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STRUCTURE AND DEVELOPMENT OF PHYTOPLANKTON IN FLOW-THROUGH LAKE PASŁĘK, ESPECIALLY IN WINTER (OLSZTYŃSKIE LAKE DISTRICT, NORTH-EASTERN POLAND)

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Summary. Phycological observations, carried out from autumn 2007 till spring 2009, involved phytoplankton in Lake Pasłęk (north-eastern Poland). The observations comprised analysis of the dominance structure and intensity of phytoplankton development, especially during the winter season. It was found that the duration of ice cover was a factor that significantly differentiated the dynamics of modifications in the taxonomic structure and affected the rate and intensity of the development of phytoplankton.

Key words: phytoplankton, anthropogenic lake, seasonal modifications, protected areas

INTRODUCTION

Modifications in the dominance structure and intensity of development of phytoplankton as well as changes in the dynamics of such modifications are characteristics for phytoplankton assemblages under changeable environmental conditions. By maintaining their recurrence, such changes establish a tendency and direction of modifications in aquatic ecosystems [Sommer *et al.* 1986, Wirtz and Eckhardt 1996]. Each incidence of environmental stress may trigger a series of harmonised changes, which can lead to floristic modifications within an assemblage of plankton algae, causing a series of uncontrollable fluctuations in the life of water ecosystems [Burchardt 1993, Burchardt *et al.* 1994].

The purpose of this study was to analyse seasonal changes in the dominance structure and intensity of development of the phytoplankton in Lake Pasłęk, particularly during the winter season.

MATERIAL AND METHODS

The object for our study was Lake Pasłęk, situated in Olsztyńskie Lake District (north-eastern Poland). This is a lake artificially created in the 19th century, with 9.3 ha in surface area and 6 m in depth, weakly developed shoreline and surrounded by forest [Endler *et al.* 1999, Grzybowski *et al.* 2008]. The lake belongs to a system of lakes and rivers connected with the upper course of the River Pasłęka and together with the whole system constitutes a nature reserve called the Beaver Shelter on the Pasłęka River. It also belongs to the Natura 2000 network.

Our observations were conducted from the autumn of 2007 till the spring of 2009, but particularly during the winter season. Samples were collected once a month from the water depth and with a plankton net of the mesh size 30 μm. Our preliminary quantitative analysis of the phytoplankton was based on samples of live plankton, but the main analyses were performed on fixed samples. The analyses were completed according to Starmach [1989].

RESULTS

The phytoplankton collected during the autumn and winter of 2007/2008 was characterised by an evident dominance of *Bacillariophyceae*, which coincided with a low taxonomic diversity. The percentage of diatoms in the whole algal phytoplankton reached 90% at the most. In November and December, *Asterionella formosa* was the dominant species, with *Fragilaria* var. *acus* being the sub-dominant. The growth of phytoplankton was very intense. The lowest amount of phytoplankton, which appeared in January, coincided with a change in the dominance structure. The percentage of *Chrysophyceae* increased to 40% and comprised mainly species belonging to the genus *Dinobryon*. The growth of golden algae occurred during the melting of the ice cover which in the winter season of 2007/2008 did not cover the lake for more than 4 weeks (Fig. 1, 2). As early as February 2008, *Bacillariophyceae* resumed growth. The species of diatoms which had been dominant previously were again most numerous. During the whole winter, blue-green algae were present in the phytoplankton. In early summer, the receding *Bacillariophyceae* were replaced by *Cyanoprokaryota* whose growth eventually made them the dominant group in the summer. They were periodically accompanied by *Dinophyceae*, most numerously represented by *Ceratium hirundinella*. The dominance structure changed again in November, when the assemblage was dominated by *Flagilaria ulna* var. *acus* while *Asterionella formosa* was the sub-dominant. Apart from *Bacillariophyceae*, *Chrysophyceae* of the genus *Dinobryon* developed quite abundantly. In 2008/2009, the taxonomic structure of the phytoplankton in the autumn and winter season was similar to that in 2007/2008, but its growth from December to April was obviously

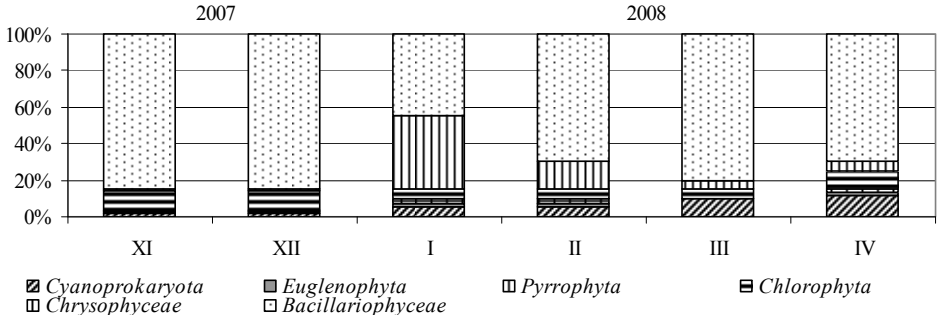

Fig. 1. Schare (%) of particular systematic groups in the phytoplankton in winter 2007/2008

