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The in situ influence of *Ceratophyllum demersum* on a phytoplankton assemblage

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Abstract

The aim of this work was to present a quantitative and qualitative analysis of a phytoplankton assemblage under the influence of *Ceratophyllum demersum* L. during a two-year field study. Literature data obtained under laboratory conditions indicate that *C. demersum* may cause a decrease in the blue-green algae biomass, which is considered to be evidence of the significance of allelopathy. The observations reported in the current paper indicated that there was no clear effect on cyanoprokaryota whereas decreases in the quantity of Cryptophyta, Dinophyta, Chlorophyta, and Chrysophyceae are noted.

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INTRODUCTION

Ceratophyllum demersum is a canopy-forming submersed hydrophyte with low light requirements that inhabits shallow as well as deeper littoral habitats in fertile waters. It is thought to influence phytoplankton by competing for nitrogen and light and through allelopathic interactions. In the period of intensive growth *C. demersum* takes up large amounts of inorganic nitrogen thus causing temporal nitrogen limitation in summer. In fall, by contrast, the decomposing plant tissues of freely floating mats of *C. demersum* are an important source of nutrients (Mjelde and Faafeng 1997, van Donk and van de Bund 2002, Gross 2003). *Ceratophyllum demersum* showed allelopathic activity toward phytoplankton. Sulfur or lipophilic, labile compounds have been described as the major algicides in lipophilic extracts (Wium-Andersen et al. 1983). The data reported in the literature indicates that *C. demersum* has an allelopathic effect on planktonic algae under experimental conditions, and, in particular, on Cyanoprokaryota (Jasser 1994, 1995).

The aim of the current study was to determine if the inhibiting effect of *Ceratophyllum demersum* on phytoplankton can be observed in situ and, if so, which groups are particularly affected.

MATERIALS AND METHODS

The study was performed in the shallow Lake Jarosławieckie, a post-glacial reservoir with no flow and a maximal depth of 6.6 m. Three sampling sites were distributed along a transect traversing macrophyte communities as well as an open water site, as follows: a macrophyte-free mid-lake site; a patch of *Nymphaea alba* with *Ceratophyllum demersum*; a patch of *Phragmites australis* overgrown by *C. demersum*. Water samples were collected from the surface layer (0-50 cm) and, at the sites in plant communities, from amongst the plants in November 2000, March, May, June, July, September, and November 2001 and 2002. Water samples for phytoplankton analyses (1 l volume) were fixed with Lugol's solution and 4% formaldehyde and then sedimented to a volume of 15 ml. Individuals were counted in a Fuchs-Rosenthall chamber. Biomass was estimated from cell numbers and specific volumes (Wetzel and Likens 1991).

RESULTS AND DISCUSSION

The lowest abundance of phytoplankton was observed at the site in the *Phragmites australis* patch overgrown by *Ceratophyllum demersum*, in particular between May and September each year (Fig. 1). Due to its shallowness (shallowest of the studied sites), *C. demersum* grew throughout the

