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# QUANTITATIVE AND QUALITATIVE CHANGES OF THE PHYTOPLANKTON IN HEATED KONIN LAKES

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A B S T R A C T. Artificial water heating in Konin lakes and its intensive exchange between these lakes were the main factors affecting the phytoplankton densities and composition in the 60-ies and 70-ies. Increase of water temperature stimulated phytoplankton development, with diatoms as the dominant, this being especially noticeable in the first ten years of functioning of the cooling system. On the other hand, low water retention restricted algae development, so that phytoplankton abundance decreased gradually while its taxonomic diversity increased since the begining of the 70-ies. Another increase of total biomass of the algae, with blue-greens dominating in summer, was observed in the second half of the 80-ies. It was due to an increase of lake fertility which induced new trend in the long-term phytoplankton succession in Konin lakes.

Key words: LAKE, HEATED WATER, POLLUTION, PHYTOPLANKTON, LONG-TERM SUCCESSION.

## INTRODUCTION

Inclusion of the Konin lakes into a cooling system of two power plants caused several inter-related disturbances in the lake ecosystems and the biocenose organization on all trophic levels. Phytoplankton was a sensitive index of essential changes in the lake functioning, and determined water quality for the power plants as well as from the point of view of environment quality. Three characteristic phases can be distinguished as regards changes in the phytoplankton abundance and composition during 30 years of power plant functioning in the lake system. In the first 10 years, when the heated effluents were discharged into the lakes (60-ies), water heating became a stress inducing factor for the ecosystem („thermal shock"), and triggered the processes intensifying lake eutrophication, this being reflected also in abundant development of the phytoplankton in the warmest Lake Licheńskie (Sosnowska 1987). Algal biomass was then determined by diatoms. Short-term, irregular and frequent blooms, and mass algae appearance in all heated lakes confirmed „stress" responce of the phytoplankton and suggested lack of biological stability in the ecosystem (Dąmbska et al. 1976, Burchardt 1977).

The longer the lakes constituted the cooling system for the power plants, the more low water retention (especially in summer) became the limiting factor for intensive development of the phytoplankton in Konin lakes. This trend was noted in the 70-ies and in the first half of the 80-ies (Spodniewska 1984, Simm 1988a, b). Decreasing abundance of the phytoplankton and simultaneous increase of its taxonomic diversity pointed to overall decrease of the lake trophy (Zdanowski et al. 1988, Simm 1988a).

Since the mid-80-ies lake trophy began to increase due to progressing mineral and organic pollution of the cooling system. Phytoplankton responded increasing its biomass, with a tendency to blooms, and changing the domination structure. This is presented here basing on the algological materials collected from Konin lakes in 1987-1990. Another aim of the studies was to determine whether intensified phytoplankton development was a permanent phenomenon, giving specific character to heated lakes in the current phase of functioning of the Konin lake ecosystems.

## STUDY AREA

Studies were carried out on four lakes included into the cooling system of „Pątnów" and „Konin" power plants viz. lakes Gosławskie, Pątnowskie, Licheńskie and Ślesińskie. Lakes Gosławskie and Pątnowskie are shallow, pond-type (average depth 3.0 and 2.6 m), polymictic, eutrophic. Lake Licheńskie is deeper (average depth 4.5 m), valley-shaped, with a tendency to polymixis, eutrophic. Lake Ślesińskie is in form of a deep tunnel with developed areas of open water (average depth 7.6 m), dimictic (with the exception of the part close to the effluent discharge), less eutrophic. Lakes Gosławskie, Pątnowskie and Licheńskie are heated all year, Lake Ślesińskie is heated periodically (since May till September); in the warmest Lake Licheńskie water temperature in summer is about 26-30C, in the other lakes it ranges from 24 to 28C. Water retention in summer ranges from 1.5 to 16 days in particular lakes. Struga Biskupia is the main inflow to the complex. It brings in (through Lake Gosławskie) mine waters with high content of mineral suspension and organic pollution from the catchment area. There are also other sources of pollution: domestic sewage from housing areas and recreational sites, industrial and sanitary wastes from the power plants, cage fish culture in the channels, precipitation of industrial dust.

More detailed characteristic of the lakes and of the cooling system, as well as a description of the changes in the thermal and hydrological regime have been given by Zdanowski (1994).

## MATERIAL AND METHODS

Phytoplankton studies began in 1987 with the observations on seasonal changes in the inflow channel of „Konin" power plant, which brought water from Lake Pątnowskie. Samples collected at this station may be regarded as representative for the epilimnion of Lake Pątnowskie. They were collected at weekly intervals grom 6 Feb. 1987 till 29 May 1989. In autumn 1988 the whole cooling system was comprised in the studies. Systematic observations at monthly intervals were also made in lakes Gosławskie, Licheńskie and Ślesińskie. Samples from these stations were collected since October 1988 till November 1990.

Qualitative and quantitative analyses of the phytoplankton were made on the samples collected in the epilimnion, at one pelagic station located over the deepest part, and in the channel - from the surface water layer. Samples were preserved with Lugol's liquid, condensing the sedimenting sestone to obtain 2-5 $cm^3$ and examined under a microscope in a Fuchs-Rosenthal chamber, magn. 400 x, using a microscope Jenamed 2. The organisms were counted over different areas depending on their densities, in squares of the chamber net, giving the number of organisms (usually cells, sometimes cenobia, colonies, filaments) in 1 $dm^3$. Algae biomass was calculated basing on the other authors (Spodniewska 1984, Sosnowska 1987, Simm 1988). Small organisms, less than 30 μm, were classified as nannoplankton.

