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SPATIAL AND SEASONAL PHYTOPLANKTON DIVERSITY IN LICHEŃSKIE AND ŚLESIŃSKIE LAKES, KONIŃSKIE DISTRICT, IN 1991-1993[1]

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A B S T R A C T. Studies carried out in heated lakes of Konińskie District in 1991-1993 confirmed the tendency in phytoplankton development observed in the late eighties. An increase of total algal biomass, a decrease of nannoplankton share, and a shift towards community structure typical for eutrophic lakes were observed. Mass development of phytoplankton in summer was limited by intensive water mixing within and between the lakes.

Key words: LAKE, HEATED WATER, POLLUTION, PHYTOPLANKTON.

INTRODUCTION

Phytoplankton communities appeared to be a sensitive indicator of changes in the ecosystems of heated lakes of Konińskie District. For over 30 years the lakes have been included into a cooling system of two coal power plants (Dąmbska, Burchardt, Surdyk 1976, Spodniewska 1984, Sosnowska 1987, Simm 1988). In the first two decades changes were caused by increase of mean year temperature of water in the lakes and water mixing within and between the lakes. In the late eighties - also by eutrophication resulting from mineral and organic pollution (Socha 1994, Zdanowski 1994).

Two different types of phytoplankton seasonal succession were distinguished: in the lakes included in the cooling system all the year (Gosławskie, Pątnowskie and Licheńskie), and in the lake periodically included into the system (Ślesińskie).

An increase of mean annual biomass of algae and a shift in community structures towards eutrophic type were also observed. Thus, a new direction in phytoplankton development in all the lakes of Konińskie District took place (Socha 1994).

The aim of the present study on algae collected in 1991-1993 was an assessment of changes in algal communities in Licheńskie and Ślesińskie lakes, related to annually varying heating level and water mixing.

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MATERIAL AND METHODS

The study was carried out in 1991-1993 on two lakes out of five included into the cooling system of Konińskie Power Plants: Licheńskie and Ślesińskie, the channel carrying cooling water from Pątnowskie Lake to "Konin" Plant, discharge channels of "Pątnów" and "Konin" Plants, and Licheński channel of both plants (Fig. 1, Tab. 1).

Licheńskie Lake (area 147.6 ha, average depth 4.5 m, maximum depth 12.6 m) is included into the cooling system throughout the year. It has received heated water since 1958, which results in permanent heating by 5°C comparing to natural waters. Retention time of water is reduced to 5 days in summer. Northern part of Licheńskie Lake (forming a narrow gully) acts in summer as an "extension" of the discharge channel, carrying very warm water (up to 30°C) to Ślesińskie Lake. During cool season, when power plants rely on the so-called "closed cooling system", discharge water flows mainly to the middle and southern parts of the reservoir, and then to Pątnowskie Lake, closing the cooling system.

Ślesińskie Lake (area 152.3 ha, average depth 7.6 m, maximum depth 24.5 m) is the most distant from the power plant and included into the cooling system only from May to September.

Water from heated Licheńskie Lake has been reaching Ślesińskie since 1970, and has caused an increase of epilimnion temperature by 2-3°C on the average. Water retention time during that period was about 6-7 days.

TABLE 1

Morphometric and limnologic characteristics of Licheńskie and lesińskie lakes

Parameter	Licheńskie Lake	lesińskie Lake
Area (ha)[1]	147.6	152.3
Volume (tys. m^3)[1]	6712.3	11550.0
Max. depth (m)[1]	12.6	24.5
Mean depth (m)[1]	4.5	7.6
Max. breadth (km)[1]	0.51	0.54
Max. length (km)[1]	4.28	4.52
Year of including into the cooling system	1958 permament water discharge	1970 periodic water discharge
Daily water retention time in[2]	4.6 3.0–9.6	6.1 4.0–15.0

