Oceanological and Hydrobiological Studies
*International Journal of Oceanography and Hydrobiology*
Vol. XXXVI, Supplement 1

Institute of Oceanography | (137-145) | University of Gdańsk
ISSN 1730-413X | 2007 | eISSN 1897-3191

**Original research paper**

*Received:* *December 20, 2006*
*Accepted:* *May 11, 2007*

# Changes in phytoplankton assemblages after the reduction of sewage discharge into Lake Niegocin (Mazurian Lake District, Poland)

Andrzej Hutorowicz[1], Agnieszka Napiórkowska-Krzebietke

*The Stanisław Sakowicz Inland Fisheries Institute*
*ul. Oczapowskiego 10, 10-719 Olsztyn, Poland*

**Key words:** phytoplankton assemblages, structure, environmental change

## Abstract

The diversity of plankton assemblages from Lake Niegocin was studied from 1991 to 2001. Lake Niegocin is a eutrophic, dimictic lake in the Mazurian Lake District of Poland. The level of sewage contamination discharged into the lake from the city of Giżycko has decreased since 1994 when a new level biological sewage treatment facility became operational. A characteristic combination of species can be used to evaluate changes in the composition of phytoplankton assemblages caused by environmental changes. Significant, stable changes in the dominant and subdominant species were not observed until 1999, when the level of nutrients in the lake began to rise again.

[1] Corresponding author: *ahut@infish.com.pl*

 

## INTRODUCTION

In studies of lake phytoplankton it is assumed that seasonal dynamics and hierarchical structure are affected by various ecological factors. The magnitude of these factors and the direction in which they change can be determined. These factors determine the qualitative and quantitative parameters of plankton community structure that remains stable from year to year (Reynolds 1984, 1997; Oleksowicz 1988; Burchardt 1994 a,b; Burchardt et al. 1994; Romo and Mirakle 1995).

The ecological factors which have the greatest effect on phytoplankton assemblage population dynamics are the water mass stability and nutrient availability (Reynolds 1984). From November to April, factors that limit plankton growth are light availability and water flushing. During the summer months, limiting factors are usually nitrogen and phosphorus content (Romo and Mirakle 1995). In Lake Żarnowieckie, a large reservoir that was a component of a peak-pump electricity generation plant, a decrease in the stability of the water mass affected the formation of associations among planktonic algae (Hutorowicz 1991, 1996).

In 1994, a new level biological sewage treatment facility was opened in Giżycko in the Mazurian Lake District in northeastern Poland. The purification process included chemically precipitating phosphorus. Municipal sewage from Giżycko had been a major source of phosphorus contamination in nearby Lake Negocin. The opening of the new sewage treatment facility provided an opportunity to study how reducing external nutrient input affects the structure of phytoplankton assemblages in a large lake.

## MATERIALS AND METHODS

The species composition and biomass of individual phytoplankton species were studied from 1991 to 2001 in Lake Niegocin, a large basin with an area of 2600 hectares, an average depth of 9.9 meters, and a maximum depth of 39.7 meters. The lake lies in a catchment basin dominated by forests and croplands. From 1991 to 1999, water for phytoplankton analysis was collected at one site in the epilimnion. In 2001, water was collected at this same site and at four other sites in the southern and western parts of the lake (Fig. 1). During the spring and fall turnovers, samples were collected from the upper 10 m of the water column. During the summer, samples were collected from the epilimnion, the metalimnion, and the hypolimnion. Samples of equal volume were collected from each of the three layers and then combined. All samples were immediately preserved in Lugol's solution. A total of 65 samples for quantitative analysis were collected in this manner. At the same time, samples for qualitative analysis