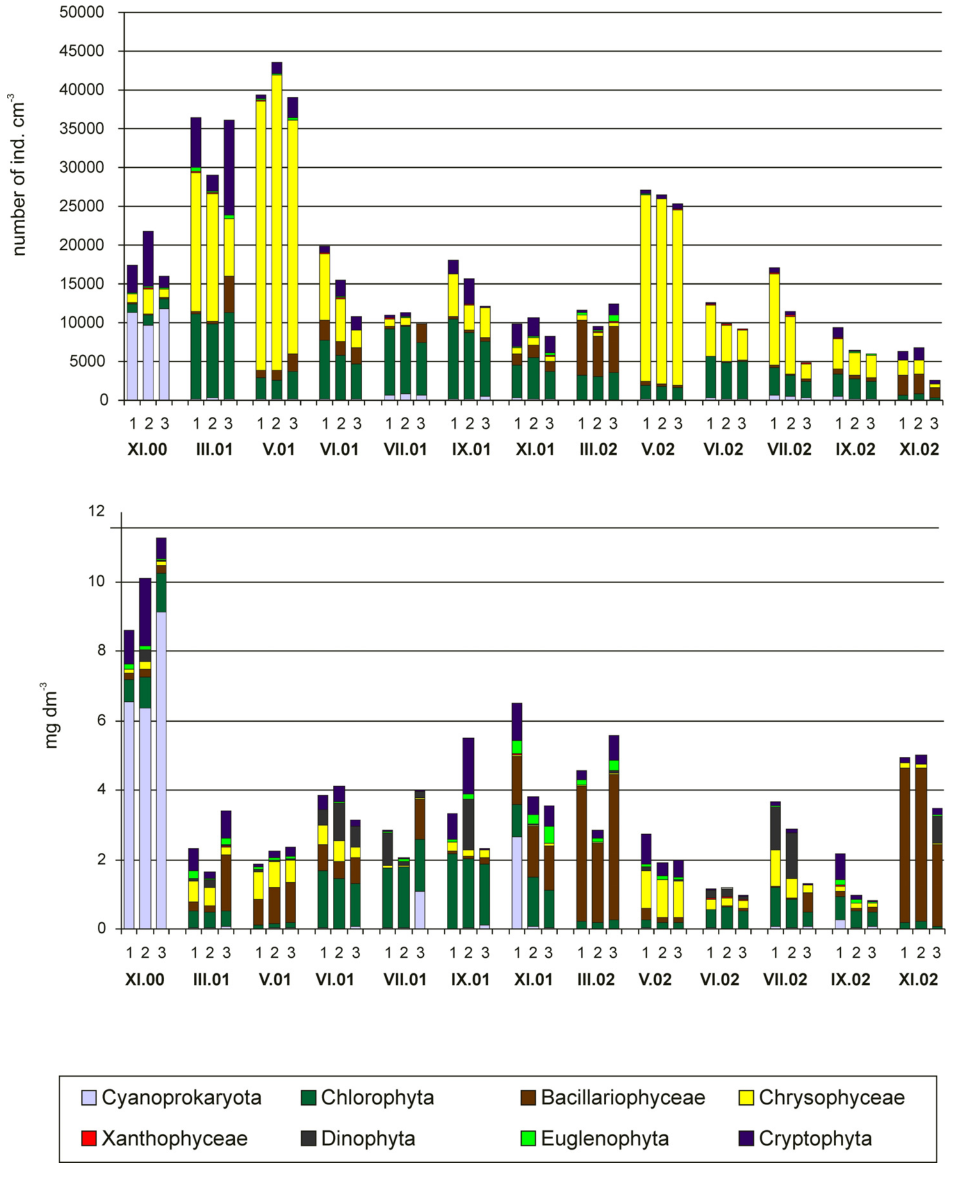

Fig. 1. Seasonal changeability of phytoplankton abundance and biomass at three sites studied in Lake Jarosławieckie between November 2000 and November 2002. 1- macrophyte-free mid lake; 2 – *Nymphaea alba* patch with *Ceratophyllum demersum*; 3 - *Phragmites australis* patch overgrown by *C. demersum*.

water column. The mean abundance of phytoplankton was lower at both sites with *C. demersum* than at the open water one (Fig. 2). The decrease in abundance was observed in the case of representatives of Cryptophyta, Dinophyta, Chlorophyta, and Chrysophyceae.

Biomass analysis indicated that the highest mean amounts were also at the macrophyte-free mid-lake site, while lower mean phytoplankton biomass was noted at both sites with *C. demersum* (Fig. 2). Possible explanations for this finding include the shading effect of nymphaeid leaves and *C. demersum* on biomass production. This factor may have been of greater importance.

Interestingly, at the site with the highest contribution of *C. demersum* (*Phragmites* patch) the dominance of diatoms and cryptophyceans was observed in March each year, which corroborates the literature data from some Norwegian *C. demersum*-dominated lakes (Mjelde and Faafeng 1997).

