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SPATIAL DISTRIBUTION OF PHYTOPLANKTON COMMUNITIES IN A SMALL WATER BODY

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ABSTRACT. The research on the structure and distribution of a phytoplankton community was carried out in a small water body – Dąbrówka pond (western Poland), during the vegetation period of aquatic plants. The aim of the study was to analyse the spatial distribution of phytoplankton in two vegetated zones: of *Potamogeton pectinatus* L. and *Phragmites australis* (Cav.) Trin. ex Stend. and also in the open water area, with an emphasis placed on the impact of physical-chemical variables as well as the relationship between phyto- and zooplankton abundance. A diverse taxonomical structure (75 taxa) was identified, which is characteristic for small water bodies. At each of the examined stations, diatoms were the dominating group in the quality structure – mainly epiphytic and benthic species. In the zone with *Phragmites australis* the richest species diversity (including diatoms) was recorded as well as the species associated with this plant bed. Cryptophytes and chlorophytes revealed highest densities in the zone of open water, diatoms and cryptophytes prevailed in the station with *Phragmites australis*, while cryptophytes and diatoms dominated in the stand of *Potamogeton pectinatus*. The highest abundance of phytoplankton was found among *Phragmites australis* and this was probably due to both a high participation of epiphytic diatoms and a high concentration of nutrients in the water. The lowest densities of planktonic algae, which were obtained in the stand of *Potamogeton pectinatus* was an effect of overshading caused by this submerged species of macrophytes.

KEY WORDS: small water body, spatial distribution, phytoplankton, zooplankton, *Phragmites australis*, *Potamogeton pectinatus*

INTRODUCTION

A thorough recognition of certain types of water bodies remains still insufficient, particularly with regard to ponds. They are usually of small size and depth and therefore there is no large variation in temperature between the pond bottom and surface waters. The water vegetation of such ecosystems tends to create a mosaic of habitats, which is a characteristic feature for ponds (Ozimek and Rybak 1994). Small water bodies also contribute to the maintenence and enrichment of biodiversity, creating optimal habitat conditions for a variety of freshwater organisms (Biodiversity... 1996).

The functioning of small water bodies is influenced by a number of environmental factors such as the concentration of nutrients, especially of nitrogen and phosphorus, pH, concentration of dissolved mineral salts and oxygen, or water transparency, which can occur over a wide range, influencing the structure of the inhabiting biocenosis (Joniak et al. 2007). Variation in the physical and chemical parameters of the waters and sediments as well as the morphological features of a certain water body will also have an impact on the development of specific aquatic vegetation types (Bosiacka and Radziszewicz 2002), which in turn will have an effect on the creation of specific communities of phytoplankton. The frequent changes of environmental parameters are often reflected in the rich species diversity and the great dynamics of the phytoplankton community compared to large reservoirs (Zimba et al. 2001). Therefore, ponds create a very interesting object for hydrobiological investigations.

A study which was carried out on the Dąbrówka water body in the late spring revealed a presence of *Typhetum latifoliae*, *Zannichellietum palustris* and *Potametum lucentis* (Kuczyńska-Kippen and Nagengast 2006). The present study on the phytoplankton communities was made in two macrophyte phytocoenoses – *Phragmitetum australis* and *Potametum pectinati* and comparatively in the open water zone.

In the Dąbrówka water body a distribution in zooplankton community structure was observed in respect to both rotifers and crustaceans, whose densities differed significantly between particular stations (Kuczyńska-Kippen and Nagengast 2006).

Even though ponds are usually of a small surface, they may create a number of differentiated habitats within a restricted area due to various species of aquatic plants. Hence, the aim of the study was to test the relationships between the phytoplankton community structure and physical-chemical features of a habitat and zooplankton density. Additionally it was planned to describe the habitat preferences of particular phytoplankton species.

MATERIAL AND METHODS

Dąbrówka water body, which is situated in the central part of the Wielkopolska region (Oborniki district), western Poland, is a shallow, macrophyte-dominated pond with a surface area of 0.5 ha and maximum depth of 1.5 m. It is partly surrounded by fields and along its bank there is a tree-lined circumference with dominating *Alnus glutinosa* (L.) Gaertn.

