and the correlations were significant ($r=0.46$, $p=0.044$; $r=0.62$, $p=0.004$), while those of picochlorophytes decreased, but the correlations were not significant ($r=-0.15$, $p=0.529$; $r=-0.14$, $p=0.551$). The contribution of APP to total phytoplankton biomass was not significantly correlated with total phytoplankton biomass ($r=-0.13$, $p=0.562$) in that group of lakes (Fig. 2). Results of phytoplankton analysis in those lakes confirmed the suggestions of Stockner [11] about an increase in APP abundance and volume accompanying an increase in trophic state, but its contribution to total phytoplankton biomass did not decrease significantly. The high APP biomass (1.2 and 1.0 mg l^{-1}) and simultaneously its highest contribution (56 and 33%) to total phytoplankton biomass, were recorded in lakes with low or medium values of total phytoplankton biomass, ranging from 2 to 3 mg l^{-1}, i.e. in mesotrophic water bodies, which is consistent with Pick's [7] hypothesis about non-linear relationships between APP and trophic state of lakes.

4. Conclusions

Results from the analysed groups of lakes show that prokaryotic and eukaryotic components of APP need to be considered separately in studies of relationships between APP and trophic state of lakes. Cyanobacteria, which are usually much more abundant, affect those relationships more strongly in neutral and alkaline waters, and are successful in colonizing habitats with a low trophic level. Theoretically they can reach higher growth rates than eukaryotic algae, because of the lower costs of maintenance of their relatively simple cell structure, as compared with other groups of algae [22]. In contrast, picochlorophytes, which tolerate low pH and prefer more fertile habitats, extend the ecological importance of APP in other directions. Thus APP, as a complex composed of components with so diverse requirements, is predisposed to be successful in many types of aquatic habitats.

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