[1] *acc. to Jańczak 1989, 1990*
[2] *acc. to Zdanowski 1993*

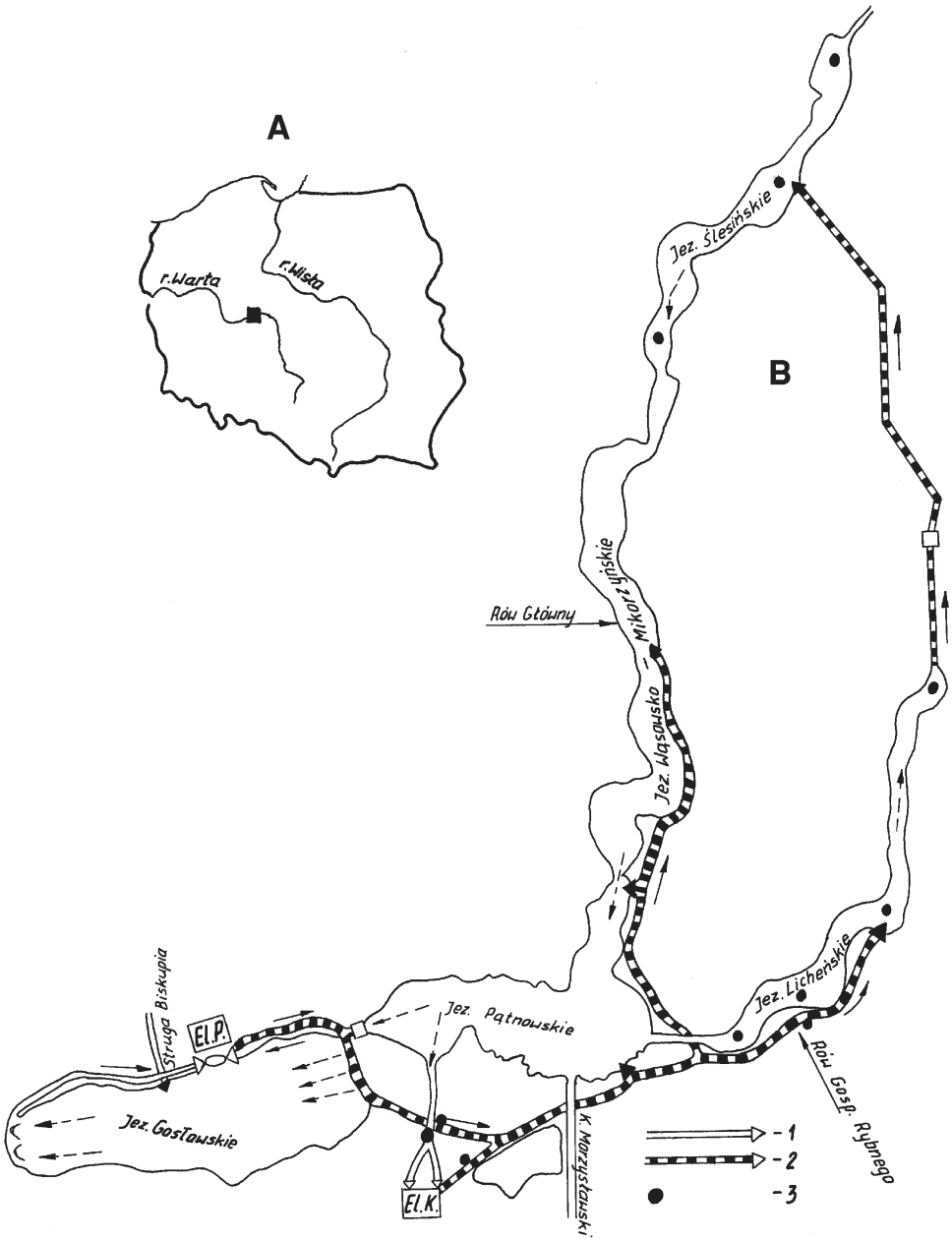

Fig. 1. B - Konińskie Power Plant cooling system, 1 - supplying channel, 2 - discharge channel, 3 - study site.

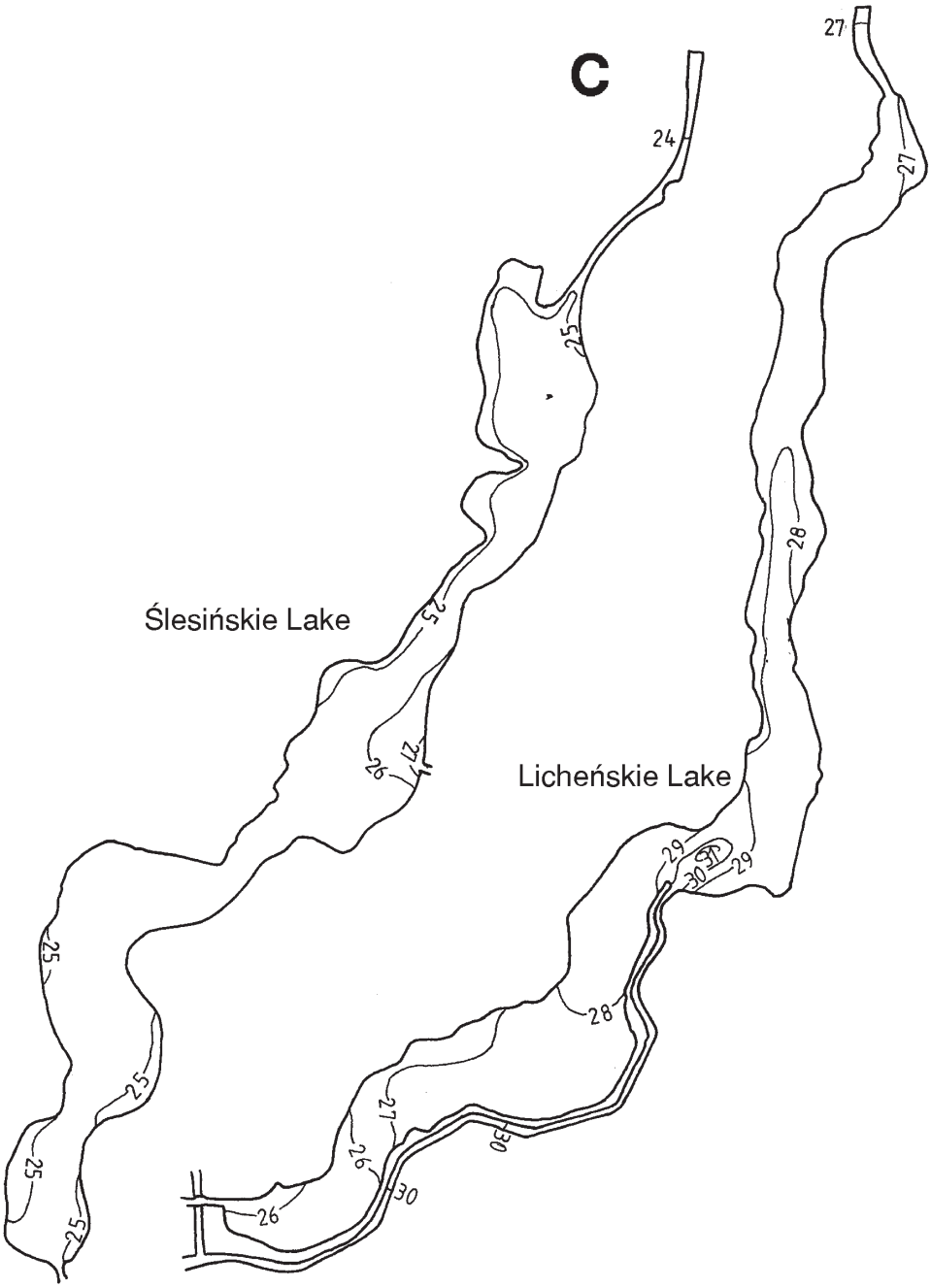

Fig. 1. C - Surface water temperature distribution in Licheńskie and lesińskie lakes on Aug. 16, 1991.

More complete information about the lakes, cooling systems, thermal regimes and hydrology can be found in the papers by Zdanowski (1994) and Socha (1994).

Phytoplankton was sampled in the seasons characteristic for Konińskie Lakes: early spring (March), before and after starting of the so-called "extended cooling system" (May and June), in summer (July/August), and in autumn, after closing of the "extended cooling system" (October).

Algae were sampled from the deepest points, discharge zones, and from parts of reservoirs periodically excluded from the main flow of effluents in both lakes (Fig. 1). Sampling site in the supplying channel of "Konin" plant was situated about 1 km from the water source in Pątnowskie Lake, in the discharge channel of "Pątnów" plant - about 2 km from the discharge, and in Licheński channel - about 5 km from the discharge from "Konin" plant and about 7 km from the discharge from "Pątnów" plant.