## RESULTS

### PHYTOPLANKTON IN LAKE PĄTNOWSKIE (1987-1990)

Phytoplankton communities in Lake Pątnowskie were poor in 1987. Average annual biomass of the algae was 1.4 $mg/dm^3$, maximal 6.2 $mg/dm^3$ (Fig. 1). Diatoms dominated; they represented 63% of the total biomass. Blue-green algae, *Dinophyceae*,

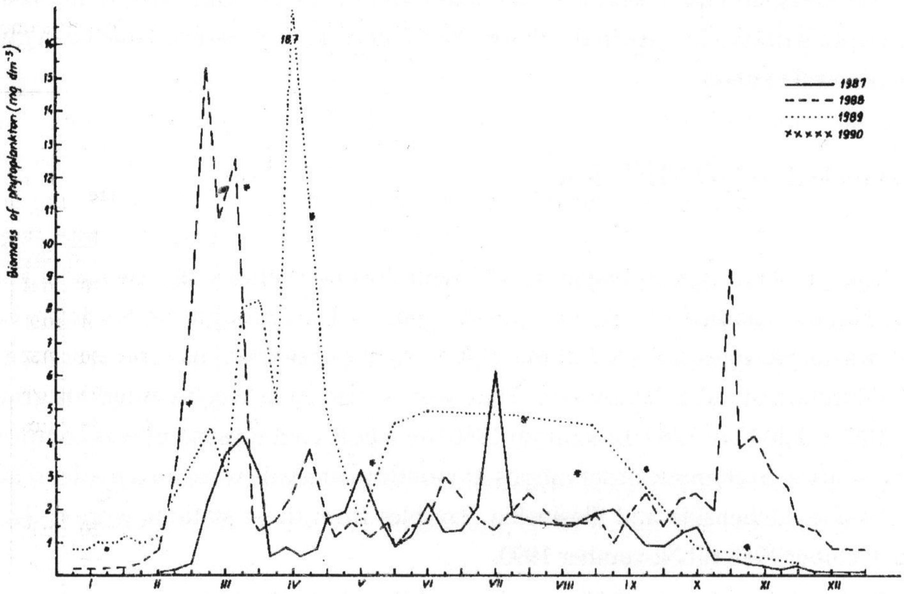


Fig. 1. Seasonal variations of total phytoplankton biomass in Lake Pątnowskie in 1987-1990

*Chrysophyceae* and green algae were abundant in spring and summer, reflecting diversified composition of the phytoplankton.

Noticeable increase of the phytoplankton biomass (by 90%) was observed in 1988. Average annual biomass of the algae amounted to 2.7 mg/dm$^3$, and maximal level was 15.3 mg/dm$^3$. Diatoms still dominated (73%) and determined the increase of algae abundance. Share of the other taxonomic groups was similar or lower than in 1987.

Biomass increase in 1988 proved to represent a long-term trend. In 1989 average annual biomass continued to increase (by 41%) to 3.8 mg/dm$^3$, reaching maximally 18.7 mg/dm$^3$, and in 1990 the biomass increased by 30% (average biomass 4.9 mg/dm$^3$, maximal 11.7 mg/dm$^3$). Diatoms dominated all the time; they constituted 55% and 62% in 1989 and 1990 respectively. The increase of the phytoplankton biomass in 1989-1990 was caused by more abundant development of diatoms and blue-green algae. Share of the latter was 17.5% in 1989, while *Cryptophyceae* represented 16% in 1990. Abundance of *Dinophyceae* and green algae also increased. *Chrysophyceae* were also present in the phytoplankton, and rarely euglenins and *Xanthophyceae*. Totally, the average annual biomass of the phytoplankton in 1990 increased 3.5 times compared to its level in 1987.

TABLE 1

Range and average levels of the phytoplankton biomass ($mg/dm^3$), percentages of particular taxonomic groups and of the nannoplankton in Konin lakes in 1987-1990