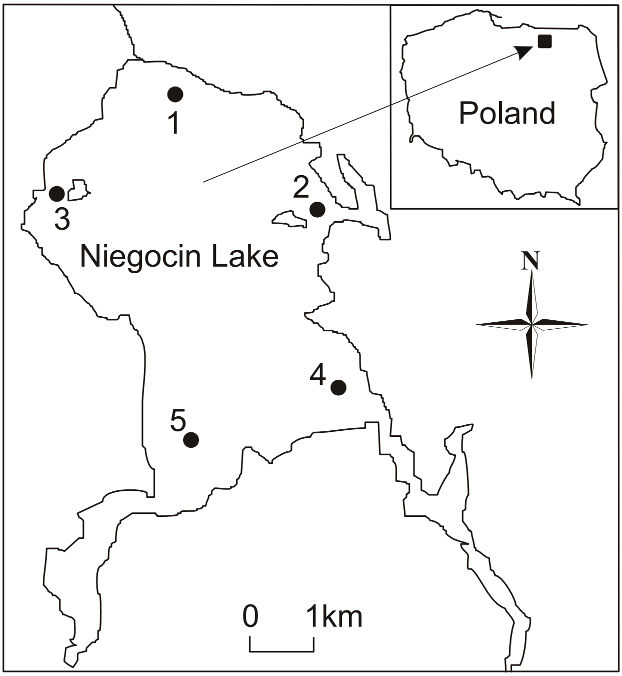


**Fig. 1.** Sampling sites on Lake Niegocin.

were also taken by passing lake water through a no. 25 plankton net. Algae were counted in a sedimentation chamber under an inverted microscope. The biomass of each species was estimated based on calculated cell volumes. Data on species composition, dominant species, and the biomass of individual species are presented elsewhere (Napiórkowska-Krzebietke and Hutorowicz 2006). The results of the analysis of taxonomic changes in phytoplankton assemblages are presented in the current paper. A total of 225 taxa in the phytoplankton hierarchy were identified and ranked according to biomass. Ranking was carried out using the dichotomized separation method with discriminating species with the help of TWINSPAN software (Hill 1979). The phytosociological constancy for each species was also calculated using the Braun-Blanquet scale (Pawłowski et al. 1959).

## Results And Discussion

Clear changes in the species composition and structure of the phytoplankton assemblage were observed only in the sixth year after the new sewage treatment facility had become operational. The similarity dendrogram for the phytoplankton samples based on the ranking data is presented in Figure 2. At the first level of separation, the phytoplankton samples fell into two branches, each with a characteristic species composition. The left branch represents 43 samples collected in 2000 and 2001, and the right branch represents all of the samples collected from 1991 to 1999 (Fig. 2). At the third level of separation, a sub-branch of the right branch was identified, representing four samples collected during August from 1995 to 1999, the first five years the new sewage treatment facility was in operation. At the fourth level of separation, a sub-branch of the right branch was identified, representing eleven samples collected from August 1991 to May 1995 prior to the facility being fully operational. A sub-branch of the left branch was also identified, represented by seven samples collected during the spring and summer months from 1995 to 1999.

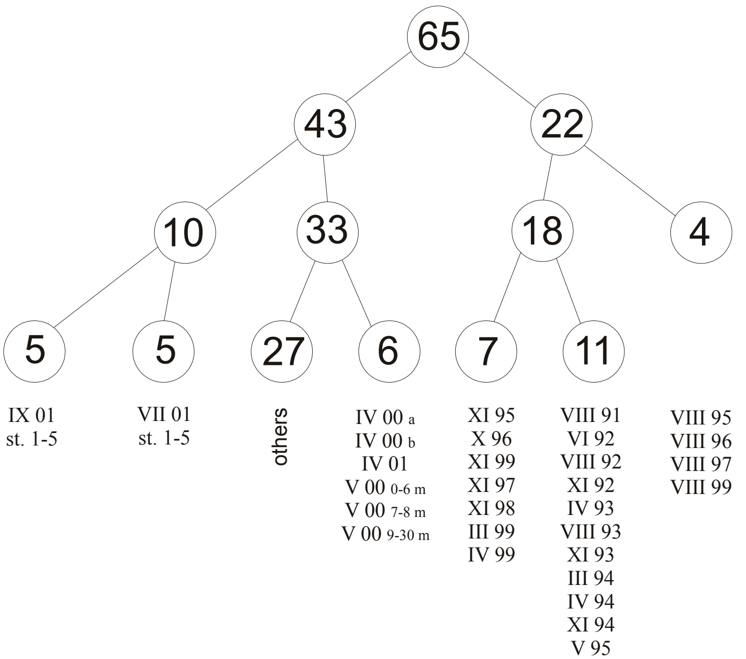


**Fig. 2.** Similarity dendrogram for the phytoplankton samples from Lake Niegocin from 1991 to 2001 calculated using TWINSPAN software.

The preliminary analysis of individual species with TWINSPAN software divided species into distinct groups based on whether they preferred conditions that prevailed before or after the facility was fully operational. The similarity dendrogram for the 225 phytoplankton taxa based on the ranking data is presented in Figure 3. At the third level of separation, a sub-group of the right branch was identified and was represented by 99 taxa which were encountered more often and in greater abundance in samples collected in 2000 and 2001. Among them, six species had a biomass greater in 2000 and 2001 than from 1991 to 1999, occurring at the fifth degree of constancy: *Stephanodiscus neoastrea*, *Microcystis aeruginosa*, *Fragilaria capucina* var. *capucina*, *Aulacoseira islandica*, *Nitzschia pusilla*, *Chlamydomonas* sp. In 2000 and 2001, *Fragilaria crotonensis* also occurred at the fifth degree of constancy, although its biomass was essentially the same as it was from 1991 to 1999. This was also true for *Navicula sciuteloides* in isolated samples (Table 1).