Lake phytoplankton samples were collected from the epilimnion (0-5 m), and in the channels from the surface layer. Samples were preserved with Lugol solution and concentrated by sedimentation to 2-5 cm^3. Phytoplankton was analysed quantitatively and qualitatively, using microscope Jenamed 2 and Fuchs - Rozenthal chamber, at 400 x magnification. Biomass (fresh mass) of algae was calculated from the number of individuals of each taxon and their measured volume. Nannoplanktonic fraction of algae up to 30 μm in diameter was distinguished.

RESULTS

1. PHYTOPLANKTON COMPOSITION AND STRUCTURE IN LICHEŃSKIE AND ŚLESIŃSKIE LAKES

Total biomass of phytoplankton in Licheńskie Lake in 1991-1992 was similar to that observed in 1990 (annual average about 5.0 mg/dm^3, range: 0.7-15.3 mg/dm^3); in 1993 - was higher about 40% (annual average: 8.0 mg/dm^3, range: 0.9-28.7 mg/dm^3). In Slesińskie Lake, in 1991-1993 total algal biomass fluctuated within the range of 0.9-24.5 mg/dm^3, and was similar to that noted in the lake in the late eighties.

Diatoms predominated the community structure, with the highest percentage share in Ślesińskie Lake (50-70%). In Licheńskie Lake diatoms comprised about 40%, while larger cryptophytes - 30%. In Ślesińskie Lake cryptophytes were also relatively abundant (20%). Other numerous phytoplankters occuring in the two lakes were:

blue-greens (in Licheńskie up to 15% in 1992), dinoflagellates (5-15%), greens (3-7%), chrysomonads (up to 10%). A decrease in the share of nannophytoplankton was observed in both lakes. In Licheńskie nannoplankton comprised 59% in 1991, while in 1993 it dropped down to 20% of total algal biomass. This probably resulted from summer development of blue-green- dinoflagellate community of filamentous and colonial blue-greens (*Anabaena flos-aquae* Breb. ex Bornet et Flahault, *Aphanizomenon gracile* (Lemm.) Elenkin, *Microcystis incerta* (Lemm.) Starmach, *M. aeruginosa* Kutz.), and large dinoflagellate (*Peridinium inconspicuum* Lemm., *Ceratium hirundinella* (O. F. Mull) Bergh). Cryptophytes were numerous during cool seasons (*Cryptomonas erosa* Ehr., *C. ovata* Ehr.).

In Ślesińskie Lake nannoplankton represented from 44% to 71% of total phytoplankton biomass in 1991-1993. In summer 1993, the usually predominating filamentous *Melosira granulata* (Ehr.) was replaced by very numerous *Stephanodiscus astraea v. minutulus* (Kutz) Grun. under 30 μm in diameter, so this increased nannoplankton share up to 71%.

2. PHYTOPLANKTON COMMUNITIES OF LICHEŃSKIE AND ŚLESIŃSKIE LAKES IN SPRING

During cold seasons (from September to April), when only "closed cooling system" operates in "Pątnów" and "Konin" plants, not only Ślesińskie, but also northern part of Licheńskie Lake are out of the system. This was reflected by the density and structure of algal communities of heated and non-heated parts of the system.

Ślesińskie Lake, similarly as natural reservoirs, stagnates and freezes in winter. In early spring a diatom dominant (*Stephanodiscus astraea*) developed, attaining biomass from 11.7 to 17.9 mg/dm^3 in 1992 (Fig. 4). Water temperature was about 4°C, and DO saturation about 130%. Water transparency decreased from 6.5 m to 2.3-2.5 m, and so did concentration of nutrients: total phosphorus level dropped from 0.148 mg/dm^3 to 0.073-0.100 mg/dm^3, and total nitrogen - from 6.53 mg/dm^3 to 1.15-2.41 mg/dm^3 (Tab. 3).

In non-freezing Licheńskie Lake early spring algal community attained biomass from 4.0 to 29.0 mg/dm^3. Diatoms predominated in the community (*Stephanodiscus hantzschii* Grun., *S. astraea* (Ehr.) Grun., *S. astraea v. minutulus*), and cryptophytes (*Cryptomonas erosa*, *C. ovata*, and *Rhodomonas minuta* Skuja). Water was rich in nutrients: total phosphorus concentration was 0.121-0.163 mg/dm^3, and total nitrogen -