The research was carried out in the late spring time (22 June 2006) in three sampling sites: in two vegetated stands – *Potamogeton pectinatus* L. and *Phragmites australis* (Cav.) Trin. ex Stend. and also in the open water zone. Phytoplankton material was taken at each site using a plexiglass core sampler (∅ 50 mm), which is the method advised for studies within the littoral zone (Schriver et al. 1995). The 1.5 l samples were fixed immediately with Lugol solution and after a few hours additionally with 4% formalin. Samples for qualitative and quantitative analyses of phytoplankton were sedimented to a volume of 5 ml. Numbers of cells were counted in a Fuchs-Rosenthal chamber (chamber parameters: height – 0.2 mm, area of one field – 0.0625 mm^2). Single cells and algae cenobia were regarded as one individual. In the case of trychomes, one segment of 100 μm length was regarded as one individual; in the case of the colony of cyanobacteria (*Microcystis*) a surface of 400 $μm^2$ was regarded as one individual.

Water samples were collected in order to analyse the chemical content. Chlorophyll *a* was determined fluorometrically and corrected for degradation products according to Lorenzen (1966) and its concentrations was given as active photosynthetic pigments.

The U-Mann-Whitney test was applied in order to evaluate differences in phytoplankton densities between particular stations.

RESULTS

The physical-chemical analyses in the investigated pond revealed that the concentrations of total nitrogen, nitrites as well as the mean chlorophyll *a* content, conductivity and pH were similar at particular sampling stations (Table 1). Within the stand of *Phragmites australis* the total phosphorus concentration and that of nitrates, and within the bed of *Potamogeton pectinatus* total concentration of dissolved oxygen reached the highest values.

In the examined water body a total number of 75 phytoplankton taxa, representing seven systematical groups (*Cyanoprokaryota*, *Chlorophyta*, *Bacillariophyceae*, *Euglenophyta*, *Cryptophyceae*, *Dinophyceae* and *Chrysophyceae*) was recorded (Table 2, 3). The participation

Table 1. The values of chosen physical-chemical variables of water quality at particular stations

Station	TP (mg $P \cdot l^{-1}$)	TN (mg $N \cdot l^{-1}$)	Nitrate (mg $NNO_3 \cdot l^{-1}$)	Nitrite (mg $NNO_2 \cdot l^{-1}$)	chl *a* (μg·l^{-1})	Oxygen (%)	pH	Conductivity (μS·cm^{-1})	Temperature (°C)
P	0.139	0.18	0.118	0.009	4.06	42.7	7.7	788	18.7
Phr	0.169	0.12	0.126	0.010	3.42	28.2	7.66	785	18.0
Pot	0.154	0.15	0.109	0.008	3.85	108.7	8.44	769	21.2

P – Pelagial, Phr – Phragmites, Pot – Potamogeton.

Table 2. Number of phytoplankton taxa in the particular localities

Taxonomic group	Total	P	Phr	Pot
Cyanoprokaryota	8	1	5	3
Chlorophyta	21	12	11	5
Bacillariophyceae	33	19	25	9
Euglenophyta	4	0	4	0
Cryptophyceae	5	5	4	4
Dinophyceae	3	2	0	1
Chrysophyceae	1	0	1	0
Total	75	39	51	22

Legend as in Table 1.

Table 3. Taxonomic composition of phytoplankton in the investigated small water body

Phytoplankton	P	Phr	Pot
1	2	3	4
Cyanoprokaryota			
Gloeocapsa minuta (Kütz.) Hollerb.		+	+
Lyngbya contorta Lemm.		+	
Merismopedia punctata Meyen	+		
Microcystis wesenbergii Komárek			+
Oscillatoria limosa Agardh		+	
Oscillatoria mougeotii Kütz. ex Lemm.		+	
Oscillatoria pseudominima Skuja			+
Planktothrix agardhii (Gom.) Anagn. et Kom.		+	
Chlorophyta			
Ankistrodesmus falcatus (Corda) Ralfs	+		
Ankistrodesmus stipitatus (Chod.) Kom.-Legn.		+	
Chlamydomonas bergii Nygaard	+		
Chlamydomonas globosa Snow	+		
Closterium acerosum (Shrank) Ehr.		+	
Closterium moniliferum (Bory) Ehren.		+	
Closterium strigosum Bréb.	+	+	
Coelastrum astroideum De Notaris			+
Cosmarium sp.	+		
Cosmarium laeve Rabenhorst		+	
Crucigenia tetrapedia (Kirchner) W. et G.S. West	+		+
Desmodesmus communis (Hegew.) Hegew.	+	+	
Pediastrum boryanum (Turp.) Menegh.		+	
Scenedesmus dimorphus (Turp.) Kütz.	+		
Scenedesmus ecornis (Ehrenb.) Chodat	+	+	+
Scenedesmus opoliensis (P.G. Richter) E.H. Hegew.	+		
Spirogyra sp.		+	
Tetraedron caudatum (Corda) Hansgirg		+	
Tetraedron minimum (A. Braun) Hansgirg	+	+	
Tetraedron triangulare Kors.	+		+
Ulothrix zonata (Weber & Mohr) Kutz.			+
Bacillariophyceae			
Achnanthes flexella (Kütz.) Brun.	+	+	+
Amphora ovalis Kütz.	+	+	
Anomoeoneis sphaerophora var. *sculpta* O. Müll.	+		
Cocconeis placentula Ehr.	+	+	
Cyclotella sp.	+	+	
Cymbella affinis Kütz.		+	+
Cymbella cistula (Hemp.) Grun.		+	
Cymbella ehrenbergii Kütz.		+	
Cymbella helvetica Kütz.	+	+	
Cymbella ventricosa Kütz.		+	
Epithemia sorex Kütz.	+		
Fragilaria capucina var. *capucina* Desm.	+	+	
Fragilaria construens (Ehr.) Grun. var. Venter Sippen	+	+	
Fragilaria ulna (Nitzsch) Lange-Bertalot		+	

