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Influence of *Ceratophyllum demersum* L. on phytoplankton structure in a shallow eutrophic lake

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Key words: phytoplankton, *Ceratophyllum demersum*, emergent vegetation, pelagic zone, shallow lake

Abstract

Phycological analyses were conducted in the shallow, eutrophic Lake Rosnowskie Duże (western Poland). Water samples were collected in 2002 and 2003 during the growing season from the submerged vegetation zone (*Ceratophyllum demersum* L.) and comparatively from the emergent vegetation zone (*Typha angustifolia* L.) and the pelagic zone. Phytoplankton was dominated by Chlorophyta, Bacillariophyceae, and Cyanoprokaryota. In comparison with other zones, the highest values of abundance and biomass of Chlorophyta were recorded in the submerged vegetation zone. Additionally, *Ceratophyllum demersum* was found to inhibit diatom development, which is probably connected with the secretion of allelopathic substances by this plant. The aim of the current study was to analyze the influence of *Ceratophyllum demersum* L. on the structure of phytoplankton in a shallow, eutrophic lake.

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INTRODUCTION

Macrophyte communities influence many aspects of lake structure and function. They play important roles in lakes by stabilizing the sediments (e.g. reduced re-suspension and increased sedimentation), absorbing nutrients both from the bottom sediments and from the overlying water layer (Basu et al. 2000, Lau&Lane 2002), and competing with phytoplankton for nutrients (Schriver et al. 1995). Heavy growth of macrophytes also inhibits the production of phytoplankton by shading (Asaeda&van Bon 1997). Moreover, macrophyte beds are favorable for zooplankton development, due to the refuge they provide against fish predation. Many species of submerged macrophytes produce allelopathic substances that suppress algal growth, e.g., *Chara globularis* Thuillier, *Myriophyllum spicatum* L., *Najas marina* ssp. *intermedia* (Wolfgang) Casper, and *Ceratophyllum demersum* L. (Mjelde&Faafeng 1997, Gross et al. 2003). It has been proved that these allelopathic substances can cause an increase in the trophic level of lakes (Burks et al. 2000).

The aim of the current study was to analyze the influence of *Ceratophyllum demersum* (rigid hornwort) on the qualitative and quantitative structure of phytoplankton in a shallow, eutrophic lake.

MATERIALS AND METHODS

Lake Rosnowskie Duże is located in the Wielkopolska National Park (near the city of Poznań in western Poland). As a result of the progressing sediment deposition and colonization of the lake by emergent vegetation, the lake has been separated naturally into four basins that differ in depth and surface area. The investigated basin is small and shallow (area 3 ha, max. depth 3.5 m). Submerged macrophytes (*Ceratophyllum demersum* L.) were present only in this basin of the lake.

Phytoplankton research was conducted in 2002 and 2003 during the growing season of macrophytes (May–August). Water samples were collected biweekly in spring, and monthly in summer from three zones: submerged macrophytes (*Ceratophyllum demersum* L.), emergent macrophytes (*Typha angustifolia* L.), and the pelagic zone. The samples (total 27) were collected using plastic bottle, from the surface layer of water (at a depth of c. 0.5 m) and next preserved with Lugol's solution and formalin. In the laboratory, they were sedimented and next analyzed qualitatively and quantitatively. Individuals were counted in a Fuchs-Rosenthal chamber. Biomass was estimated from cell numbers and specific volumes (Kawecka&Eloranta 1994). The concentration of chlorophyll *a* was analyzed with the Lorenzen method after acetone extraction (Polish Standards 1986). Values of trophic state index were estimated according

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to Carlson's (1977) logarithmic transformation based on chlorophyll *a* concentration and Secchi depth. The Shannon-Weaver diversity index (Margalef 1957) was used to define the species diversity of phytoplankton inhabiting the different zones. Standard statistical methods were preformed to describe and analyze the data using STATISTICA for Windows 6.0. All the data were log-transformed before preforming the tests. The paired-samples t test was used to compare the abundance of algae at the sapling points studied.

RESULTS

During the study period, 131 taxa of prokaryotic and eukaryotic algae were observed in the investigated basin of the lake. The dominant group of phytoplankton was Chlorophyta (57 taxa). The highest number of taxa (110) was recorded in the emergent vegetation zone, where the highest number of diatoms (35 taxa) was also observed. The lowest number of species (97 taxa) was noted in the pelagic zone. In comparison with other zones, the highest number of cyanoprokaryotes (18 taxa) and green algae (54 taxa) were noted in *Ceratophyllum* beds. At this station, the highest number of exclusive species (7) was noted: *Closterium incurvum* Bréb., *Cosmarium dentiferum* Corda, *Cosmarium margaritatum* (Turp.), Ralfs *Merismopedia glauca* (Ehrenb.) Nägeli, *Microcystis grevillei* (Hass.) Elenkin, *Lyngbya birgei* G. M. Smith, and *Phacus acuminatus* Stokes.

Quantitative analysis of planktonic algae showed that Chlorophyta and Bacillariophyceae were dominant groups in the investigated zones (Figs. 1, 2).