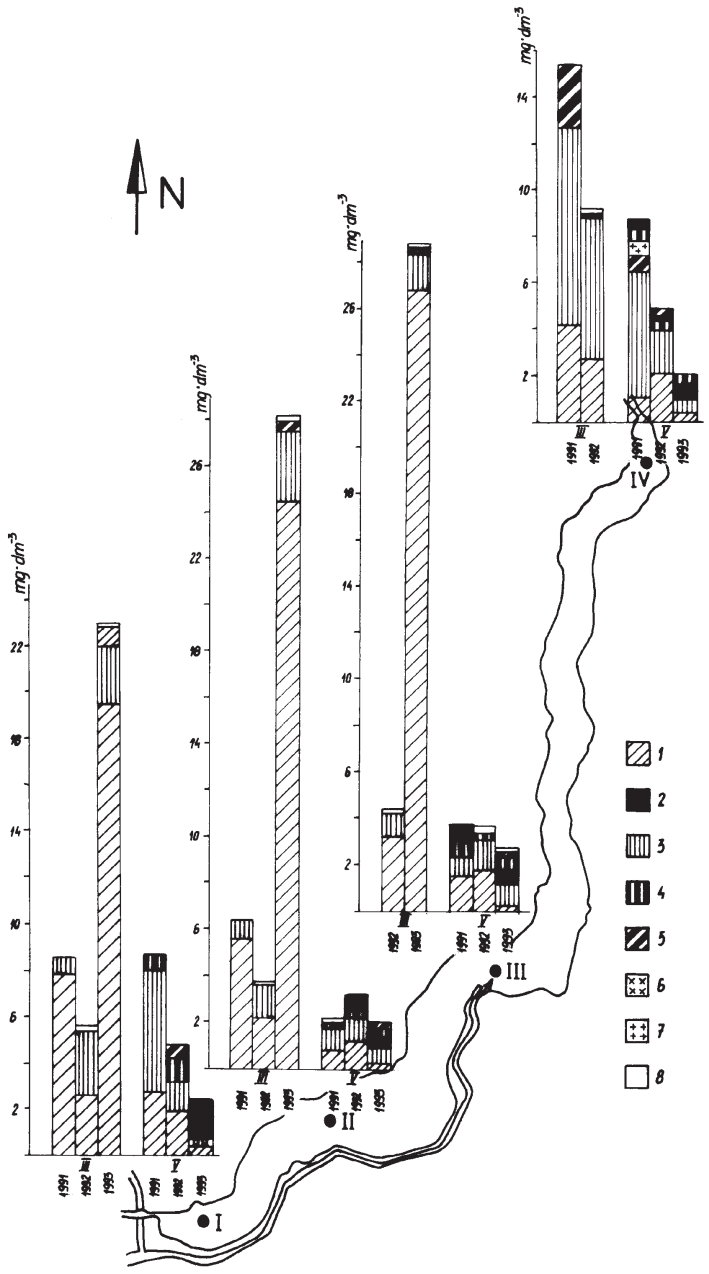

Fig. 2. Total algal biomass and structure in spring (March and May) in Licheńskie Lake in 1991-1993. 1 - diatoms, 2 - blue-greens, 3 - cryptophytes, 4 - greens, 5 - dinoflagellates, 6 - euglenophytes, 7 - chrysomonads, 8 - other.

6.29-8.31 mg/dm^3 at the beginning of the growing season. Algae caused water supersaturation with oxygen up to 106-121% and reduced water transparency from 2.5 m to 1.4-1.8 m (Tab. 2).

Domination in diatom and cryptophyte communities differed in various parts of Licheńskie Lake due to the differences in thermal conditions and hydrology.

In northern part (site IV) which was excluded from the cooling system and did non mix, water was almost as stable vertically as in natural conditions. Surface water temperature was lower (average 7.0°C) than in the middle and western parts (up to 11.9°C), although higher than in natural waters. Algal biomass in this site was twice as high as in flow-through part of the lake. Cryptophytes predominated in the algal community (56-68% of algal biomass) over diatoms (up to 29%) (Fig. 2). In the middle part (sites II and III), and western part (site I) diatoms predominated (73-93% of total algal biomass).

Analyses of plankton in the supplying channel of "Konin" plant revealed that similar community structure occured in Pątnowskie Lake.

In the effluent discharge channels, diatom-cryptophyte dominated communities were partly destroyed because of high mortality caused by mechanical damages to algae and thermal stress after passage through the power plant cooling devices. In the discharge channels algal biomass fluctuated within the range of 6.3-11.3 mg/dm^3.

After starting the "extended cooling system", which usually took place in late May, there was intensive water flow in all lakes. Temperature of the epilimnion increased to 16-19°C in Ślesińskie and to 20-25°C in Licheńskie Lake. The increase was sometimes quite abrupt, especially when rapid increase of air and heated effluent (up to 29°C) temperatures occured at the same time. During that period, die-offs of diatom blooms were observed, and summer plankton communities started to build up. In late May and early June algal biomass at all sites was considerably lower than in March (1.7-8.7 mg/dm^3). Community structures were casual and no distinct differences in the numbers of dominants were observed among the sites of both lakes (Figs. 2, 4). Diversity of the communities increased due to the development of warm-water species.

Among the dominants, diatoms and cryptophytes of spring blooms were still present, but various species of blue-green algae (*Anabaena flos-aquae*, *Microcystis incerta*, *Aphanizomenon gracile*), greens of *Chlorococcales* (*Scenedesmus quadricauda* (Turpin) Breb.), and of *Ulotrichales* (*Planktonema lauterbornii* Schmidle), chrysomonads (*Syncrypta* vol*vox* Ehr., *Dinobryon sociale* Ehr.) were also observed. Increases of water trans-

TABLE 2

Mean values of selected physico-chemical biologic and hydrologic parameters in the epilimnion of Licheńskie Lake in 1991-1993

Station	Month	Heated water discharge m^3/sek.	Water temp. °C	Oxygen mgO_2/dm^3	Saturation %	Oxidability mgO_2/dm^3	Tot-P mg/dm^3	Tot-N mg/dm^3	SD m	Total biomass of algae mg/dm^3	
										mean	range
I	I	10.0	2.1	11.3	82	9.0	0.121	6.29	2.50	1.0	1.0
	III	10.0	7.5	14.6	121	10.0	0.129	2.93	1.55	12.4	5.6–23.0
	V	5.0	19.8	8.3	89	8.7	0.076	1.18	1.47	5.2	2.3–8.7
	VI	5.0	22.2	8.2	93	8.3	0.069	2.17	1.80	5.2	5.2
	VII/VIII	5.0	27.2	8.7	109	9.0	0.120	2.20	1.57	10.4	2.8–19.1
	X	15.0	13.2	9.3	88	8.0	0.049	8.00	2.65	2.9	1.4–5.1
II	I	10.0	2.4	12.0	87	9.0	0.121	8.55	2.50	0.9	0.9
	III	10.0	7.9	13.7	114	10.0	0.127	3.08	1.83	12.9	3.9–28.3
	V	5.0	21.2	10.1	112	8.3	0.071	1.68	1.77	2.5	2.1–3.1
	VI	5.0	22.9	8.8	101	8.7	0.071	2.06	1.30	7.8	7.8
	VII/VIII	5.0	27.5	8.6	108	8.8	0.103	2.03	1.58	6.9	4.0–9.8
	X	15.0	13.6	9.0	86	7.9	0.083	4.60	2.67	2.9	1.3–3.7
III	I	10.0	6.5	11.3	92	8.7	0.163	8.31	2.50	0.9	0.9
	III	10.0	10.7	11.9	106	9.9	0.118	2.84	1.65	16.5	4.3–28.7
	V	16.0	22.5	9.0	103	9.1	0.078	1.37	1.23	3.4	2.7–3.7
	VI	17.0	24.9	7.6	91	9.3	0.077	1.11	1.40	2.3	2.3
	VII/VIII	21.0	29.4	8.1	106	6.6	0.087	2.59	1.42	5.8	2.5–8.5
	X	15.0	15.5	9.0	90	7.9	0.075	3.21	2.77	1.1	0.7–1.4
IV	I	-	-	-	-	-	-	-	-	-	-
	III	-	7.0	13.4	110	9.7	0.130	2.38	1.40	12.2	9.2–15.3
	V	11.0	21.2	9.1	101	8.7	0.075	1.35	1.23	5.2	1.9–8.7
	VI	12.0	22.4	8.9	102	9.8	0.088	2.30	1.80	7.5	7.5
	VII/VIII	16.0	28.0	11.4	144	8.9	0.108	3.32	1.53	6.1	4.1–8.8
	X	-	12.9	9.6	90	8.6	0.072	3.71	3.07	3.8	3.1–4.3