1	2	3	4
Fragilaria ulna var. *acus* (Kütz.) Lange-Bertalot		+	
Gomphonema acuminatum Ehr.	+	+	+
Gomphonema augur var. *gautieri* Van Heurck.			+
Gomphonema intricatum Kütz.		+	+
Gomphonema olivaceum Kütz.		+	+
Gyrosigma attenuatum (Kütz.) Rabenhorst	+	+	
Navicula sp.		+	+
Navicula anglica Ralfs	+		
Navicula cryptocephala Kütz.	+	+	
Navicula cuspidata (Kütz.) Kütz.	+	+	
Navicula minima Grun.			+
Navicula mutica Kütz. var. *ventricosa* (Kütz.) Cl.		+	
Navicula radiosa Kütz.	+	+	+
Nitzschia acicularis (Kütz.) W. Smith	+		
Nitzschia palea Kütz.		+	
Nitzschia sigma (Kütz.) W. Smith		+	
Pinnularia maior (Kütz.) Rabenhorst	+	+	
Stauroneis anceps Ehr.	+	+	
Stauroneis phoenicentron Ehr.	+		
Euglenophyta			
Euglena acus var. *acus* Ehr.		+	
Euglena sp.		+	
Phacus acuminatus Stokes		+	
Phacus mirabilis Pochmann		+	
Cryptophyceae			
Cryptomonas erosa Ehr.	+	+	+
Cryptomonas marssonii Skuja	+	+	+
Cryptomonas ovata Ehr.	+		
Cryptomonas platyuris Skuja	+	+	+
Cryptomonas rostrata Troitzkaja emend. I. Kiselev	+	+	+
Dinophyceae			
Gymnodinium sp.	+		
Peridinium cinctum (O.F Müller) Ehr.			+
Peridinium incospicuum Lemm.	+		
Chrysophyceae			
Dinobryon divergens Imhoff		+	

Legend as in Table 1.

of a particular phytoplankton group in the taxonomical structure at certain stations was alike. *Bacillariophyceae* (33 taxa in total), which occurred most abundantly in the zone of the common reed (25 taxa), was a dominating group. *Chlorophyta* (21 taxa in total) was also abundant in the species composition of the phytoplankton community. Station with *Phragmites australis* was also characterised by the richest species variation of phytoplankton (51 taxa), as well as by the greatest amount of species occurring exclusively there (*Lyngbya contorta*, *Oscillatoria limosa*, *O. mougeotii, Planktothrix agardhii, Ankistrodesmus stipitatus*, *Closterium acerosum*, *C. moniliferum*, *Cosmarium laeve*, *Pediastrum boryanum*, *Spirogyra* sp. and *Tetraedron caudatum*). The lowest taxonomical diversity was observed in the case of the *Potamogeton pectinatus* bed (22 taxa).

Total phytoplankton density reached a level of 775 ind.·ml^{-1}. Cryptophytes, which accounted for 45% of the total phytoplankton density, were the dominating group. The highest abundance of cryptophytes was found in the zone of open water (Fig. 1). On analysing the spatial distribution of the phytoplankton densities it was observed that the highest total abundance of phytoplankton occurred in the zone of *Phragmites*