| Taxonomic groups of algae | 1987 | | | 1988 | | | 1989 | | | 1990 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | range | aver-age | % | range | aver-age | % | range | aver-age | % | range | aver-age | % |
| **LAKE PĄTNOWSKIE** | | | | | | | | | | | | |
| *Cyanophyceae* | 0.01–1.70 | 0.11 | 7.8 | 0.01–1.27 | 0.14 | 5.2 | 0.01–3.73 | 0.66 | 17.5 | 0.01–1.70 | 0.44 | 9.0 |
| *Euglenophyceae* | 0.01–0.03 | 0.01 | 0.7 | 0.01–0.03 | 0.01 | 0.4 | 0.01–0.05 | 0.01 | 0.3 | 0.01–0.04 | 0.01 | 0.2 |
| *Dinophyceae* | 0.01–1.31 | 0.18 | 12.8 | 0.01–1.55 | 0.22 | 8.2 | 0.01–1.68 | 0.44 | 11.7 | 0.04–2.10 | 0.37 | 7.6 |
| *Cryptophyceae* | 0.03–0.33 | 0.13 | 9.2 | 0.04–1.08 | 0.25 | 9.3 | 0.06–1.35 | 0.32 | 8.5 | 0.30–1.75 | 0.78 | 15.9 |
| *Chrysophyceae* | 0.01–0.27 | 0.06 | 4.2 | 0.01–0.30 | 0.05 | 1.9 | 0.01–0.22 | 0.09 | 2.4 | 0.01–0.16 | 0.06 | 1.2 |
| *Bacillariophyceae* | 0.04–4.13 | 0.89 | 63.2 | 0.13–14.8 | 1.96 | 73.1 | 0.20–17.9 | 2.07 | 54.8 | 0.39–9.47 | 3.06 | 62.4 |
| *Xanthophyceae* | 0.01–0.10 | 0.01 | 0.7 | 0.01–0.07 | 0.01 | 0.4 | 0.01–0.17 | 0.04 | 1.1 | 0.02 | - | - |
| *Chlorophyceae* | 0.01–0.10 | 0.02 | 1.4 | 0.01–0.24 | 0.04 | 1.5 | 0.01–0.54 | 0.14 | 3.7 | 0.01–0.50 | 0.18 | 3.7 |
| Total | 0.09–4.22 | 1.41 | 100.0 | 0.17–15.3 | 2.68 | 100.0 | 0.41–18.7 | 3.77 | 100.0 | 0.81–11.7 | 4.90 | 100.0 |
| 1/ | | | 39.0 | | | 51.1 | | | 16.0 | | | 44.7 |
| **LAKE GOSŁAWSKIE** | | | | | | | | | | | | |
| *Cyanophyceae* | | | | | | | 0.01–0.93 | 0.22 | 9.8 | 0.01–0.35 | 0.11 | 2.7 |
| *Euglenophyceae* | | | | | | | 0.02–0.10 | 0.04 | 1.8 | 0.01–0.54 | 0.16 | 3.9 |
| *Dinophyceae* | | | | | | | 0.01–0.55 | 0.09 | 4.0 | 0.03–0.38 | 0.10 | 2.5 |
| *Cryptophyceae* | | | | | | | 0.04–0.55 | 0.24 | 10.8 | 0.05–2.03 | 0.77 | 18.7 |
| *Chrysophyceae* | | | | | | | 0.01–0.05 | 0.02 | 0.9 | 0.01–0.11 | 0.03 | 0.7 |
| *Bacillariophyceae* | | | | | | | 0.07–5.45 | 1.52 | 68.2 | 0.23–12.1 | 2.78 | 67.6 |
| *Xanthophyceae* | | | | | | | 0.01–0.12 | 0.02 | 0.9 | - | - | - |
| *Chlorophyceae* | | | | | | | 0.01–0.26 | 0.08 | 3.6 | 0.01–0.54 | 0.16 | 3.9 |
| Total | | | | | | | 0.17–6.11 | 2.23 | 100.0 | 0.42–14.8 | 4.11 | 100.0 |
| 1/ | | | | | | | | | 29.6 | | | 68.9 |
| **LAKE LICHEŃSKIE** | | | | | | | | | | | | |
| *Cyanophyceae* | | | | | | | 0.01–2.87 | 0.57 | 17.4 | 0.01–1.15 | 0.25 | 4.3 |
| *Euglenophyceae* | | | | | | | 0.01–0.04 | 0.01 | 0.3 | 0.01–0.04 | 0.01 | 0.2 |
| *Dinophyceae* | | | | | | | 0.02–1.30 | 0.27 | 8.2 | 0.06–0.74 | 0.21 | 3.6 |
| *Cryptophyceae* | | | | | | | 0.11–1.24 | 0.43 | 13.1 | 0.23–7.40 | 1.82 | 31.3 |
| *Chrysophyceae* | | | | | | | 0.01–0.10 | 0.03 | 0.9 | 0.01–0.17 | 0.05 | 0.8 |
| *Bacillariophyceae* | | | | | | | 0.14–7.99 | 1.82 | 55.5 | 0.41–9.68 | 3.17 | 54.5 |
| *Xanthophyceae* | | | | | | | 0.01–0.14 | 0.03 | 0.9 | 0.01–0.03 | 0.01 | 0.2 |
| *Chlorophyceae* | | | | | | | 0.01–0.50 | 0.12 | 3.7 | 0.02–0.73 | 0.30 | 5.1 |
| Total | | | | | | | 0.39–8.36 | 3.28 | 100.0 | 0.83–17.9 | 5.82 | 100.0 |

Share of nannoplanktonic organisms in total biomass of the algae was 40% on the average, only in 1990 it decreased to 16% (Tab. 1).

## PHYTOPLANKTON IN LAKES PĄTNOWSKIE, GOSŁAWSKIE, LICHEŃSKIE AND ŚLESIŃSKIE (1989-1990)

Average annual biomass of the algae increased in 1990 in all lakes constituting the cooling system of the power plants. In relation to 1989 this increase was 80% in Lake Gosławskie (from 2.2 to 4.1 $mg/dm^3$) and Licheńskie (from 3.3 to 5.8 $mg/dm^3$), 30% in Lake Pątnowskie (from 3.8 to 4.9 $mg/dm^3$), and 6% in Lake Ślesińskie (from 6.2 to 6.5 $mg/dm^3$). Share of nannoplanktonic organisms differed in particular lakes. The highest biomass of these organisms was always recorded in Lake Gosławskie (up to 69% in 1990) the lowest in Lake Ślesińskie (9-28%). It was more or less similar in lakes Pątnowskie and Licheńskie (16-23% in 1989 and 45-48% in 1990). In 1989 nannoplanktonic organisms were less abundant than in 1990.