parency were observed periodically, especially in Ślesińskie Lake. Concentrations of nutrients were similar in both lakes: total phosphorus - 0.064-0.088 mg/dm^3, and total nitrogen - 1.11-3.63 mg/dm^3, stimulating algal growth (Tab. 2, 3).

Summarising, in spring, when only "closed systems" operated, separate for each power plant, Ślesińskie Lake was isolated from heated effluents, and community structure was homogenous within the whole lake. This was confirmed by statistical analysis (Student's t test) which did not reveal significant differences in total algal biomass and biomass of particular algal groups between the sites.

In Licheńskie Lake, biomass of cryptophytes in northern gully of the reservoir differed in a statistically significant way from the other sites. Northern part of the lake, exclu-

TABLE 3

Mean values of selected physico-chemical biologic and hydrologic parameters in the epilimnion of lesińskie Lake in 1991-1993

Station	Month	Heated water discharge m^3/sek.	Water temp. °C	Oxygen mgO_2/dm^3	Saturation %	Oxidability mgO_2/dm^3	Tot-P mg/dm^3	Tot-N mg/dm^3	SD m	Total biomass of algae mg/dm^3	
										mean	range
I	I	-	1.3	11.7	83	9.6	0.148	6.53	6.50	4.0	4.0
	III	-	4.8	16.7	130	9.9	0.100	1.15	2.30	11.7	11.7
	V	1.0	16.2	13.3	110	9.5	0.077	0.12	2.10	4.0	1.7–7.1
	VI	1.0	18.3	10.1	106	10.2	0.079	2.40	2.50	5.4	5.4
	VII/VIII	1.0	24.5	10.4	122	9.0	0.122	2.24	2.25	15.9	6.6–24.5
	X	-	10.5	9.0	80	8.5	0.088	2.74	5.58	3.6	1.4–6.3
II	I	-	-	-	-	-	-	-	-	-	-
	III	-	3.8	16.6	126	11.5	0.094	2.41	2.50	17.9	17.9
	V	11.0	15.9	10.3	103	10.0	0.074	1.80	2.07	3.1	2.7–4.0
	VI	12.0	19.1	8.9	95	8.3	0.076	1.50	3.30	3.8	3.8
	VII/VIII	16.0	24.8	9.5	113	9.6	0.084	1.54	2.18	12.4	2.8–18.5
	X	-	10.8	9.1	82	8.2	0.083	0.92	4.27	3.1	0.9–6.2
III	I	-	-	-	-	-	-	-	-	-	-
	III	-	3.6	17.1	129	10.2	0.073	1.68	2.40	16.7	16.7
	V	10.0	16.2	10.9	109	10.0	0.064	1.72	2.32	4.1	3.0–4.9
	VI	11.0	18.6	9.5	101	8.3	0.082	3.63	3.30	2.6	2.6
	VII/VIII	15.0	24.9	11.0	130	9.2	0.098	2.28	2.30	19.7	12.8–24.1
	X	-	10.3	9.2	81	8.5	0.054	1.23	4.80	3.0	2.1–4.6

ded from the main flow of the discharge water, with less turbulence, favoured cryptophyte communities (*Cryptomonas* and *Rhodomonas*). Cryptomonas individuals attained 50 μm in length, and their biomass reached 9.0 mg/dm^3. Phytoplankton of the northern part of the lake was dominated by cryptophytes and differed from diatom - cryptophyte communities in the middle-west part, and from the supplying channel carrying water from Pątnowskie Lake to "Konin" power plant and Ślesińskie Lake.

3. PHYTOPLANKTON COMMUNITIES OF LICHEŃSKIE AND ŚLESIŃSKIE LAKES IN SUMMER

In the most heated Licheńskie Lake, summer phytoplankton biomass was rather low (2.5-4.0 mg/dm^3) in 1991, but higher (5.3-19.0 mg/dm^3) in 1992 and 1993. The biomass fluctuated irregularly and within wide ranges at particular sites; this was related to uneven distribution of the discharge waters to Ślesińskie and Pątnowskie lakes in successive years. Distribution of water determined stability or lability of the

biocenoses of south-west or north basins of the reservoir. An interesting situation occured in Licheńskie Lake in August 1993, at a flow of discharge waters from this lake to Ślesińskie higher than to Pątnowskie, total algal biomass in the north basin (of high flow) - site IV, was 5.3 mg/dm^3, while in weakly mixed south-west part (site I) it attained 19.1 mg/dm^3 (Fig. 3). Community structures also differed between the sites. Diatoms and cryptophytes predominated (39.3% and 22.1% of total biomass, respectively) in north gully, both taxa consisted of species able to grow under high turbulence conditions. On the other hand, large dinoflagellates, which prefer still water predominated (69%) in the south-west basin. This group comprised only 6% of the biomass at site IV. Water temperature between site I and IV differed by about 2°C.

Generally, summer phytoplankton structure in Licheńskie Lake was characterised in the successive years by irregular share of various groups of algae. Blue-greens comprised 8-42% of total algal biomass, dinoflagellates - 6-69%, diatoms - 10-39%, cryptophytes - 10-37%, and greens 7-14%. Summer community developed in water temperature 26-30°C, at stimulating nutrient levels (total phosphorus: 0.087-0.120 mg/dm^3, and total nitrogen: 2.03-3.32 mg/dm^3). Water transparency was about 1.5 m (Tab. 2). In the summer phytoplankton community of Licheńskie Lake the following species of algae predominated: dinoflagellates *Ceratium hirundinella* (O.F. Mull.) Bergh and *Peridinium inconspicuum*, blue-greens: *Microcystis incerta*, *M. aeruginosa* and *Aphanizomenon gracile*, cryptophytes: *Cryptomonas erosa*, *C. ovata*, diatoms: *Stephanodiscus hantzschii*, *S. astraea v. minutulus*, greens: *Chlorococcales* and *Euglena hemichromata* Skuja.