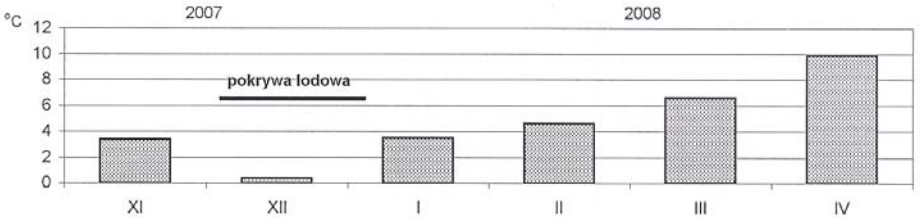

Fig. 2. Temperature of surface waters in Pasłęk Lake in winter 2007/2008

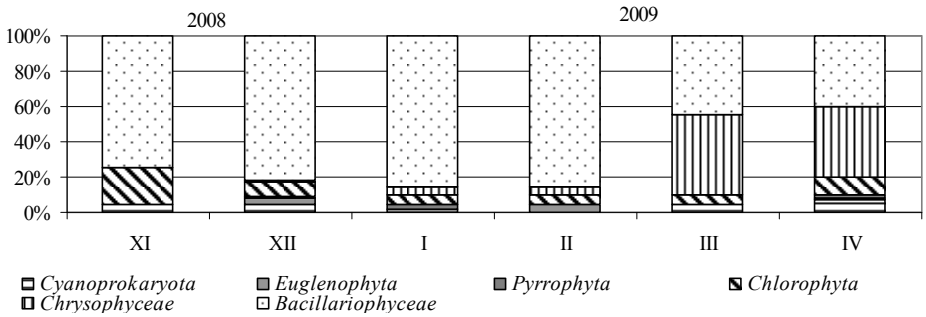

Fig. 3. Schare (%) of particular systematic groups in the phytoplankton in winter 2008/2009

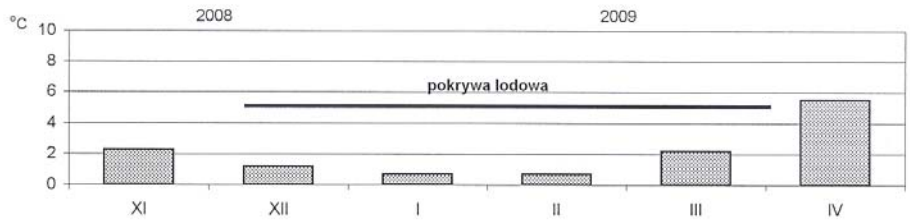

Fig. 4. Temperature of surface waters in Pasłęk Lake in winter 2008/2009

much weaker (without mass occurrences of *Asterionella formosa*), although the dominance structure consisted of the same species. *Chrysophyceae* of *Synura* sp. reached the position of the dominant microorganism as late as the turn of March and April, when the ice cover disappeared, having stayed on the lake for nearly 4 months (Fig. 3, 4).

DISCUSSION

The structure and development of phytoplankton respond to varying environmental conditions and the modifications they undergo are a consequence of the changeable physicochemical conditions and biocenotic relationships occurring in the aquatic ecosystem [Burchardt 1993, Burchardt *et al*. 1994, Reynolds 2000]. Changing sunlight intensity and the related water temperature are among the most important factors which shape the tendencies and condition the direction of changes which take place within assemblages of plankton algae [Ganf and Oliver 1982, Dauta *et al.* 1990]. In Lake Pasłęk, the thermal and light conditions were a factor that modelled the structure, rate and intensity of the development of the phytoplankton, especially during the winter seasons, which during our study were entirely different. The duration of the ice cover element was a factor which considerably differentiated these phytoplankton characteristics between the winters of 2007/2008 and 2008/2009. In both years, the lake froze in December, but in the winter of 2007/2008 the ice cover stayed on the lake for just 4 weeks. It did not reduce significantly the percentage of diatoms in the phytoplankton, which began to develop intensively in autumn, as is typical for this group of algae [Lafforgue *et al.* 1995, Reynolds 1988, 2000]. Diatoms which have a higher photosynthesis to respiration ratio at lower temperatures do well at both low water temperatures and small light intensity, which enable them to develop even under ice cover [Tuji 2000]. Apart from intensively growing *Bacillariophyceae*, in January 2008 *Chrysophyceae* began to grow in Lake Pasłęk. This sudden increase in the abundance of golden algae could have been connected with the increase in ambient temperature, which made the ice cover recede. The presence of *Chrysophyceae* is typical of spring and early summer [Burchardt 1993, Burchardt *et al.* 1994, Reynolds 2000]. However, as the temperature stopped to rise, the growth in the number of golden algae fell rapidly and diatoms began to dominate. The development of diatoms during a mild winter is a typical phenomenon, but when a lake freezes or is frozen only for a short time, so-called algal blooms can occur even in early spring [Bleiker and Schanz 1989, Krivtsov *et al.* 2000], although rapidly increasing temperature may lead to diatoms being superseded by growing assemblages of blue-green algae which are more adaptable to extreme environmental conditions, including extreme temperatures. The fast adaptability to changes in environment, which is typical of blue-green algae, enables them to compete successfully and gain a competi-

