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PHYTOPLANKTON VERSUS THERMAL CONDITIONS IN THE PHOTIC ZONE OF LAKES OF DIFFERENT TROPHY (KUC, MAJCZ WIELKI, MIKOŁAJSKIE, NORTH-EASTERN POLAND)

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Summary. The study dealt with the phytoplankton of lakes different in their trophy, such as lakes Kuc, Majcz Wielki and Mikołajskie. The research comprised analysis of the taxonomic structure and intensity of the growth of phytoplankton in two years, 2007 and 2008, which were different in terms of thermal conditions. It was demonstrated that the thermal conditions in lake waters within the photic zone are among the conditions shaping the dynamics of changes in the dominance structure and rate of development of phytoplankton during the trophic transformations occurring in the analysed lakes.

Key words: phytoplankton, lake, seasonal changes, trophy

INTRODUCTION

Each trophic type of lakes is characterised by a specific taxonomic composition, dominance structure and intensity of development of phytoplankton [Sommer *et al.* 1986, Wirtz and Eckhardt 1996]. Such changes are associated with the changing environmental conditions as well as biocenotic relationships which exist within an aquatic ecosystem formed under specific trophic conditions [Currie 1990, Carpenter *et al*. 1997, Tallberg *et al*. 1999]. Thermal conditions in the photic zone are among the primary factors which affect life of a phytoplankton assemblage [Ganf and Oliver 1982, Dauta *et al.* 1990]. They can model the dominance structure and dynamics of the growth of phytoplankton, depending on conditions that a given ecosystem creates. In lakes which differ in their trophy, thermal conditions in the photic zone can be one of the elements establishing the rate and direction of trophic changes [McQueen *et al.* 1986, Vezjak *et al*. 1998, Baird *et al.* 2001].

The aim of the study was to present an analysis of seasonal changes in the taxonomic composition, dominance structure and intensity in the development of phytoplankton versus the thermal conditions in the photic zone of lakes which differed in their trophy.

MATERIAL AND METHODS

The research involved three lakes in the Mazurskie Lake District (north--eastern Poland), i.e. Kuc, Majcz Wielki and Mikołajskie [Hillbricht-Ilkowska 1989]. Studies on phytoplankton were conducted from April 2007 to November 2008. Samples were collected once a month from water depth, with a plankton net of the mesh size of 30 µm. The preliminary quantitative analysis was performed on live samples captured with the plankton net. The main quantitative and qualitative analysis of phytoplankton was completed on fixed material collected from water depth and prepared for analysis according to Starmach's method [1989].

RESULTS

The phytoplankton in Lake Kuc. In spring 2007 and 2008, the largest share in the total amount of phytoplankton in Lake Kuc was attributed to *Chrysophyceae* which, in both years of the study, consisted of species belonging to the genus

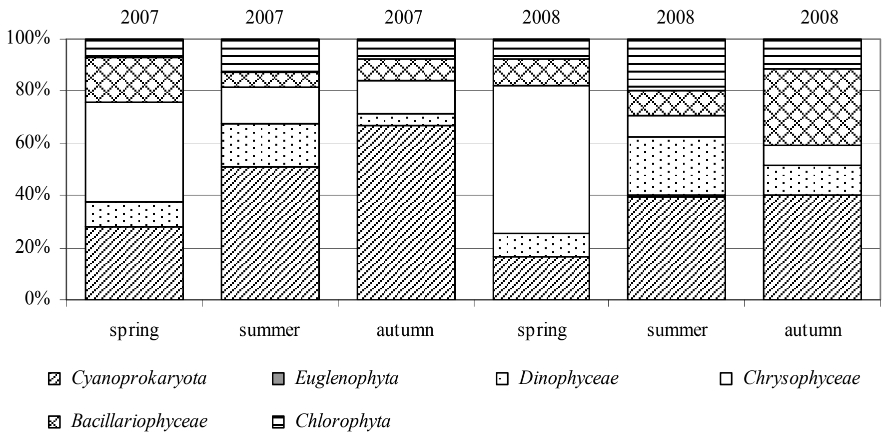

Fig. 1. Schare (%) of particular systematic groups in the phytoplankton in Lake Kuc