Statistical analysis did not reveal significant differences in total biomass and biomasses of particular algal groups between the sites of Licheńskie Lake. The analysis showed also quantitative and qualitative similarity of phytoplankton communities of Licheńskie Lake and of the supplying channel carrying water from Pątnowskie Lake to "Konin" plant, which indicated homogeneity of summer phytoplankton in the two lakes.

Ślesińskie Lake in summer was no more isolated since it has been included into the "extended cooling system" and strongly mixed. In 1991-1993 a diatom-dominated community developed (40-88% of total biomass), with an addition of various blue-green, cryptophyte, dinoflagellate and green species.

Among the diatoms, *Melosira granulata* (Ehr.) Ralfs, and *Stephanodiscus astraea v. minutulus* were the most numerous. Total summer phytoplankton biomass fluctuated within the range of 6.6-24.5 mg/dm^3. At the discharge (site II), situated in the middle

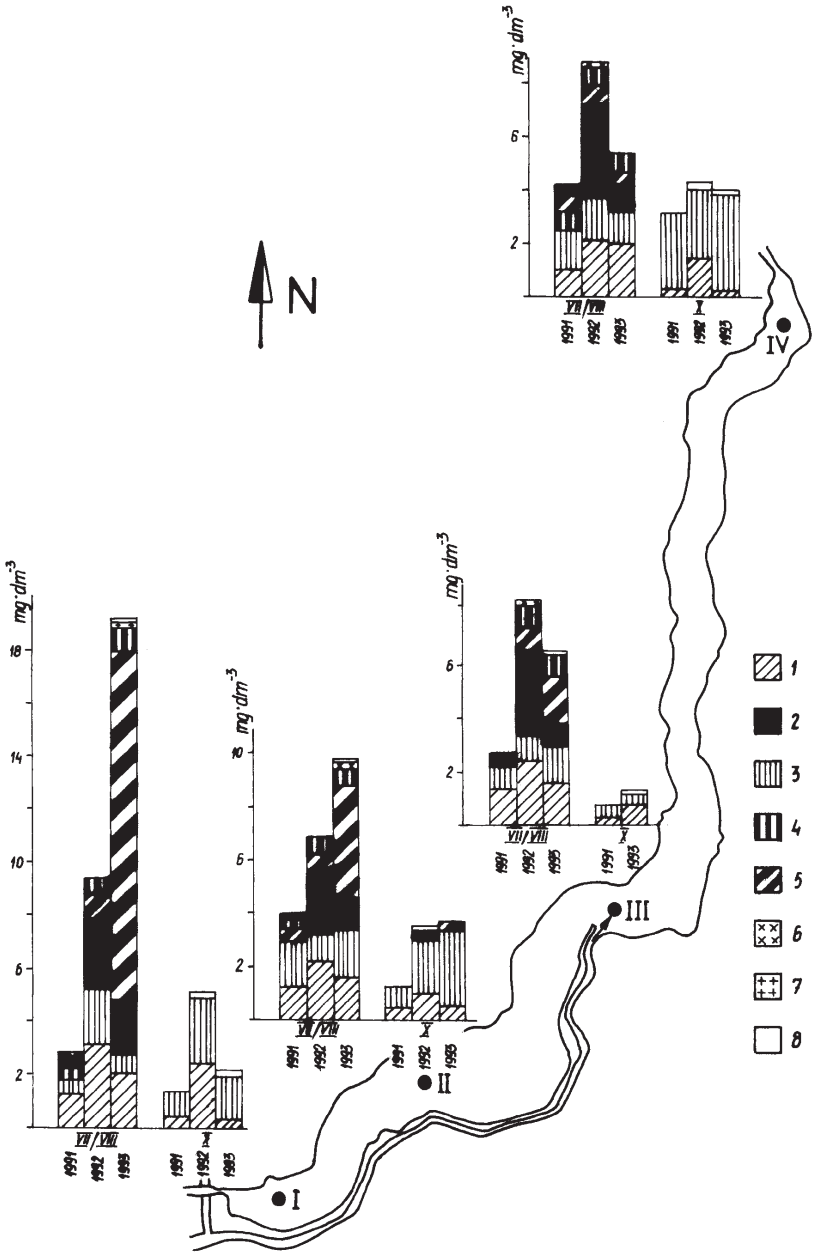

Fig. 3. Total biomass and structure of phytoplankton in summer (June/July) and in autumn (October) in Licheńskie Lake in 1991-1993. 1 - diatoms, 2 - blue-greens, 3 - cryptophytes, 4 - greens, 5 - dinoflagellates, 6 - euglenophytes, 7 - chrysomonads, 8 - other.