Importantly, the current study, in contrast to those performed by Jasser (1994, 1995), did not confirm the inhibiting effect of *C. demersum* on the development of blue-greens. In the period of mass occurrence of *Pseudanabaena catenata* Lauterborn in the studied lake (November 2000), both the abundance and biomass of this species exhibited the highest values at the site overgrown by *C. demersum*. The ongoing decomposition of *C. demersum* debris might have supplied the blue-greens with nutrients. What is more, 13 cyanoprokaryotic taxa were observed at this site only, while there were five at both of the sites with contributions of *C. demersum* (Table 1). The abundance of six cyanoprokaryotic taxa increased along with increasing share of *C. demersum*. This seems to confirm the lack of the inhibiting effect of *C. demersum* on Cyanoprokaryota. Furthermore, at the site with *Phragmites australis* overgrown by *C. demersum* only an invasive cyanoprokaryotic species *Cylindrospermopsis raciborskii* (Wołosz.) Seenayya et Subba Raju was detected in September. It can form dense blooms in shallow and nutrient-rich lakes (Padisak 1997). At this site the whole water column was overgrown by *C. demersum* which, with additional isolation from the open water by a wide belt of floating-lived vegetation, also developed with *C. demersum*, might have decreased wind-induced water movement and increased water temperature and, thus, promoted this potentially toxic species (Saker, Griffiths 2000).

The visible decline of cyanoprokaryotic species abundance along with an increasing share of *C. demersum* was detected only in two cases: *Chroococcus minimus* (Keissler) Lemmermann and *Phormidium tenue* (Ag. ex Gom.) Anagn. et Kom. All of the above-mentioned examples of cyanoprokaryotic occurrence at sites studied seem to confirm generally the lack of the inhibiting effect of *C. demersum* on Cyanoprokaryota. In contrast, Chlorophyta, Chrysophyceae, Xanthophyceae, Dinophyta, and Cryptophyta exhibited considerable sensitivity

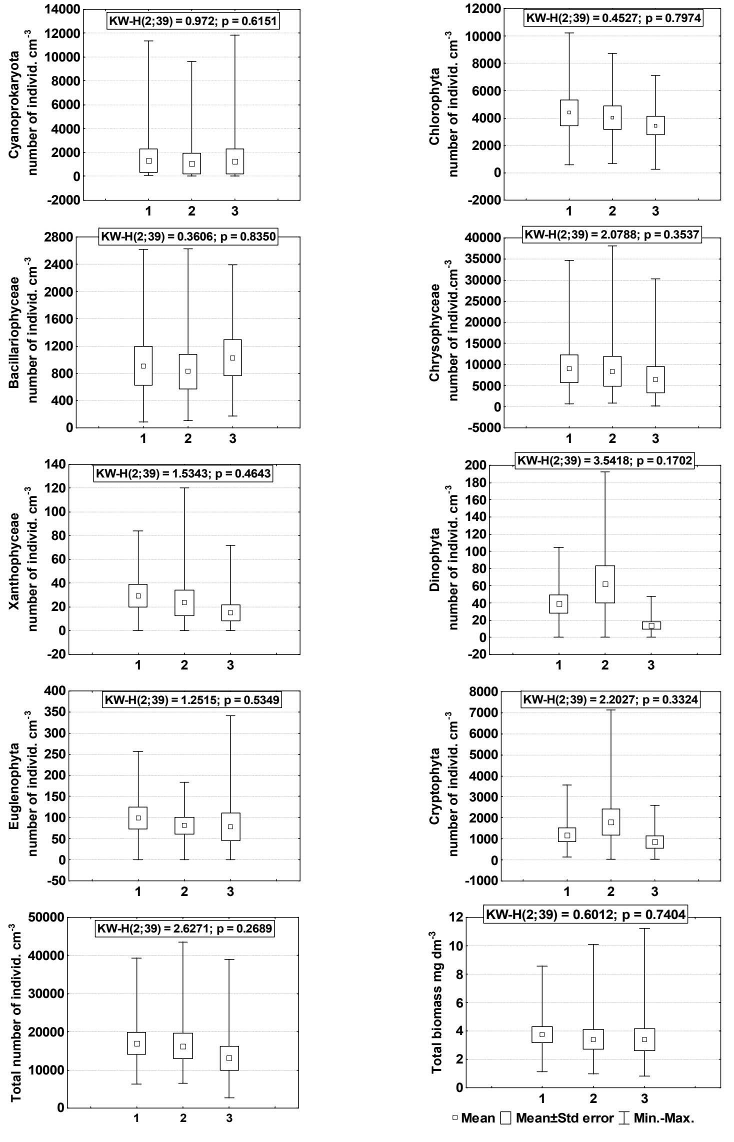

Fig. 2. Mean, minimal and maximal quantities of total abundance and biomass and abundance in phytoplankton groups. At each site N = 13. Statistical significance of the differences among studied sites was checked with ANOVA with the Kruskal-Wallis H-test. 1- macrophyte-free mid lake; 2 – *Nymphaea alba* patch with *Ceratophyllum demersum*; 3 - *Phragmites australis* patch overgrown by *C. demersum*.