The highest mean abundance of Chlorophyta in summer (4613 ind. ml^{-1}, SD=6492.1) and the highest mean biomass in spring (5.78 mg l^{-1}, SD=9.693) were recorded in the submerged vegetation zone in comparison with other zones. In this zone, the taxa that dominated most frequently were: *Ankistrodesmus falcatus* (Corda) Ralfs, *Crucigenia tetrapedia* (Kirchner) W. et G.S. West, *Crucigeniella rectangularis* (Näg.) Komárek, *Desmodesmus communis* (Hegew.) Hegew., *Kirchneriella contorta* (Schmidle) Bohlin, *Tetraedron minimum* (A. Braun) Hansgirg. Considering the abundance of Chlorophyta in spring and summer, statistically significant changes were noted between the submerged vegetation zone and the pelagic zone (paired-samples *t*-test: p=0.05, t=-2.288). The mean abundance and biomass of Bacillariophyceae in spring (386 ind. ml^{-1}, SD=488.5; 0.26 mg l^{-1}, SD=0.342) and summer (448 ind. ml^{-1}, SD=537; 0.29 mg l^{-1}, SD=0.28) were the lowest in the zone with *Ceratophyllum demersum* in comparison with other stations. Statistically significant differences between the submerged vegetation zone and pelagic zone were noted in the abundance of Bacillariophyceae (paired-samples t test: p=0.047, t=-2.346)., Chrysophyceae and Dinophyceae (Figs. 1, 2) also

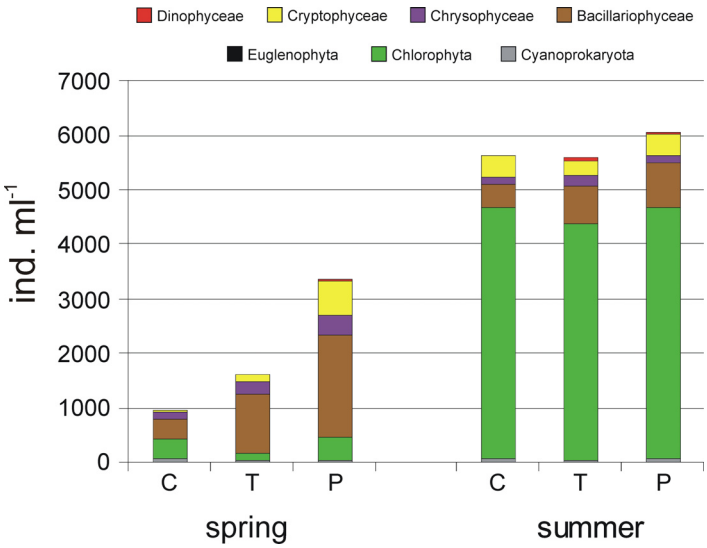


Fig. 1. Mean phytoplankton abundance at sampling stations (C = *Ceratophyllum*; T = *Typha*; P = pelagic zone) in Lake Rosnowskie Duże in 2002 and 2003.

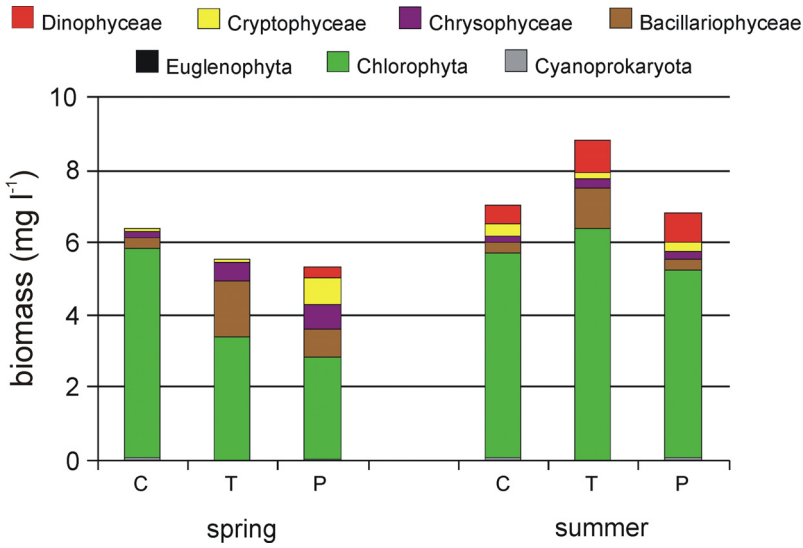


Fig. 2. Mean phytoplankton biomass at sampling stations (C = *Ceratophyllum*; T = *Typha*; P = pelagic zone) in Lake Rosnowskie Duże in 2002 and 2003.

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had the lowest abundance and biomass in the submerged vegetation zone, but the differences between this zone and the pelagic zone were not significant ($p>0.05$).

The Shannon-Weaver biodiversity index was the highest (up to 4.1) within the *Ceratophyllum demersum* stand (in summer). The highest mean value of this index was observed in spring in this zone in comparison with other stations (Fig. 3).

