Oceanological and Hydrobiological Studies
International Journal of Oceanography and Hydrobiology
Vol. XXXVIII, Supplement

Institute of Oceanography (1-9) University of Gdańsk
ISSN 1730-413X 2009 eISSN 1897-3191

Original research paper

Received: *June 14, 2006*
Accepted: *August 17, 2006*

Enteromorpha (Chlorophyta) populations in the Nielba River and Lake Laskownickie

Beata Messyasz[1]

Department of Hydrobiology , Faculty of Biology
Adam Mickiewicz University
ul. Umultowska 89, 61-614 Poznań

Key words: *Enteromorpha intestinalis*, *Enteromorpha compressa*, green macroalgae, green algae, macrophytic algae, littoral zone

Abstract

Enteromorpha intestinalis (4 forms) and *E. compressa* (2 forms) were identified in Lake Laskownickie, while only *E. intestinalis* (2 forms) was identified in the Nielba River. The massive appearance of both species of *Enteromorpha* in the lake was occurred mostly during early summer (June) with the position of the population in the water column ranged from benthic to floating. In the Nielba River *E. intestinalis* developed in May or June with maximum coverage in July or in the beginning of August. In both cases *Enteromorpha* preferred sunny places and well oxygenated waters. Additionally, it was found that in both habitats thallus was significantly higher at the end of the summer than at the beginning.

[1] Corresponding author: *messyasz@amu.edu.pl*

INTRODUCTION

Enteromorpha Link is a common macrophytic green alga with a tubular thallus found mainly in salty waters (Kirchhoff and Pflugmacher 2000, Lee 1999, Romano et al. 2003, Żbikowski et al. 2005). It is often possible to observe some species in different types of freshwater habitats, as little is yet known of its ecology (Kowalski 1975, Sitkowska 1999, Vladimirescu 2007). Both *Enteromorpha intestinalis* (L.) Link as well as *Enteromorpha compressa* Greville have a wide range of acceptable salinity, temperature and light conditions, meaning that it can be found frequently. (Woodhead and Moss 1975, Reed and Russel 1979). A dense population of *Enteromorpha intestinalis* is strongly related to eutrophication and can be used as an indicator to describe changes in the trophic state (increase of nutrient supply) of its habitats (Worm and Lotze 2006).

Species of the genus *Enteromorpha* are uncommon in freshwaters (Starmach 1972). During phycological observations conducted from the early 1990s in Wielkopolska, the appearance of numerous *Enteromorpha* populations in the littoral zone of Lake Laskownickie (near Gołańcz) and the Nielba River (in Wągrowiec) was observed. The increase in the massive appearance of this tabular thallus green alga has been observed year after year. This study is intended to widen the morphology identification and ecological distribution of *Enteromorpha* species in freshwater habitats. There is little information concerning moving waters, as found in rivers.

It is universally known that rivers and lakes are habitats with diversified physical and chemical parameters. The easy availability of nutrients is a common feature of both examined aqueous ecosystems. The aim of the study was to characterize and compare the biology and ecology of *Enteromorpha* populations from a single lake and river.

MATERIALS AND METHODS

Study area

Detailed studies were carried out at sampling stations within the littoral zone of hyper–eutrophic Lake Laskownickie and in the shallow, eutrophic lowland of the Nielba River. Lake Laskownickie (surface 19.2 ha; max. depth 7.4 m) is shallow and polimictic, lying in a natural basin of the tunnel–valley type, with an elongated, narrow shape and steep banks. It is located in the Wielkopolska region, north of Wągrowiec. This lake is the first in a row of postglacial channel lakes, has a flow through it and is situated in the catchments area of the Struga Gołaniecka River (Messyasz 1998, 2000). From 1993 on this

lake has seen continuous blooming of *Planktothrix agardhii* (Gom.) Anagn. et Kom., with its summer biomass maxima of 21.428–37.850 mg l^{-1} (Messyasz 1998, Stefaniak et al. 2005).