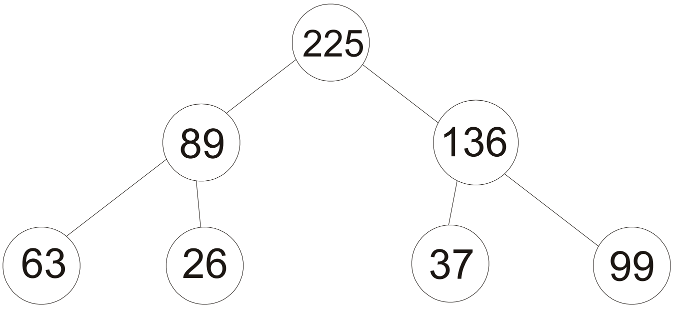


**Fig. 3.** Similarity dendrogram for the 225 phytoplankton taxa from Lake Niegocin from 1991 to 2001 calculated using TWINSPAN software.

At the third level of separation, a sub-branch of the left branch was identified, representing 63 taxa which were encountered more often and in greater abundance in samples collected from 1991 to 1999. Among them, only two species had a biomass which was higher from 1991 to 1999 than in 2000 and 2001, occurring at the fifth degree of constancy: *Planktothrix agardhii*, and *Aulacoseira* sp. No species in this sub-group occurred at the fourth degree of constancy. Species occurring at the third degree of constancy included: *Stephanodiscus hantzschii*, *Closterium limneticum* and *Stephanodiscus* sp. (Table 1).

At the third level of separation, another sub-group was identified representing 26 taxa which occurred at the same degree of constancy and with the same biomass both in 2000 and 2001 and from 1991 to 1999 (Fig. 3). Among them, three occurred at the fifth degree of constancy: *Pediastrum boryanum*, *Cryptomonas ovata*, *C.* sp., *Aphanizomenon* cf. *flos-aquae*. Two species occurred at the fourth degree of constancy: *Anabaena flos-aquae* and *Cryptomonas rostrata* (Table 1).

**Table 1**

Constancy and biomass in selected phytoplankton species that preferred either the conditions prevailing from 1991 to 1999 or those prevailing in 2000 and 2001

| | 1991-1999 | | 2000 and 2001 | |
|---|---|---|---|---|
| | Constancy [%] | Biomass [mg dm$^{-3}$] | Constancy [%] | Biomass [mg dm$^{-3}$] |
| *Stephanodiscus neoastrea* Håk. et Hick. | 64 | 0.002 <0.001-0.017 | 100 | 0.139 <0.001-1.055 |
| *Fragilaria crotonensis* Kitt. | 41 | 0.013 <0.001-0.063 | 95 | 0.017 <0.001-0.080 |
| *Nitzschia pusilla* Grun. em. Lange-Bert. | 14 | <0.001 <0.001<0.001 | 93 | 0.003 <0.001-0.019 |
| *Navicula scutelloides* W. Sm. ex Greg. | 18 | <0.001 <0.001<0.001 | 91 | <0.001 <0.001<0.001 |
| *Fragilaria capucina* Desm. var. *capucina* | 27 | <0.001 <0.001<0.001 | 91 | 0.017 <0.001-0.078 |
| *Microcystis aeruginosa* (Kütz.) Kütz. | 55 | 0.001 0.001-0.005 | 88 | 0.439 0.005-2.484 |
| *Aulacoseira islandica* (Müll.) Sim. | 45 | 0.009 <0.001-0.082 | 86 | 0.387 <0.001-2.695 |
| *Amphora ovalis* (Kütz.) Kütz. | 14 | <0.001 <0.001<0.001 | 70 | 0.001 <0.001-0.009 |
| *Aphanizomenon flos-aquae* (L.) Ralfs ex Born. et Flah. | 86 | 0.241 <0.001-2.834 | 72 | 0.122 <0.001-0.981 |
| *Cryptomonas ovata* Ehr. | 86 | <0.001 <0.001<0.001 | 98 | <0.001 <0.001<0.001 |
| *Pediastrum boryanum* (Turp.) Menegh. | 82 | 0.007 <0.001-0.032 | 84 | 0.010 <0.001-0.052 |
| *Cryptomonas rostrata* Troitz. em. Kis. | 77 | <0.001 <0.001<0.001 | 95 | <0.001 <0.001<0.001 |
| *Anabaena flos-aquae* (Lyngb.) Bréb. ex Born. et Flah. | 73 | 0.057 <0.001-0.404 | 77 | 0.066 <0.001-0.566 |
| *Leptolyngbya thermalis* Anagn. in Anagn. et Kom. | 73 | 0.072 <0.001-0.451 | 49 | 0.563 <0.001-3.087 |
| *Planktothrix agardhii* (Gom.) Anagn. et Kom. | 82 | 1.043 <0.001-7.921 | 28 | 0.053 <0.001-0.547 |
| *Stephanodiscus hantzschii* Grun. in Cl. & Grun. | 55 | 0.020 <0.001-0.112 | 21 | 0.005 <0.001-0.028 |
| *Stephanodiscus* sp. | 55 | 0.117 0.001-0.501 | 0 | |
| *Closterium limneticum* Lemm. | 50 | 0.001 <0.001-0.005 | 5 | <0.001 <0.001<0.001 |
| *Staurastrum mansfeldtii* Delp. | 45 | 0.010 0.006-0.045 | 5 | <0.001 <0.001<0.001 |