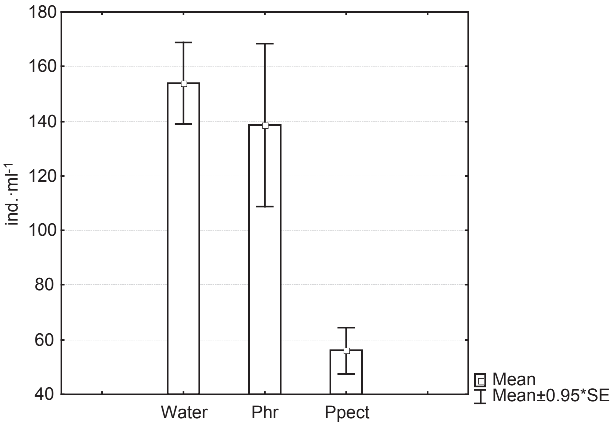

FIG. 1. Mean abundance of cryptophytes in the particular localities (Water = Pelagial, Phr – *Phragmites australis*, Ppect – *Potamogeton pectinatus*)

australis (432 ind.·ml^{-1}) and the lowest within the zone of *Potamogeton pectinatus* (108 ind.·ml^{-1}). There was also a difference in the dominating groups of phytoplankton between the examined stations (Fig. 2). In the open water area cryptophytes (154 ind.·ml^{-1}) and chlorophytes (58 ind.·ml^{-1}) dominated, while in the zone of rushes – diatoms (219 ind.·ml^{-1}) and cryptophytes (139 ind.·ml^{-1}) and finally at the station with *Potamogeton* – cryptophytes (56 ind.·ml^{-1}) and diatoms (47 ind.·ml^{-1}). *Cryptomonas erosa* was a dominating species at all the investigated sites. *Cryptomonas marssonii* dominated both in the zone of open water and among the common reed, while *Gomphonema olivaceum* dominated in the common reed and within the *Potamogeton* stand. Another species – *Chlamydomonas bergii* dominated exclusively in the pelagic zone and *Oscillatoria limosa* dominated only in the zone of *Phragmites*. In the Dąbrówka water body statistically significant differences in phytoplankton abundance were recorded between the studied sites in respect to the following species: *Gloeocapsa minuta* (Z = –1.96, p = 0.05), *Crucigenia tetrapedia* (Z = +1.96, p = 0.05), *Tetraedron triangulare* (Z = +1.96, p = 0.05), *Achnanthes flexella* (Z = –1.96, p = 0.05), *Gomphonema acuminatum* (Z = –1.96, p = 0.05), *Gomphonema intricatum* (Z = –1.96, p = 0.05), *Gomphonema olivaceum* (Z = –1.96, p = 0.05), *Navicula cryptocephala* (Z = –1.96, p = 0.05), *N. radiosa* (Z = –1.96, p = 0.05), *N. cuspidata* (Z = –1.96, p = 0.05), *Stauroneis anceps* (Z = –1.96, p = 0.05). Among the above species all diatoms and *Gloeocapsa minuta* from among cyanoprokaryotes reached the highest densities in the stand of *Phragmites australis*. Small-bodied chlorophytes – *Crucigenia tetrapedia* and *Tetraedron triangulare* – were most abundant in the zone of *Potamogeton pectinatus*.

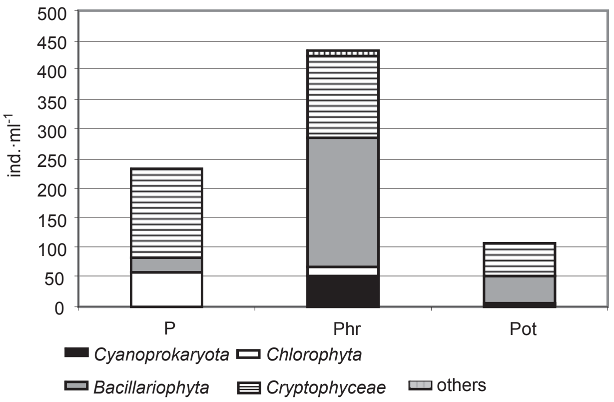

FIG. 2. Abundance of phytoplankton in the particular localities in the investigated water body in 22.06.06 (legend as in Table 1)

The analysis of the relationship between the algae densities and environmental factors revealed that cyanoprokaryotes ($r = 0.80$, $p < 0.05$) and diatoms ($r = 0.79$, $p < 0.05$) positively correlated with total phosphorus concentration.