The Nielba River begins at Lake Rgielskie and is only 7 km long. Its nitrogen and phosphorus load is high due to inflows of sewage from the catchment area including the town of Wągrowiec. The river has a slow (0.89 – 1.03 m^3 s^{-1}) flow rate (Messyasz 2003).

Samples

Enteromorpha was collected biweekly during the summer period in the years 1994–1995 and 2005–2006. During the collection season, 500 thallus of *Enteromorpha* were measured in order to estimate the morphologically of different forms occurring at the sampling stations. A light microscope was used to determine the type and size of cells and their setting in the thallus. In order to assess the ecological conditions of its habitats, physical and chemical analyses of water parameters were included. Additionally the structure of the planktonic algae community in the water between *Enteromorpha* thalluses was examined.

RESULTS

During the summer seasons in the Nielba River, the presence of single specimens of *E. intestinalis* was recorded from May or June, filling the surface of about 0.90 m^2. Its maximum coverage was noted in July or at the beginning of August. While in the zone of the littoral of Lake Laskownickie this species formed dense mats about the surface covering an average of 15 m^2. *E. intestinalis* consisted of four filament forms in Lake Laskownickie and two forms in the Nielba River which differed in their morphometric features (Table 1). Distinct diversifying morphometric features concerned the shape and size of cells, the length of thallus and presences of branching. In both examined ecosystems numerous branches were formed by greater forms of *E. intestinalis*. In the case of lake form no. 3, a difference was observed in the colour of this macroalga, which was an olive green shade.

Enteromorpha compressa was present in Lake Laskownickie for most seasons. In general, the mats of both *Enteromorpha* taxa developed from June onwards, with its position in the water column ranging from benthic to floating. It was frequently found on the borders of patches of *Enteromorpha intestinalis*, although the communities which it created were also compact with a surface area on average of about 10 m^2. The features of *E. compressa* forms are presented in Table 2. Both forms differed in the shape of cells and the presence or the lack of branches.

Table 1

Morphometric features of *Enteromorpha intestinalis* forms found in lakes and rivers.

Feature	Lake Laskownickie				Nielba River	
	1	2	3	4	1	2
Thallus	thin, round tube, smooth	thin, inflated tube, smooth	thin, round tube, rough	thin, inflated tube, rough	thin, round tube, smooth	thin, round tube, rare rough
Branching	absent	absent	rare	rare	absent	rare
Length [cm]	5 – 13	7 – 18	6 – 20	5 – 23	6 – 15	6 – 17
Colour	yellow green	yellow green	olive green	yellow green	yellow green	yellow green
Cells shape	irregular-longish	irregular-longish, roundish	irregular-longish, trigonous	irregular-longish, roundish	irregular-longish, roundish	irregular-longish, trigonous
Cells size [µm]	12 x 13	12 x 15	16 x 13	12 x 15	12 x 14	13 x 15

Table 2

Morphometric features of *Enteromorpha compressa* forms in Lake Laskownickie.

Features	Form 1	Form 2
Thallus	thick, rough, tube	thick, rough, tube
Branching	absent	rare
Length [cm]	6 – 20	6 – 17
Cell shape	irregular - square	irregular – 5-6 sides
Cell size [µm]	10 – 15	10 – 13

On the basis of chemical analyses of the water, it was found that trophic conditions in both habitats were quite similar (Table 3). Large concentrations of ammonium nitrogen, phosphates and the conductivity were recorded in both the water of the lake and of the river indicate eutrophy. In addition, there was a positive trend for nitrate concentrations in the water ($r = 0.294$, $p = 0.05$) and a negative trend for dissolved phosphorus concentrations ($r = -0.211$, $p = 0.05$) with an *Enteromorpha intestinalis* thallus size in Lake Laskownickie. Such a relation was not recorded in the case of this species in the river.

Table 3

Average values (in brackets) and range of the changeability of chemical parameters for the summer period (1994–1995/2005–2006) in Lake Laskownickie and River Nieba.