Dinobryon (with the dominant *Dinobryon divergens*), accounting for up to 70% of the total biomass of phytoplankton. Diatoms reached no more than 10% of the total phytoplankton mass. In both years, during spring, the contribution of blue-green algae reached up to 25%. In 2007, during the successive summer months, it rose up to 40–65%, whereas in the summer of 2008 it remained at 40%. Also, the taxonomic structure among the dominant *Cyanoprokaryota* species was different between the two years. In the early summer of 2007 (June), the highest growth was attained by *Anabaena lemmermanii*. In high summer, *Aphanizomenon flos-aquae* was the dominant, and in late summer *Woronichinia naegeliana* began to dominate. In 2008, among the dominant taxa of *Cyanoprokaryota* there were also so-called filamentous forms which mostly belonged to *Planktothrix*. In the autumn of 2007, the percentage of blue-green algae in the phytoplankton ranged from 55 to 78%, whereas in the analogous time of the year 2008 it reached only 40%. The dominant species belonged to *Planktothrix*. Apart from blue-green algae, a considerable share in the total phytoplankton was attributed to *Chrysophyceae* (up to 20%) and in the next year – to *Bacillariophyceae* (up to 30%) (Fig. 1).

The phytoplankton in Lake Majcz Wielki. In the early spring of 2007, 70% of phytoplankton was made up by *Cyanoprokaryota*, which was caused by a mass occurrence of one species, i.e. *Planktothrix aghardii*. The growth of blue-green algae did not last throughout the spring season, as diatoms began to dominate before the summer. The share of *Bacillarophyceae* in the entire phytoplank-

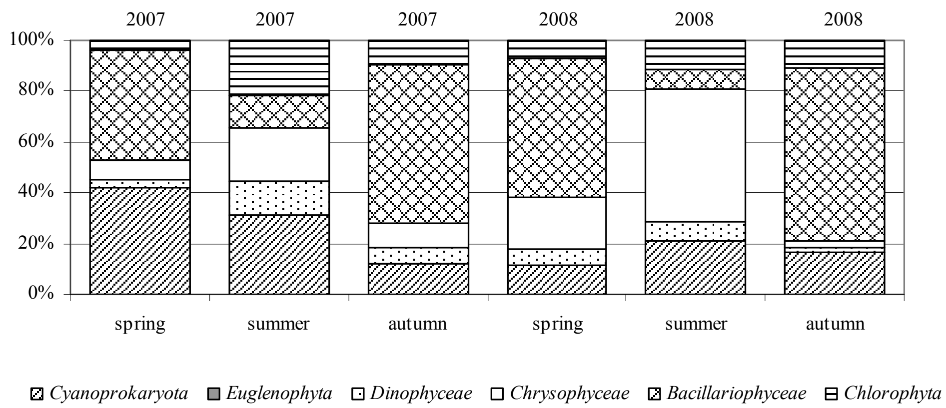

Fig. 2. Schare (%) of particular systematic groups in the phytoplankton in Lake Majcz Wielki

ton biomass was 62%. The most numerous were *Asterionella formosa* and *Fragilaria ulna* var. *acus*. The same species dominated in 2008, but their dominance was not preceded by any growth in blue-green algae. The percentage of diatoms varied from 82 to 28%. In late spring and in summer, the highest share was determined for *Chrysophyceae* which made up between 30 and 75% of the phytoplankton biomass. In both years, species belonging to the genus *Dinobryon* dominated, with *Dinobryn divergens* being most abundant. *Cyanoprokariota* were the most numerous in summer, when their contribution to the total phytoplankton was from 23 to 65% in 2007, and the dominant species was *Woronichinia neageliana*. In 2008, filamentous blue-green algae of the genera *Planktothrix* and *Limnothrix* dominated, constituting around 36% of the phytoplankton biomass. In the autumn of both 2007 and 2008, *Bacillariophyceae* made up about 70% of the total phytoplankton biomass (Fig. 2).

The phytoplankton of Lake Mikołajskie. *Bacillariophyceae* contributed the most to the spring phytoplankton, both in 2007 and in 2008, when they constituted about 80% of the total biomass. In 2007, the dominant species belonged