DISCUSSION

The data presented in this paper shows that in a small water body located within pastoral catchment area a differentiation in the phytoplankton community structure was recorded in the spatial aspect. This mainly concerned the algae abundance and was related to a number of environmental factors, such as physical--chemical, habitat features relating to the presence of various species of macrophytes, which differ morphologically and spatially as well as the interactions between phytoplankton as producers and zooplankton as its consumers. On analysing the taxonomical structure of the phytoplankton community a rich species composition was found, which is typical for ponds (DELLA BELLA et AL. 2008). Domination of diatoms (particularly in the macrophyte-dominated stations) was probably due to a high participation of benthic and epiphytic species represented the following genera: *Cocconeis*, *Cymbella*, *Fragilaria*, *Gomphonema* and *Navicula*. The above mentioned diatoms have often been recorded from small water bodies as well as from shallow lakes (MICHELUTTI et AL. 2003, SIMKHADA and JUTTNER 2006, VILLANUEVA 2006). In the zone within the *Potamogeton* only diatoms of the genera *Gomphonema* and *Navicula* dominated, while no epiphytic species, often attributed to this zone such as *Cocconeis placentula*, *Diatoma hiemale*, *Amphora* sp., *Fragilaria ulna* (SULTANA et AL. 2004, ERSANLI and GONULOT 2007) were recorded here.

In small water bodies communities of algae of small sizes are very common (PODBIELKOWSKI and TOMASZEWICZ 1982). This tendency was fully reflected in the case of the examined pond, where species from the cryptophytes group were dominating among the total phytoplankton abundance. Among this group of algae taxa, which have a wide range of tolerance towards the environmental factors, *Cryptomonas erosa* and *C. marssonii* occurred in great densities (MESSYASZ 1996). The fact that *C. erosa*, oval in shape, dominated at all studied sites is also worth mentioning. JAVORNICKY (2003) states that in macrophyte-dominated small water bodies, cryptophytes of an oval or ellipsoidal shape often prevail. The greatest abundance of cryptophytes and small chlorophytes was observed in the zone of open water, where the pressure of zooplankton grazing was quite small. Food resources available to zooplankton may often depend on the species-specific food selectivity. In most cases phytoflagellates such as *Rhodomonas*, *Chlamydomonas* or *Cryptomonas* are grazed by planktonic species more efficiently than coccal forms such as e.g. *Chlorella* or *Scenedesmus* (Gilbert and Bogdan 1981, Bogdan and Gilbert 1987, Knisely and Geller 1986). In the open water area of the examined pond the lowest abundance of both cladocerans and copepods was found (Kuczyńska-Kippen and Nagengast 2006), possibly due to the presence of visual predators selectively feeding on the larger part of the zooplankton community, which prefer the above mentioned groups of algae (Wilk-Woźniak et al. 2001). Moreover, in this area the highest value of conducticity was noted. A high content of mineral compounds dissolved in the water may have advantageously influenced development of cryptophytes.

The highest abundance of phytoplankton in the zone with *Phragmites australis* (compared to the remaining stations), was connected with a high participation of epiphytic diatoms. Furthermore, a large abundance of cyanoprokaryota at this station (also compared to the remaining stations) was possibly due to the reasonably high concentration of total phosphorus. The statistical analyses confirmed the fact that the cyanoprokaryota densities were positively correlated with total phosphorus. In addition, the higher concentration of nitrogen and alkaline pH of the water may also have had an advantageous impact on the development of cyanoprokaryota.

When analysing the distribution of phytoplankton abundance within habitats dominated by macrophytes several factors should be taken into consideration. The submerged macrophytes may create a perfect concealment conditions for zooplankton trying to avoid the predators, both visual and tactile (Jeppesen et al. 1997, Burks et al. 2001, Lau and Lane 2002); they also restrict light availability, slowing down or inhibiting the process of phytoplankton photosynthesis (Tracy et al. 2003). Furthermore, aquatic plants are great competitors for light and nutrients with periphytic and planktonic organisms (Donk et al. 1993, Schriver et al. 1995). Hydromacrophytes also restrict the water currents in the littoral area of water bodies, thereby favouring an increase in the sedimentation rate and restricting the exchange process between the area of open water and the littoral (Lampert and Sommer 2001). In the case of the investigated pond a small abundance as well as a quite poor taxonomical structure of the phytoplankton community in the zone with fennel pondweed was recorded. Since the mean zooplankton densities were also the lowest in this macrophyte stand, the situation was not due to high grazing pressure on phytoplankton (Kuczyńska-Kippen and Nagengast 2006). Similarly, the chemistry of the water could not have a greater impact on the structure of the phytoplankton community inhabiting the fennel pondweed bed. There was a high content of dissolved oxygen as well as high concentrations of available nutrients – phosphorus and nitrogen – recorded within this macrophyte stand, creating favourable conditions for phytoplankton growth. Therefore, the most stright-forward explanation of the limiting function of *Potamogeton* on the phytoplankton communities is the light restriction caused by this macrophyte. *Potamogeton pectinatus* is characterized by numerous long, narrow leaves, which are variable in shape and may be linear or thread-like, circular or grooved in cross-section, therefore they may contribute to light restriction in this morphologically complicated habitat.

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