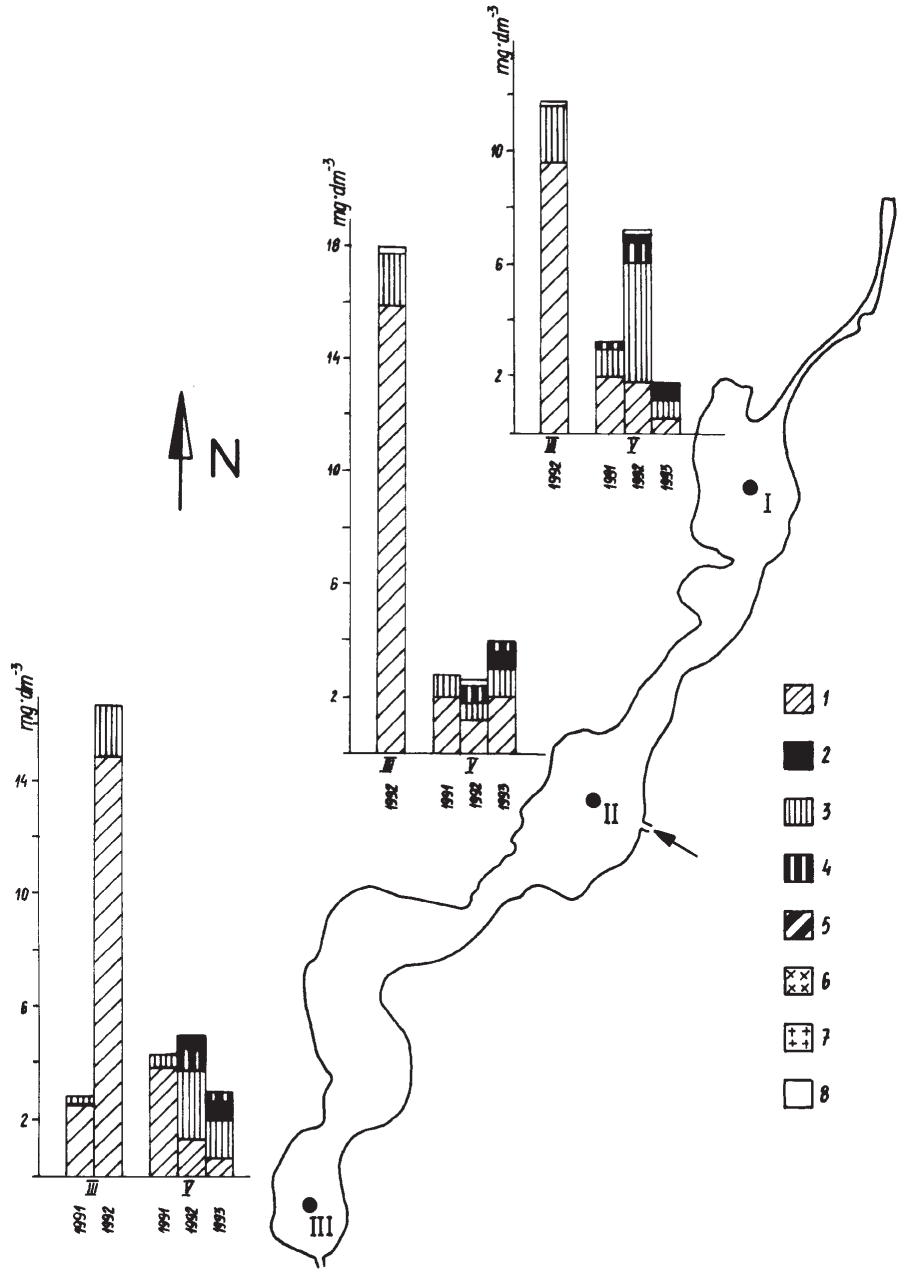

Fig. 4. Total biomass and structure of phytoplankton in spring (March, May) in Slesińskie Lake in 1991-1993. 1 - diatoms, 2 - blue-greens, 3 - cryptophytes, 4 - greens, 5 - dinoflagellates, 6 - euglenophytes, 7 - chrysomonads, 8 - other.

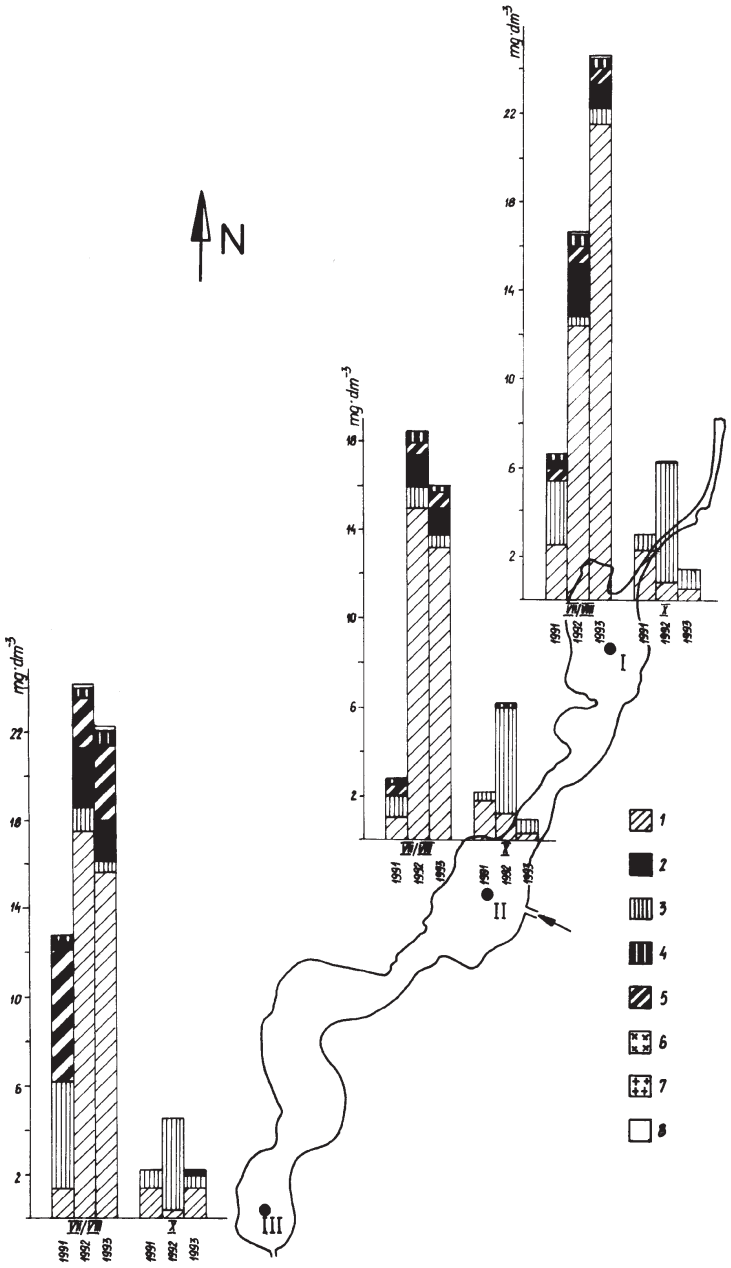

Fig. 5. Total biomass and structure of phytoplankton in summer (June/July) and in autumn (October) in Slesińskie Lake in 1991-1993. 1 - diatoms, 2 - blue-greens, 3 - cryptophytes, 4 - greens, 5 - dinoflagellates, 6 - euglenophytes, 7 - chrysomonads, 8 - other.

basin of the lake and strongly mixed from the surface to the bottom, algal biomass was usually lower than in the north (site II), and south basin (site III) (Fig. 5).