Values of the analyzed trophic parameters in 2002 and 2003 indicate that Lake Rosnowskie Duże is eutrophic. The visibility in the water column was low in the investigated basin during the studied period and ranged from 1 – 1.4 m. The TSI (trophic state index) was as high as 60 units for Secchi depth and 65 units for chlorophyll *a*.

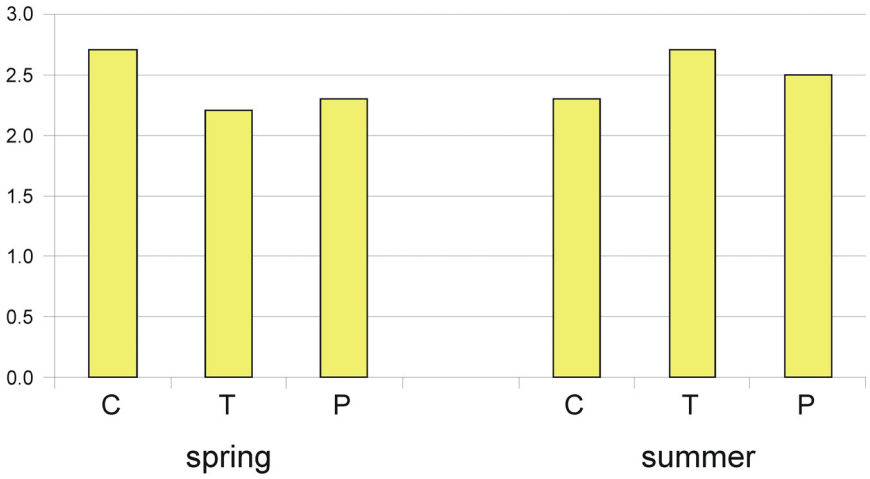


Fig. 3. Mean values of Shannon-Weaver biodiversity index at sampling stations (C = *Ceratophyllum*; T = *Typha*; P = pelagic zone) in Lake Rosnowskie Duże in 2002 and 2003.

DISCUSSION

The results of the phycological research indicate that *Ceratophyllum demersum* forms a specific habitat for phytoplankton development in the lake ecosystem. Patches of this submerged macrophyte species significantly affect the qualitative and quantitative structure of the phytoplankton. Of the three zones investigated, the submerged vegetation zone in Lake Rosnowskie Duże was the most compact and complicated morphologically. Research conducted

by Reynolds (1995) and Celewicz et al. (2004) showed that the more varied the vegetation structure is, the better the living conditions it provides for the organisms that colonize it. This is why the proportion of exclusive taxa (i.e., those found exclusively in a given zone) was the highest within patches of *Ceratophyllum*. The highest Shannon-Weaver diversity index value was also recorded in this zone when the macrophytes were fully developed. Thus, dense patches of submerged vegetation provide a specific habitat and contribute to increased numbers of phytoplankton species (Kuczyńska-Kippen&Messyasz 1998). Patches of submerged macrophytes in shallow eutrophic lakes can also inhibit phytoplankton growth (Wigand et al. 2000). *Ceratophyllum demersum* is known for its negative effect on phytoplankton development due to secretion of allelopathic substances (Mjelde&Faafeng 1997, Gross et al. 2003). In Lake Rosnowskie Duże a considerable decrease was recorded in the abundance and biomass of Bacillariophyceae in patches of *Ceratophyllum* in comparison with other zones. This suggests that *Ceratophyllum* inhibits the growth of diatoms. This phenomenon was observed mainly in spring, when macrophyte growth was the most intense, and hence the secretion of allelopathic substances was higher than in summer (Jasser 1995). However, the low contribution of Bacillariophyceae to the quantitative structure of phytoplankton in the submerged vegetation zone can additionally result from grazing pressure exerted by zooplankton. It was also noted in the lake studied that in patches of *Ceratophyllum* a high (often the highest) number of species and high abundance of Chlorophyta were recorded in comparison with other sampling stations. Allelopathic substances secreted by this macrophyte species probably stimulate the development of Chlorophyta, mainly of small-sized green algae of the order Chlorococcales, which dominated in the submerged vegetation zone of the studied lake. A study by Mulderij et al. 2003 confirms that *Ceratophyllum demersum* does not limit the growth of Chlorophyta. Jasser (1995) as well as van Donk & van de Bund (2002) observed an increase in the biomass of green algae of the genera *Chlorella* and *Chlamydomonas* in clumps of *Ceratophyllum demersum*. Literature data (Nakai et al. 1999, Körner&Nicklisch 2002) show that *Ceratophyllum* inhibits the growth of Cyanoprokaryota. In contrast, the present study in Lake Rosnowskie Duże did not reveal any limiting influence of *Ceratophyllum* on the growth of Cyanoprokaryota, Cryptophyceae, or Euglenophyceae.

The process of the secretion of chemical substances by *Ceratophyllum demersum* and their influence on various taxonomic groups of phytoplankton has not been thoroughly studied yet. Strong relationships are still being searched for, as are the causes of such relationships. The results of the current study indicate that there is an association between such relationships and the developmental stage of the macrophyte. It is necessary to continue observations

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for many years (in natural water bodies) in order to analyze more precisely and explain this interesting phenomenon.

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