Based on ranking analysis, significant changes in the species composition of the phytoplankton assemblage were not clearly evident until 1999, almost six years after the new sewage treatment facility had become operational. However, the phytoplankton biomass began to increase again during the summer of 1999, indicating that the trophic level of the lake was rising once more (Napiórkowska-Krzebietke and Hutorowicz 2006). In contrast to the changes in the species composition, the reduction in the nutrient input resulting from the opening of the new facility was clearly evident as early as 1995 throughout the systematic phytoplankton groups. A clear decrease in phytoplankton biomass was observed. Changes were also observed in the dominant species and in the species hierarchy in the systematic groups (Napiórkowska-Krzebietke and Hutorowicz 2006). These changes were also accompanied by a change in the species composition of the non-dominant species, although these changes were not as significant as they would be in 1999 and 2000 (Fig. 2). Two groups of samples could be distinguished based on these changes. The first group was represented by eleven samples collected before the facility became operational, and the second group consisted of seven samples collected after it had become operational. These two groups were identifiable only when the similarity dendrogram for the samples was analyzed at the fourth level of separation. This suggests that the species composition of the non-dominant phytoplankton underwent major changes not when the content of biogenic compounds decreased after the new sewage treatment facility began operating, but when the trophic level of the lake began to rise again.

Dominant species play a leading role in the phytoplankton communities (Bucka 1966, Reynolds 1984, Burchardt et al. 1994, Romo and Miracle 1995), just as they do in communities of terrestrial plants (Pawłowski et al. 1959). Since dominant species are those which occur in the highest numbers under a particular set of environmental conditions, they can be described as "common species", that is, species that can best adapt to environmental changes (Burchardt and Łastowski 1999). The phytoplankton assemblages characteristic for a particular set of environmental conditions, such as trophic level, differ mainly in terms of which species are dominant (Starmach 1962; Sosnowska 1974; Spodniewska 1978, 1979; Oleksowicz 1988; Reynolds 1984; Burchardt et al. 1999). Nonetheless, in the twentieth century, studies on algal plankton assemblages were already undertaken based on sociological methods that consider not only species hierarchy but also constancy (Starmach 1962, Bucka 1966, Sosnowska 1974). In assemblages of periphytic algae growing on macrophytes, there is a rather large group of species that occur at a high degree of constancy (Bohr 1962). This indicates that a stable combination of characteristic species remains in place. This phenomenon has also been observed in phytoplankton communities (Hutorowicz 1991). The species composition of the phytoplankton assemblage in Lake Żarnowieckie was very similar in two successive vegetative seasons, even though different species of cyanobacteria were dominant (Hutorowicz 1991). This is consistent with Bohr's observations that the characteristic combination of plankton species is determined by the sum of the ecological parameters of the environment, and that the abundance of plankton species is affected by ecological factors which change in magnitude over the course of the year (Bohr 1962). In Lake Żarnowieckie, the characteristic species composition of pelagic and littoral phytoplankton assemblages turned out to be more stable than the hierarchical structure, which quickly changed as a result of water flushing after the lake was incorporated into the circulation of a peak-pump electricity generation plant. The numerical analysis of the phytoplankton assemblages from Lake Niegocin presented in this study, however, indicates that the species composition might also be useful in evaluating changes in phytoplankton assemblages resulting from changes in nutrient levels.

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