Table 1

Mean abundance of blue-green algae at three sites studied in Lake Jarosławieckie between November 2000 and November 2002. 1- macrophyte-free mid lake; 2 – *Nymphaea alba* patch with *Ceratophyllum demersum*; 3 - *Phragmites australis* patch overgrown by *Ceratophyllum demersum*. For each species at each study site N = 13

Taxa	1	2	3
Anabaena oscillarioides Bory	<0.05	<0.05	0.05 – 0.1
Cylindrospermopsis raciborskii (Wołosz.) Seenayya et Subba Raju	<0.05	<0.05	0.05 – 0.1
Limnotrix guttulata (van Goor) Anagn.	<0.05	<0.05	0.05 – 0.1
Lyngbya aestuarii (Mertens) Liebmann	<0.05	<0.05	0.05 – 0.1
Lyngbya nigra Agardh	<0.05	<0.05	0.05 – 0.1
Oscillatoria limosa Agardh	<0.05	<0.05	0.05 – 0.1
Oscillatoria sp.	<0.05	<0.05	0.05 – 0.1
Oscillatoria subbrevis Schmidle emend. Claus	<0.05	<0.05	0.05 – 0.1
Phormidium chalybeum (Mert. ex Gom.) Anagn. et Kom.	<0.05	<0.05	0.05 – 0.1
Phormidium cortianum (Menegh. ex Gom.) Anagn. et Kom.	<0.05	<0.05	0.05 – 0.1
Phormidium koprophilum (Skuja) Anagn.	<0.05	<0.05	0.05 – 0.1
Phormidium puteale (Mont. ex Gom.) Anagn. et Kom.	<0.05	<0.05	0.05 – 0.1
Phormidium splendidum (Grev. ex Gom.) Anagn. et Kom.	<0.05	<0.05	6.1 – 20
Komvophoron constrictum (Szafer) Anagn. et Kom.	<0.05	0.05 – 0.1	0.05 – 0.1
Oscillatoria sancta (Kützing) Gomont	<0.05	0.05 – 0.1	0.05 – 0.1
Phormidium diguetii (Gom.) Anagn. et Kom.	<0.05	0.05 – 0.1	0.05 – 0.1
Porphyrosiphon martensianus (Menegh. ex Gom.) Anagn. et Kom.	<0.05	0.05 – 0.1	0.05 – 0.1
Pseudanabaena galeata f. *tenuis* (Böcher) V. Poljanskij	<0.05	0.11 – 2	0.11 – 2
Chroococcus turgidus (Kützing) Nägeli	<0.05	0.11 – 2	0.11 – 2
Jaaginema geminatum (Menegh. ex Gom.) Anagn. et Kom.	<0.05	0.11 – 2	6.1 – 20
Microcystis flos-aquae (Wittrock) Kirchner	<0.05	0.11 – 2	0.11 – 2
Phormidium amphibium (Ag. ex Gom.)	0.11 – 2	0.05 – 0.1	2.1 – 6
Pseudanabaena galeata Böcher	0.05 – 0.1	0.11 – 2	2.1 – 6
Pseudanabaena limnetica (Lemm.) Kom.	6.1 – 20	6.1 – 20	21 – 100
Chroococcus minimus (Keissler) Lemmermann	>141	101 – 140	21 – 100
Phormidium tenue (Ag. ex Gom.) Anagn. et Kom.	2.1 – 6	0.11 – 2	0.11 – 2

Mean number of individuals ml^{-1} in the two-year study	
	<0.05
	0.05 – 0.1
	0.11 – 2
	2.1 – 6
	6.1 – 20
	21 – 100
	101 – 140
	>141

to *Ceratophyllum demersum* as was evidenced by the results of the present study.

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