Lake Ślesińskie was characterized by abundant development of the phytoplankton throughout the vegetation season. It was decisively diatomic plankton (about 80%), and its maximal biomass reached 23 $mg/dm^3$. Maximum was always recorded in March. Share of *Dinophyceae* and green algae increased in summer, while no euglenins were recorded in this period.

On the other hand, the phytoplankton was the least abundant in Lake Gosławskie. This lake is shallow, intensively mixed and stirred. Diatoms dominated also in this lake (68%). They were accompanied by fairly abundant *Cryptophyceae* (11-19%). Biomass of blue-green algae, *Dinophyceae* and green algae was always lower than in other lakes, while euglenins were more abundant here.

Share of the diatoms in Lake Licheńskie was 55% on the average. Biomass of blue-green algae was relatively high, up to 17% of the phytoplankton biomass. *Cryptophyceae* represented up to 31% in 1990 (the highest level in the lakes under study), and *Dinophyceae* and green algae were also significant.

Composition of the phytoplankton in Lake Pątnowskie was similar to that in Lake Licheńskie (Tab. 1, Fig. 4, 5). Maximal biomass of the algae recorded in 1989-1990 was 18.7 $mg/dm^3$ in Lake Pątnowskie (in 1989), 17.9 $mg/dm^3$ in Lake Licheńskie (in 1990), and 14.8 $mg/dm^3$ in Lake Gosławskie (in 1990). In all the cases these maxima referred to early spring diatom blooms.

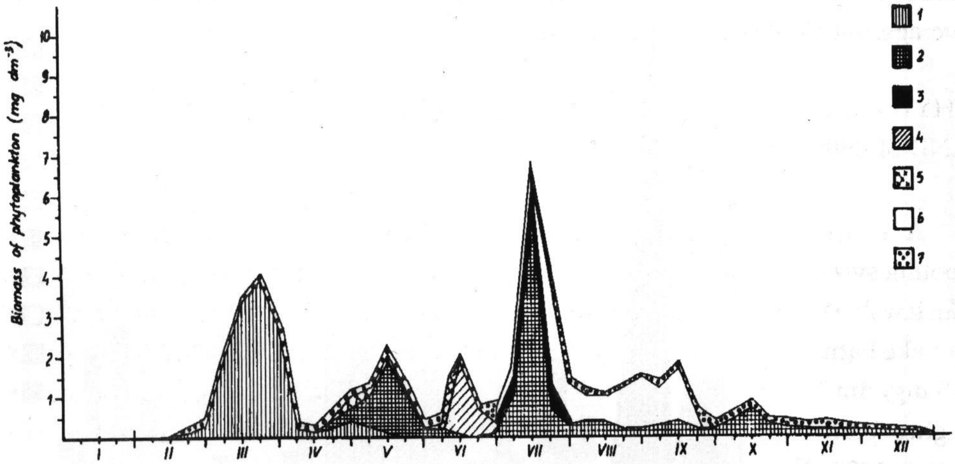


Fig. 2. Seasonal variations of biomass dominants in the phytoplankton of Lake Pątnowskie in 1989. 1 - *Stephanodiscus hantzschii* Grun., 2 - *Melosira granulata* (Ehr.) Ralfs, 3 - *Microcystis incerta* (Lemm.) Starmach comb. nov., 4 - *Aphanizomenon flos-aquae* (L.) Ralfs, 5 - *Dinobryon sertularia* Ehr., 6 - *Ceratium hirundinella* (O.F.Mull.) Bergh, 7 - *Cryptomonas erosa* Ehr.

## PHYTOPLANKTON DOMINANTS

Algologic studies carried out in 1987-1990 in the heated lakes near Konin revealed the following seasonality of the dominants (Fig. 2, 3, 4, 5):

**in winter:** diatoms - *Stephanodiscus hantzchii* Grun., *S. astraea* (Ehr.) Grun., S. *astrea v. minutulus* (Kutz.) Grun. *Melosira italica* (Ehr.) Kutz., *M. italica v. tenuissima* (Grun.) O. Mull., *M. granulata v. angustissima* (O.Mull.) Hust. and *Asterionella formosa* Hass. and *Cryptophyceae* - *Cryptomonas erosa* Ehr., *C. Ovata* Ehr. and *Rhodomonas minuta* Skuja;

**in spring:** the same taxons as above and blue-green algae - *Aphanisomenon flos-aquae* (L.) Ralfs, *Anabaena flos-aquae* Breb. ex Bornet et Flahault;

in summer: blue-green algae - *Anabaena flos-aquae*, *A. solitaria* Klebahn, *A. spiroides* Klebahn, *A. affinis* Lemm., *Microcystis incerta* (Lemm.) Starmach, *M. aeruginosa* Kutz. and *Dinophyceae*: *Ceratium hirudinella* (O.F.Mull.) Bergh and *Peridinium inconspicuum* Lemm. In addition to this, *Melosira granulata* (Ehr.) Ralfs was met in Lake Ślesińskie and *Euglena hemichromata* Skuja in Lake Gosławskie;

**in autumn:** diatoms - *Melosira italica*, *M. italica v. tenuissima*, *Cryptophyceae* - *Cryptomonas erosa*, *Rhodomonas minuta* and (only in Lake Licheńskie) green algae *Ankistrodesmus falcatus* (Corda) Ralfs.