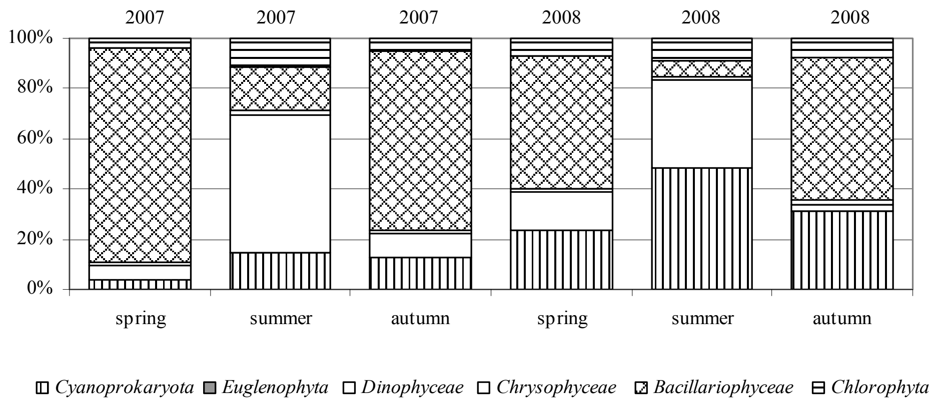

Fig. 3. Schare (%) of particular systematic groups in the phytoplankton in Lake Mikołajskie

to the genus *Aulacoseira*, with *Tabellaria fenestrata var. asterionelloides* and *Asterionella formosa* being subdominants. In 2008, A*sterionella formosa* proved to dominate strongly, being only accompanied by *Tabellaria fenestrata var. asterionelloides*. In summer 2007, the most numerous were *Dinophyceae*, contributing between 45 and 70% of the total phytoplankton biomass. The evidently dominant species was *Ceratium hirundinella*. The share of *Dinophyceae* in 2008 reached about 35% and the dominant group were *Cyanoprokariota*, with the percentage ranging from 36 to 46%. In autumn, *Bacillariophyceae* dominated. The percentage of diatoms varied from 56% in 2008 to 78% in 2007. The dominance structure was similar to that found in spring (Fig. 3).

DISCUSSION

The taxonomic structure and intensity of development of phytoplankton are conditioned by a series of mutually related abiotic and biotic factors. Phytoplankton responds very quickly to even the smallest change in the above factors, and at the same time has some influence on their shape [Currie 1990, Carpenter *et al*. 1997, Tallberg *et al.* 1999].