tive advantage under unstable environmental conditions [Shapiro 1990]. Konopka and Brock [1978] proved that the intensity of photosynthesis in blue-green algae can be also high at low temperatures. In Lake Pasłęk blue-green algae were present during the whole winter season of 2007/2008, and in April they grew in number so that in May they were the dominant group in the phytoplankton. The structure and development of phytoplankton in 2008/2009, when Lake Pasłęk was covered with ice for four months (from December to April), took a different course. The adaptability mechanisms of diatoms enabled them to maintain their dominant position, but proved to be insufficient for them to continue further growth [Lafforgue *et al*. 1995, Tuji 2000]. Apart from *Bacillariophyceae*, other algae typical of winter season appeared in small numbers [Burchardt 1993, Burchardt *et al.* 1994, Reynolds 2000]. Their development was also rather limited. Invariably, one of the consequences of unfavourable environmental conditions, such as a long duration of ice cover, is the inhibited growth of phytoplankton. Phytoplankton resumes intensive growth after the ice cover melts, but often begins to grow under the ice [Schmitt and Nixdorf 1999]. In Lake Pasłęk, when the ice cover disappeared, diatoms were accompanied by *Chrysophyceae* of the genus *Synura* which found such suitable conditions for their development that they were present in the lake throughout the whole spring, next to diatoms. During the spring of 2009, blue-green algae failed to gain dominance within the algal assemblage in Lake Pasłęk.

The remarkable flexibility of most of plankton algae and blue-green algae enables them to dwell under changeable environmental conditions, although each species of these microorganisms has different life requirements, optimum conditions for development and range of ecological tolerance. Such requirements, in combination with other biotic and abiotic dependences, model the composition and development of assemblages of plankton plants. However, the general structure of a phytoplankton assemblage and the succession it undergoes, although dependent on a complex of conditions created by an ecosystem, should maintain its repeatability [Sommer *et al.* 1986, Reynolds 1988, 2000]. Differences in the dynamics of changes in the dominance structure of phytoplankton as well as the rate and intensity of its development, related to the duration of ice cover (which is most often associated with changes in the temperature of water), beside other elements of the ecosystem, can indicate directions and tendencies in the modifications occurring in lakes under meteorologically unstable conditions (i.e. during the so-called mild winters).

CONCLUSION

Changes in the dominance and intensity of development characteristic for an assemblage of phytoplankton confirm the changeability of environmental conditions. The factor which considerably differentiated the dynamics of changes in

the taxonomic structure as well as affecting the rate and intensity of the development of phytoplankton was the duration of ice cover. The duration of ice cover may serve as a good indicator which will help to capture the tendencies and direction of the changes taking place in lakes during unstable weather conditions.

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STRUKTURA I ROZWÓJ FITOPLANKTONU PRZEPŁYWOWEGO JEZIORA PASŁĘK ZE SZCZEGÓLNYM UWZGLĘDNIENIEM OKRESÓW ZIMOWYCH (POJEZIERZE OLSZTYŃSKIE, POLSKA PÓŁNOCNO-WSCHODNIA)

Streszczenie. Badania fykologiczne prowadzono od jesieni 2007 r. do wiosny 2009 r. Przedmiotem badań był fitoplankton jeziora Pasłęk. Zakres badań obejmował analizę struktury dominacji i intensywności rozwoju fitoplanktonu, ze szczególnym uwzględnieniem okresów zimowych. Stwierdzono, że czas zalegania pokrywy lodowej był czynnikiem znacząco różnicującym dynamikę zmian struktury taksonomicznej i wpływającym na tempo i intensywność rozwoju fitoplanktonu.

Słowa kluczowe: fitoplankton, jezioro Pasłęk, zmiany sezonowe, obszary chronione