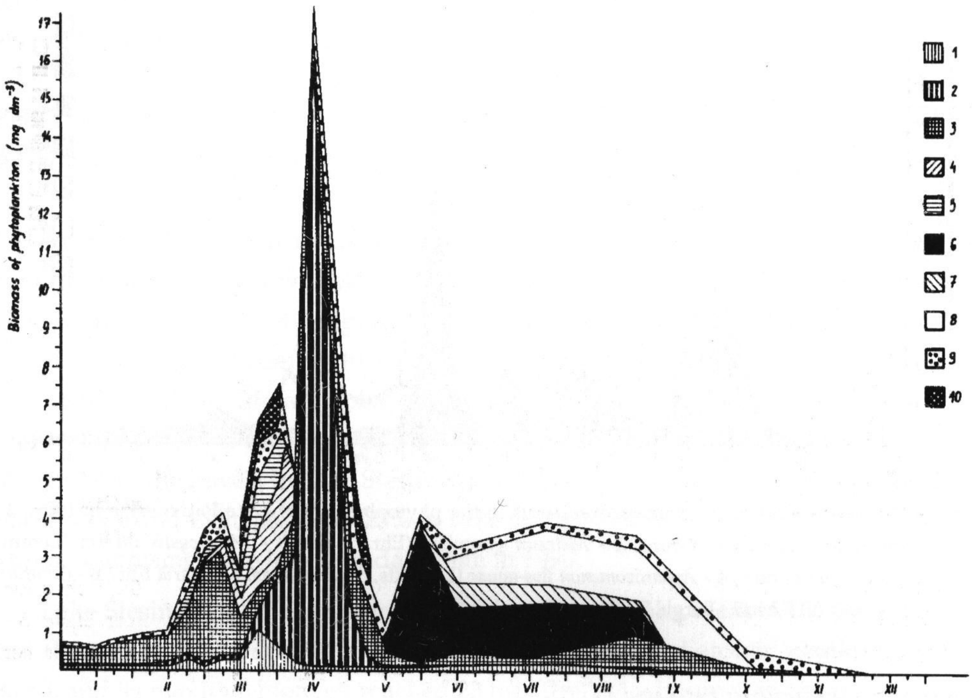

Fig. 3. Seasonal variations of biomass dominants in the phytoplankton of Lake Pątnowskie in 1989 1 - *Stephanodiscus hantzschii* Grun., 2 - *Stephanodiscus astraea* (Ehr.) Grun., 3 - *Melosira italica v. tenuissima* (Grun.) O.Mull., 4 - *Asterionella formosa* Hass., 5 - *Melosira varians* Ag., 6 - *Anabaena solitaria Klebahn, A. flos-aquae* Breb. ex Bornet et Flahault, 7 - *Microcystis incerta* (Lemm.) Starmach comb. nov., 8 - *Ceratium hirundinella* (O.F.Mull.) Bergh, 9 - *Cryptomonas erosa Ehr., 10 - Diatoma elongatum* (Lyng.) Ag.

As regards the seasonal succession of the phytoplankton communities attention should be given to diatom blooms in early spring (mainly from the genus *Stephanodiscus*), which commenced earlier and earlier in the consecutive years (since mid-February), and lasted longer (up to 11 weeks). Also they attained higher biomass levels (up to about 20.0 mg/dm$^3$). This variability was caused most of all by the winter anomalies: higher air temperatures in 1988-1990 compared to earlier years, which caused an additional increase of water temperatures in the lakes.

Numerous appearance of summer dominants (blue-green algae and *Dinophyceae*) was connected with favourable thermal, light and trophic conditions in lakes Pątnowskie and Licheńskie, whereas about 10-day water exchange in the whole cooling system enhanced theirr distribution throughout the lake system.

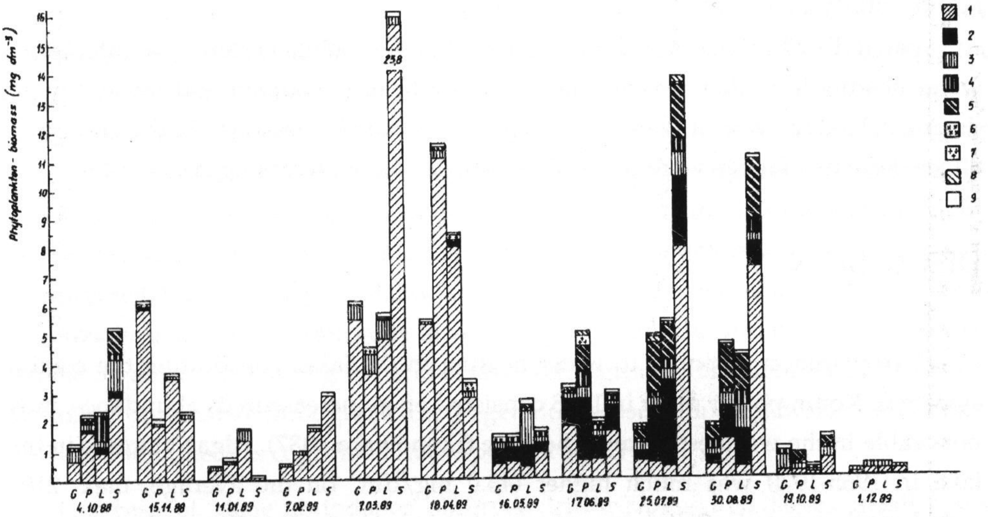


Fig. 4. Total biomass and phytoplankton composition in lakes: Gosławskie (G), Pątnowskie (P), Licheńskie (L) and Ślesińskie (S) in different seasons of 1988 and 1989. 1 - diatoms, 2 - blue-green algae, 3 - *Cryptophyceae*, 4 - green algae, 5 - *Dinophyceae*, 6 - euglenins, 7 - *Chrysophyceae*, 8 - *Xanthophyceae*, 9 - other