Parameter	Lake Laskownickie n = 28	River Nieba n = 26
Conductivity [µS cm^{-1}]	648 – 1136 (752)	605 – 1396 (714)
pH	7.47 – 8.68 (8.28)	6.44 – 8.71 (7.32)
Oxygen [mg l^{-1}]	0.0 – 9.8 (6.9)	4.5 – 9.7 (5.8)
Chlorides [mg l^{-1}]	98 – 133 (107)	80 – 127 (102)
Nitrate nitrogen [mg l^{-1}]	0.00 – 0.70 (0.24)	0.12 – 0.81 (0.39)
Ammonium nitrogen [mg l^{-1}]	0.42 – 1.05 (0.68)	0.49 – 1.59 (0.82)
Phosphates [mg l^{-1}]	0.00 – 1.01 (0.33)	0.05 – 1.40 (0.24)

Comparing the algae taxonomical structure in particular seasons, *Cocconeis placentula* Ehr., *Cyclotella radiosa* (Grun.) Lemm., *Cymbella minuta* Hilse ex Rabenhorst, *Coelastrum microporum* Nageli in A. Braun, *Pediastrum boryanum* (Turp.) Meneghini, *Desmodesmus communis* (Hegew.) Hegew. and *Rhodomonas minuta* Skuja were species found in large numbers in both the river and lake communities of phytoplankton. While *Planktothrix aghardii* (D.C. ex Gom.) An. et Kom., *Merismopedia glauca* (Ehr.) Nag., *Chlamydomonas globosa* Snow, *Dictyosphaerium pulchellum* Wood, *Monorphidium arcuatum* (Kors.) Hind., *Monoraphidium griffithii* (Berk.) Kom.-Legn., *Tetraedron minimum* (A. Br.) Hansg. and *Euglena pisciformis* Klebs were planktonic algae species which achieved a large biomass within *Enteromorpha* patches in Lake Laskownickie during the research period. At the same time, dense populations were observed of *Aphanocapsa incerta* (Lemm.) Cr. et Kom., *Amphora ovalis* Kützing, *Fragilaria pinnata* Ehr., *Gomphonema olivaceum* (Horn.) Breb., *Navicula cincta* (Ehr.) Ralfs, *Navicula capitata* Patrick in Patrick & Reimer and *Cosmarium regnellii* Wille only in the Nielba River.

DISCUSSION

The data obtained in the present study show that *E. compressa* and *E. intestinalis* can appear in large numbers in the littoral zone of eutrophic freshwaters. The results of the present study agree with previous studies, which found a wide range of *Enteromorpha* appearing in different environments (Reed and Russel 1979, Woodhead and Moss 1975, Worm and Lotze 2006). The high trophy of waters of both Lake Laskownickie and the Nielba River reflect the similar conditions of both habitats. The resemblance between the habitats can include physical factors such as flow of water. On account of the fact that a small river of the Struga Gołaniecka flows through Lake Laskownickie and that the Nielba River is a lowland river with a slow flow rate, this permanent movement of water may also play an important role in shaping appropriate conditions for mass *Enteromorpha* development. Examinations by Endler et al. (2006) demonstrated large *E. intestinalis* (L.) f. *maxima* Link patches on the Dymer River in Poland. This macroalga tolerated changes in water temperature and lighting caused by emersion and submersion of its thallus. Similar results were found in this study at the Nielba River station with the presence of *E. intestinalis* indicating that this green alga tolerates the mechanical effect of water movement. This taxa clearly had suitable conditions for its development in the river as well as in the lake.