In lakes Kuc, Majcz Wielki and Mikołajskie, changes in the temperature of sunlit water layer modelled differently the dominance structure and dynamics of the growth of phytoplankton in the consecutive phenological seasons in 2007 and 2008. In spring 2007, *Chrysophyceae* contributed most strongly to the formation of the phytoplankton assemblage in Lake Kuc. In Lake Mikołajskie, this role was played by *Bacillariophyceae*, and in Majcz Wielki diatoms became dominant following a brief occurrence of blue-green algae in early spring, which could have been caused by a sudden increase in the temperature of lake water, which preceded the development of *Planktothrix aghardii*. The quick response to changes, typical of blue-green algae, enables them to compete successfully under unstable ambient conditions [Shapiro 1990]. Presence of blue-green algae in early spring is characteristic for lakes of high trophy, but in a study performed in 1985 Lake Majcz Wielki was classified as a mesotrophic lake [Hillbricht-Ilkowska 1989]. However, Hillbricht-Ilkowska and Wiśniewski [1996] classified this lake as an meso-eutrophic one, which can explain the fact that in 2008 only *Bacillariophyceae* dominated there throughout the whole spring season. In lakes Mikołajskie and Kuc the same groups of phytoplankton dominated in 2008 as in 2007, but the occurrence of dominant species was shifted in time. *Dinobryon divergens*, which in 2007 was dominant at the turn of spring and summer, in 2008 began to dominate as early as in April. In Lake Mikołajskie, *Astrionella formosa* became dominant in April 2008, but in 2007 it did not dominate until May. The spring of 2008 was warmer, which may have been a cause of earlier development of phytoplankton. Higher water temperatures are most often associated with better photic conditions, as a result of which waters mix and a pool of available biogenic nutrients enlarges, which stimulates development of dynamically growing algae [Dauta *et al.* 1990, Tuji 2000]. Under such conditions, algal blooms can occur, similarly to a situation when after a cooler spring season temperatures suddenly rise. Rapid growth in temperature may lead to diatoms being superseded by developing populations of blue-green algae which are more readily adaptable to changeable environmental conditions, including temperature [Lafforgue *et al*. 1995], as was seen in 2007. The summer season started with high water temperature which over the whole summer ranged within a few degrees. The summer phytoplankton in 2007, both in Lake Kuc and in Lake Majcz Wielki, was characterised by changeable and increasing in the course of summer contribution of blue-green algae, with other co-occurring phytoplankton groups. Also, dominant species changed. Under changing environmental conditions, species compete with one another to gain dominance, thus eliminating some less adaptable species [Lafforgue *et al*. 1995]. Changes in the taxonomic structure and intensity of development of phytoplankton are frequently a result of changes in the temperature of water, and are sometimes associated with changes in the dominance structure. In Lake Mikołajskie, *Dinophyceae* (*Ceratium hirundinella*) dominated and their development was only periodically inhibited by *Cyanoprokaryota*, when the latter began to develop on a mass scale. In 2008, the temperature of the photic zone in this lake was more even. Over the whole summer, the dominance structure of phytoplankton in Lake Kuc was similar, and the contribution of blue-green algae was relatively stable. In Lake Majcz Wielki, there was a tendency of *Cyanoprokaryota* increasing their contribution to the total phytoplankton, although their growth was weak. In Lake Mikołajskie, blue-green algae became dominant as soon as late spring and remained dominant until autumn. The even temperature of the lake water favoured maintaining a similar dominance structure throughout the whole summer in the phytoplankton assemblages created by blue-green algae which possess several adaptability mechanisms enabling them to maintain a competitive advantage over other algae [Shapiro 1990]. Mass occurrence of blue-green algae is always characteristic for highly trophic water reservoirs [Reynolds 1988, 2000, Burchardt 1993, Burchardt *et al.* 1994]. On the other hand, *Ceratium hirundinella* in an index taxon of a high range of environmental requirements, which enables this organism to be present in lakes of different trophy. Its ecological status changes depending on the trophic type of a lake, and its is not only its number but also its presence as such that indicates a certain trophic condition of a lake [Burchardt 1993, Burchard *et al.* 1994, Burchardt and Łastowski 1999]. In eutrophic lakes, *Ceratium hirundinella* plays a role of the dominant, as was observed in Lake Mikołajskie. The primary factor which limits the development of blue-green algae is astacicism of aquatic environment [Lafforgue *et al.* 1995]. In Lake Kuc it did not put an end to the dominance of blue-green algae, either in 2007, when autumn was warmer and a jump in temperatures smaller, or in 2008. Blue-green algae, present in the plankton already in spring and maintaining their position over the entire summer and autumn, played a decisive role in the formation of the annual structure and intensity of development of phytoplankton in this lake, which is characteristic for eutrophic lakes [Burchardt 1993, Reynolds 2000]. In Lake Mikołajskie species belonging to *Bacillariophyceae* were most numerous, while in Lake Majcz Wielki diatoms were dominant in autumn phytoplankton. A large number of *Bacillariophyceae*, typical of eutrophic waters, as well as a considerable presence of *Chrysophyceae*, which are characteristic for waters of lower trophy, may imply certain instability of the trophic conditions in this lake.

CONCLUSION

The observed changes in the dominance structure and intensity of development characteristic for the analysed phytoplankton assemblages confirmed the variable thermal conditions in the photic zone of the lakes, different in their trophy. The thermal conditions in the photic zone of the three analysed lakes were one of the factors which modelled the structure and intensity of development of phytoplankton during the trophic changes occurring in the lakes. Changes in the thermal conditions in the photic zone, by differentiating the structure and intensity of development of phytoplankton as well as the dynamics of changes in phytoplankton assemblages under given trophic conditions, may suggest tendencies or even establish the rate and direction of trophic changes.

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FITOPLANKTON A WARUNKI TERMICZNE W STREFIE FOTYCZNEJ JEZIOR ZRÓŻNICOWANYCH TROFICZNIE (JEZIORO KUC, JEZIORO MAJCZ WIELKI, JEZIORO MIKOŁAJSKIE, POLSKA PÓŁNOCNO-WSCHODNIA)

Strszczenie. Przedmiotem badań był fitoplankton zróżnicowanych troficznie jezior. Były to: jezioro Kuc, jezioro Majcz Wielki, Jezioro Mikołajskie. Zakres badań obejmował analizę struktury taksonomicznej i intensywności rozwoju fitoplanktonu w różniących się warunkami termicznymi latach 2007 i 2008. Stwierdzono, że warunki termiczne wody w strefie fotycznej były jednym z elementów modelujących dynamikę zmian struktury dominacji oraz tempa rozwoju fitoplanktonu w procesie zmian troficznych zachodzących w badanych jeziorach.

Słowa kluczowe: fitoplankton, jezioro, zmiany sezonowe, trofia