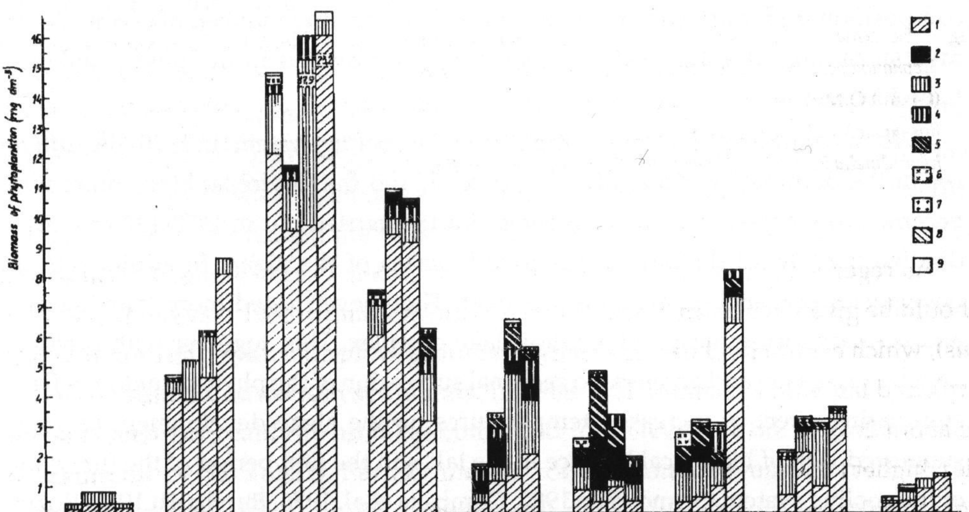


Fig. 5. Total biomass and phytoplankton composition in lakes: Gosławskie (G), Pątnowskie (P), Licheńskie (L) and Ślesińskie (S) in different seasons of 1990. 1 - diatoms, 2 - blue-green algae, 3 - *Cryptophyceae*, 4 - green algae, 5 - *Dinophyceae*, 6 - euglenins, 7 - *Chrysophyceae*, 8 - *Xanthophyceae*, 9 - other

*Cryptophyceae* dominants in winter-spring and autumn have not been noted by the authors studying Konin lakes in 1965-1980.

Spatial distribution of the dominants (within the cooling system) was affected by water heating in cooller seasons, and by water heating coupled with water mixing during a 10-day cycle of water exchange in the warmer seasons. At the end of the 80-ies these two factors were coupled with the effect of increasing lake trophy.

## DISCUSSION

Phytoplankton responce to water heating in the lakes constituting the cooling system of Konin power plant in 1958 consisted of an increase in its abundance, most noticeable in the warmest Lake Licheńskie (Sosnowska 1987). Algae biomass in this lake in 1965-1970 was much higher (43.0 mg/dm$^3$ on the average, max. 210.0 mg/dm$^3$) than in Lake Ślesińskie, which was not heated at that time (4.0 mg/dm$^3$ on the average, max. 14.0 mg/dm$^3$). Total phytoplankton biomass in Lake Licheńskie was determined by diatoms, and in Lake Ślesińskie by diatoms, green algae, *Dinophyceae* and blue-green algae. This suggested that algal community simplified its composition under an anthropogenic stress. Lake heating induced also considerable diversificationn of warm-water species from *Clorococcales* in the phytoplankton of Lake Licheńskie.

When Lake Ślesińskie was included into the cooling system (in 1970) the differences in the domination gradually disappeared, and the phytoplankton communities became more or less similar in all lakes. Studies carried out in 1970-1973 confirmed dominating role of diatoms in the total biomass of the algae. In addition to this, one-species blooms became more frequent. They never lasted more than one week and appeared irregularly in the whole lake complex. This, together with prolonged vegetation season and accelerated seasonal succession of the phytoplankton, reflected stimulating effect of increased temperatures on the algae development as well as suggested lack of biological balance in the lakes in the first period of the functioning of the cooling system (Sosnowska 1987, Dąmbska et al. 1976, Burchardt 1977, Rozmiarek 1975, Szyszka 1977).

In the 70-ies, when the cooling system became stabilized, abundance of the phytoplankton in the heated lakes decreased gradually (Spodniewska 1984). Diatoms still dominated (from the genus *Melosira*), but diversity of the algal flora was determined by small coccal green algae; blue-green algae preferred the warmest Lake Licheńskie, while euglenins - Lake Gosławskie, which was polluted with mineral and organic substances. Progressing decrease of algal biomass was still noticeable at the begining of the 80-ies (Simm 1988a). In 1983-1984 biomass of the summer phytoplankton was lower than 2.0 mg/dm$^3$ and higher values (up to 10.0 mg/dm$^3$) occurred only in spring. Diatoms dominated in cooler periods but were replaced by green algae (20-30% in total biomass), *Cryptophyceae* and *Dinophyceae* (to 30%) in summer. This type of the seasonal succession and high share of nannoplanktonic forms caused that Simm (1988a) compared Konin lakes to fertile rivers of the temperate zone, at least as regards the epilimnion. In strongly mixed and polluted Lake Gosławskie, nannoplanktonic organisms belonging to various taxonomic groups (but dominated by centric diatoms) dominated throughout the vegetation season (Spodniewska 1984, Simm 1988b). The same was confirmed in the present study.