E. intestinalis was found in both studied ecosystems, in sunny locations with well oxygenated waters. *E. compressa* preferred similar habitat conditions in Lake Laskownickie as *E. intestinalis*. The river forms of *E. intestinalis* were slightly smaller than the lake forms, the individual forms disappearing rather gradually. In most cases, a morphometric form appeared abundant at least at four or five sampling dates and then was no longer observed at the next. Furthermore, it was found that the thallus was significantly higher in late summer than in June for both *Enteromorpha* taxa as well as in both habitats. In the present study, it was possible that thallus size was related to increases in water temperature. The observed differences between the increases in thallus length and the presence of branches indicate that rates estimated from the latter measurements may be more accurate in determining the species. It is frequently assumed that the rank of branching thallus is dependent on environmental conditions, mainly water temperature and salinity (Reed 1979, Woodhead and Moss 1975, Żbikowski et al. 2005). Despite the differences between form size for lake and river habitats, *E. intestinalis* achieved the same level of forming thallus branches with no differences between *Enteromorpha* groups in the period when branching and their amounts startednumber began being formed and of the grade of the branches. A sparseness of branches was characteristic for *E. compressa* thalluses.

The relatively high development of *E. intestinalis* observed in Lake Laskownickie as well as in the Nielba River may be due to the nearly constant and optimal chemical parameters that occur within these water bodies. The fact that extensive *Enteromorpha* taxa development was observed in eutrophic environments during the entire summer period agrees with previous work (Worm and Lotze 2006) and may reflect the indicative properties of these species. The results of this study suggest that high nitrate concentrations in water were important and had a positive effect on the growth of the *E. intestinalis* thallus. Such a relation was also observable in the Nilba River, although this was not statistically significant. Other factors such as chloride concentrations in the waters or ammonium nitrogen levels may also be related to more rapid *Enteromorpha* growth and may have lead to the increasing distribution of this macroalga in enriched water environments.

The higher than average concentration of *Enteromorpha* thalluses in the lake than in the river may also have affected the behaviour of the filamentous green algae found within its mats. The position of *Cladophora glomerata* in the water column was mainly benthic in the Nielba River in contrast to Lake Laskownickie, where it floated on the surface of the water between *Enteromorpha* specimens. Hillebrand (1983) found that a single mat of *Cladophora glomerata* could float at the water surface for the entire summer period. However, dense patches of *Enteromorpha* mats in Lake Laskownickie have also be associated with reduced light availability in deeper parts of the water column, which suggests that the physical surroundings (increasing overshadowing) had a great influence on the floating type of *Cladophora glomerata* behaviour. The smaller space in *Enteromorpha* mats may also have influenced *Cladophora glomerata* behaviour as there is evidence that reducing space leads to an increase in the competition for light or nutrient availability, and for life space between different taxa (Hillebrand 1983, Romano et al. 2003). Dense populations of filamentous green algae can also remove NH_4^+ from water and keep concentrations low in the water. As the *Enteromorpha* in both habitats had different levels of thickening, it is possible that the higher development of *Enteromorpha* taxa in the lake environment resulted in the *Cladophora glomerata* achieving its full potential for floating in the surface water.

Additionally, it was found that both habitats had similar planktonic algae communities containing primarily colony-forming and coccal forms taxa. These algae were mainly cosmopolitan species which are characteristic of small fertile bodies of water and of lakes with high nutrient concentrations. Observed species confirmed the eutrophic character of the waters of Lake Laskownickie (Messyasz 1998, 2000; Stefaniak et al. 2005). Differences were also observed between stations in the levels of the dominating taxa in the phytoplankton communities within *Enteromorpha* patches. The distinct dominance of diatoms

in the Nielba River was connected with a water flow characteristic of rivers. Furthermore, most diatoms were indicators of the eutrophic conditions in the water (Messyasz 2003, Reynolds 1984).

To sum up it was stated that both species of *Enteromorpha* had found favourable conditions in the investigated freshwater habitats. The *Enteromorpha* population has a wide range of morphological variations and during the season consisted of different morphological forms in Lake Laskownickie and the Nielba River. The potential relevance of these forms which are able to respond in different ways to some environmental factors is in area that requires further study.

ACKNOWLEDGMENT

This study was partly supported by the Polish Ministry of Education Science, grant No. 2PO4G 003 30.

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