Decrease of algae abundance observed in the 70-ies and 80-ies in all lakes, diversified composition of summer phytoplankton (composed of different taxonomic groups), and plankton homogeneity in the whole cooling system were connected with low water retention. It proved to be a more important factor than water heating and it modified the phytoplankton communities in conditions of lower lake trophy (Spodniewska 1984, Simm 1988a, Zdanowski 1988).

Phytoplankton biomass was still low in Lake Pątnowskie in 1987 (annual average 1.4 mg/dm$^3$), at the same level as observed by Simm (1988a, b) in 1983-1984 in lakes Gosławskie, Licheńskie, Wąsosko-Mikorzyńskie and Ślesińskie (Tab. 1, Fig. 1, 2). This confirmed the hypothesis on the decrease of algae abundance in heated and strongly mixed lakes, in which bioavailability of phosphorus was limited (Zdanowski 1988, Simm 1988a). It was also underlined that the phytoplankton did not fully utilize trophic resources of the lake, which had been immobilized in the seston and bottom sediments. In 1988-1990 biomass of the phytoplankton increased noticeably in all lakes compared to its levels at the begining of the 80-ies (Simm 1988a, Tab. 2). Further increase of the biomass was also recorded in 1990 compared to 1989 (Tab. 1). Diatoms still dominated in winter-spring in all lakes, forming early spring blooms (14.8-23.9 mg/dm$^3$). The highest biomass was noted for the species from the genus *Stephanodiscus: S. astrae* (about 20.0 mg/dm$^3$) in Lake Ślesińskie and *S. astrae v. minutulus, S. hantzschii* accompanied by *Melosira italica, M. italica v. tenuissima formosa* in other lakes.

TABLE 2

Comparison of the phytoplankton biomass (annual average, range in mg/dm$^3$) in heated Konin lakes in 1965-1984 (after Spodniewska 1984, Sosnowska 1987, Simm 1988a) and 1987-1990

| Period of studies | Lake | | | | |
|---|---|---|---|---|---|
| | Gosławskie | Pątnowskie | Licheńskie | Wąsosko-Mikorzyńskie | Ślesińskie |
| 1965–1970 | - | - | 43.2<br>1.2–210.2 | 14.3<br>0.5–76.7 | 4.0<br>0.1–14.0 |
| 1977–1980 | 6.4<br>3.9–10.2 | - | 5.9<br>2.4–12.0 | 4.0<br>0.9–11.7 | 3.6<br>0.6–7.2 |
| 1983–1984 | 1.3[1]<br>0.4–2.8<br>3.0–11.0[2] | - | 1.5[1]<br>0.6–1.9 | 1.8[1]<br>0.8–3.0 | 1.2[1]<br>0.6–4.0<br>4.0–10.0[2] |
| 1987 | - | 1.4<br>0.1–6.2 | - | - | - |
| 1988 | - | 2.7<br>0.2–15.3 | - | - | - |
| 1989 | 2.2<br>0.2–6.1 | 3.8<br>0.4–18.7 | 3.3<br>0.4–8.4 | - | 6.2<br>0.2–24.0 |
| 1990 | 4.1<br>0.4–14.8 | 4.9<br>0.8–11.7 | 5.8<br>0.8–17.9 | - | 6.5<br>0.4–23.2 |

[1] *phytoplankton biomass in summer*
[2] *phytoplankton biomass in spring*

*Cryptophyceae* were also important, especially in Lake Licheńskie (Fig. 4, 5). In summer phytoplankton the share of diatoms decreased (with the exception of Lake Ślesińskie - 64%) and of blue-green algae and *Dinophyceae* increased (*Anabaena spp., Aphanisomenon flos-aquae, Microcystis spp., Ceratium hirundinella)* to 65% in lakes Licheńskie and Pątnowskie. *Cryptophyceae* were important in all lakes, green algae in lakes Licheńskie and Ślesińskie, euglenins in Lake Gosławskie (Fig. 4, 5).

Changes in the phytoplankton abundance and composition, noted in Konin lakes at the end of the 80-ies, related to the observations from earlier 30-year period of the studies, suggest that we deal with the formation of a community characteristic of fertile eutrophic waters. These changes were reflected in: an increase of total algae biomass in the whole cooling system, longer and more abundant early spring diatom blooms, numerous appearance of blue-green algae and *Dinophyceae* in summer, presence of euglenins as an indicator of organic pollution in Lake Gosławskie, low nannoplankton biomass in 1989 due to the development of large forms of *Stephanodiscus astraea* in spring and of floating colonies of blue-green algae and large flagellates (*Ceratium hirudinella*) in summer. All these qualitative and quantitative changes of the phytoplankton in Konin lakes by the end of the 80-ies were connected with increasing lake trophy. This process resulted from progressing mineral and organic pollution of the lakes, occuring together with lake heating and climatic changes (warm winters). High water temperature stimulated the development of blue-green algae, green algae and *Dinophyceae* while it limited the development of diatoms (Reynolds 1984, Szaler et al. 1988, Tereszenkova 1989, Vinogradskaja 1991). This was generally noticeable in the phytoplankton composition in the heated lakes. Intensive blooms of blue-green algae were also observed in strongly heated and fertile waters of Ukraina, Moldavia and Russia (Szalar et al. 1988, Avinskaja 1989, Vinogradskaja 1991) used as cooling systems of the power plants. They were so heavy that the lakes became unsuitable for water cooling. In the case of Konin lakes, algal blooms were observed only in Lake Licheńskie in 1965-1971 i.e. in the initial period of heated effluent discharge. On the other hand, intensive phytoplankton development with high share of blue-green algae in the whole cooling system in 1987-1990 reflected potential possibilities of abundant growth of the algae in the lake complex, connected with high lake trophy and stimulating effect of heated effluents. Until now rapid water exchange prevented over development of the phytoplankton in Konin lakes. Lack of heavy blooms (mostly blue-green algae) is required for proper functioning of the cooling system, and is of primary importance for water quality in the lakes.

*Trans. by Maria Bnińska*

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# STRESZCZENIE


## JAKOŚCIOWE I ILOŚCIOWE ZMIANY FITOPLANKTONU W PODGRZANYCH JEZIORACH KONIŃSKICH

W latach 1987-1990 badano fitoplankton w Jez. Pątnowskim. Ogólnie biomasa glonów w 1987 r. była niska (śr. roczna - 1.4 mg/dm$^3$) i kształtowała się na poziomie obserwowanym w latach 1983-1984 w jeziorach Gosławskim, Licheńskim, Wąsosko-Mikorzyńskim i Ślesińskim (Simm 1988a). Dominowały okrzemki, mimo to fitoplankton letni charakteryzował się urozmaiconym składem taksonomicznym (tab. 1, 2; rys. 1).

W 1988 r. średnia roczna biomasa glonów wzrosła o 90% (2.7 mg/dm$^3$) w odniesieniu do 1987 r., w 1989 r. - o dalsze 41% (3.8 mg/dm$^3$). Spodziewając się wzrostu obfitości glonów w całym układzie chłodzenia jesienią 1988 r. badaniami objęto dodatkowo jeziora: Gosławskie, Licheńskie i Ślesińskie. W latach 1989-1990 we wszystkich jeziorach podgrzanych stwierdzono wyraźny przyrost biomasy fitoplanktonu w porównaniu do jej wielkości notowanych na początku lat 80-tych (Simm 1988a); znaczący wzrost biomasy notowano również w 1990 r. (w odniesieniu do 1989 r.); o 80% w jeziorach Gosławskim i Licheńskim (śr. roczne przyrosty odpowiednio: z 2.2 do 4.1 mg dm$^{-3}$ i z 3.3 do 5.8 mg/dm$^3$), o 30% w Jez. Pątnowskim (z 3.8 do 4.9 mg/dm$^3$) i o 6% w Jez. Ślesińskim (z 6.2 do 6.5 mg/dm$^3$).

W zimowo-wiosennych sezonach we wszystkich jeziorach dominowały okrzemki tworząc wczesnowiosenne zakwity (14.8-23.0 mg/dm$^3$) - rys. 2, 3. Zakwity i masowe pojawy budowały: *Stephanodiscus*

*astraea v. minutulus, S. hantzschii* w towarzystwie *Melosira granulata v. angustissima* i *Asterionella formosa* - w pozostałych zbiornikach. Ważny był również udział kryptofitów, zwłaszcza w Jez. Licheńskim. W fitoplanktonie letnim zmalał udział okrzemek (z wyjątkiem planktonu w Jez. Ślesińskim - 64%), natomiast wzrósł - sinic i bruzdnic (*Anabaena spp., Aphanizomenon flos-aquae, Microcystis spp., Ceratium hirundinella*) - do 65% w jeziorach Pątnowskim i Licheńskim. Znacząca była obecność kryptofitów w całym układzie chłodzenia, zielenic w jeziorach Licheńskim i Ślesińskim, euglenin - w Jez. Gosławskim (tab. 1, rys. 2, 3, 4, 5).

Fitoplankton w jeziorach podgrzanych koło Konina w latach 1987-1990 charakteryzował się: systematycznym wzrostem biomasy glonów, coraz obfitszymi i coraz dłuższymi w czasie wczesnowiosennymi zakwitami okrzemek, silnie wyrażoną obecnością okrzemek w sezonie wegetacyjnym w jeziorach Ślesińskim i Gosławskim, licznymi pojawami sinic i bruzdnic latem, niskim udziałem nannoplanktonu w 1989 r.

Wszystkie te ilościowe i jakościowe zmiany fitoplanktonu w jeziorach konińskich w końcu lat 80-tych korelowały ze wzrostem trofii zbiorników w wyniku postępującego zanieczyszczenia mineralnego i organicznego układu chłodzenia.

Podwyższenie żyzności jezior i ich podgrzanie to czynniki sprzyjające obfitemu wzrostowi glonów, zwłaszcza sinic - niekorzystnych zarówno z punktu widzenia czystości jezior, jak i ich zdolności chłodzącej dla potrzeb energetyki. Natomiast intensywne mieszanie wody w dalszym ciągu układ koniński przed tym zjawiskiem chroni.

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