Surface water temperature was 24.0-26.8°C, similar over the entire lake. Water transparency was about 2.2 m, and nutrient content similar as in May and June (at the start of the "extended cooling system"): total phosphorus concentration was 0.084-0.122 mg/dm^3, and total nitrogen - 1.54-2.28 mg/dm^3 (Tab. 3).

Statistical analysis did not reveal significant differences in total algal biomass and biomass of particular algal groups between the sites in Ślesińskie Lake, but revealed significant differences in biomass of diatoms and greens in Licheńskie and Ślesińskie lakes. In summer phytoplankton community of Ślesińskie Lake high densities of diatoms: *Melosira* and *Stephanodiscus* were observed, while in strongly heated Licheńskie warm-water green algae developed abundantly.

In the discharge channels (sites at the "Konin" plant discharge and Licheński channel) total algal biomass was reduced by 64% (in 1993). Biomass of dinoflagellates decreased by 90%, of cryptophytes - by 78%, blue-greens - by 66%, and greens - by 66%. Only the biomass of diatoms did not change.

Phytoplankton samples collected in the last decade of October revealed that cool-season community has already developed. Total biomass was always low in the entire cooling system and fluctuated from 0.7 to 6.3 mg/dm^3 (Figs. 3, 5). The communities were dominated by the diatoms and cryptophytes, sometimes with an addition of relatively numerous blue-greens, dinoflagellates and greens (up to 10%) in Licheńskie Lake, and in the supplying channel of "Konin" plant.

Temperatures in Licheńskie and Ślesińskie Lakes differed due to the exclusion of the latter from the cooling system. In Licheńskie surface water temperature fluctuated from 12.6 to 17.0°C, and in Ślesińskie - from 10 to 11.5°C. Water transparensy increased again: in Licheńskie up to 2.6-3.2 m, and in Ślesińskie to 4.3-5.6 m (Tab. 2, 3).

DISCUSSION

In the late eighties an increase of total algal biomass and a shift in community structure towards one typical for eutrophic lakes were observed in heated lakes of Konińskie District (Socha 1994). The changes resulted from cumulated influence of thermal and hydrologic factors and, additionally, from water eutrophication. Annual average algal biomass was 4.1-6.5 mg/dm^3 in 1990, and was higher than the values observed by Simm (1988) in the early eighties (about 2.0 mg/dm^3 in summer). In

TABLE 4

Comparison of phytoplankton biomass (annual mean, range in mg/mm^3) in Konińskie lakes in 1965–1984 (acc. to Sosnowska 1987, Spodniewska 1984, Simm 1988) and 1987–1993

Period of studies	Lakes			
	Gosławskie	Pątnowskie	Licheńskie	lesińskie
1965–1970	-	-	43.2 1.2–210.2	4.0 0.1–14.0
1977–1980	6.4 3.9–10.2	-	5.9 2.4–12.0	3.6 0.6–7.2
1983–1984	1.3[1] 0.4–2.8 3.0–11.0[2]	-	1.5[1] 0.6–1.9	1.2[1] 0.6–4.0 4.0–10.0[2]
1987	-	1.4 0.1–6.2	-	-
1988	-	2.7 0.2–15.3	-	-
1989	2.2 0.2–6.1	3.8 0.4–18.7	3.3 0.4–8.4	6.2 0.2–24.0
1990	4.1 0.4–14.8	4.9 0.8–11.7	5.8 0.8–17.9	6.5 0.4–23.2
1991	-	4.7 0.8–12.3	5.2 0.7–15.3	4.3 2.1–12.8
1992	-	4.9 2.5–7.1	5.7 3.6–9.4	11.4 2.7–24.1
1993	-	7.2 0.6–18.1	8.0 0.9–28.7	8.0 0.9–24.5

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

1987-1990 abundant diatom-cryptophyte communities developed in early spring, and in summer blue-green and dinoflagellate blooms were observed. This type of seasonal succession differed from the diatom-green succession noted by Simm (1988) in the early eighties.

Phytoplankton studies performed in 1991-1993 revealed that algal biomass in Ślesińskie Lake remained at a level noted in the late eighties (0.9-24.5 mg/dm^3) throuhout the season.

In Licheńskie Lake, on the other hand, annual average algal biomass in 1993 (8.0 mg/dm^3) was 40% higher (range: 0.9-28.7 mg/dm^3). Community structures in both lakes were similar to those observed in 1987-1990. This indicates a stable trend in the development of phytoplankton, as the one observed in the late eighties. Decreasing share of nannophytoplankton in total biomass of algae (20-27% in 1993 in Licheńskie

Lake and in the supplying channel of "Konin" plant), confirms the thesis on eutrophication of the lakes. Low densities of nannophytoplankton were accompanied by abundant development of filamentous blue-greens (*Anabaena*, *Aphanizomenon*), and large dinoflagellates (*Ceratium*, *Peridinium*).

In spring, similarly as in 1987-1990, phytoplankton of Licheńskie and Pątnowskie lakes was dominated by abundant diatom communities. On the other hand, communities of cryptophytes were characteristic only for the north gully of Licheńskie Lake (nutrient-rich, warm and stagnant water), pointing to some degree of ecological diversification between the sites. Cryptophytes, which are of high nutritional value for zooplankton (Jones, Ilmavirta 1988), became more abundant in the lake phytoplankton in 1987-1993, probably due to low grazing intensity of the zooplankton (Tunowski 1994).

In summer season, in Licheńskie and Pątnowskie lakes (shallow, nutrient-abundant, strongly mixed and heated during all the year) ecological conditions were favourable for blue-greens, dinoflagellates and green algae. Together with diatoms, cryptophytes, chrysomonads, euglenophytes and other taxa, they formed a phytoplankton community disorganised due to high water temperature, and variable discharge of water.

At various sites of Licheńskie Lake percent of particular algal taxa was irregular in summer seasons, with the only common characteristic - abundance of blue-greens and dinoflagellates.

In Slesińskie Lake (deep, stratified and only temporarily heated, less eutrophicated) environmental conditions enhanced diatom growth. Despite an immigration of blue-greens and dinoflagellates into the lake with the discharge inflow from Licheńskie, stable phytoplankton community structure of Ślesińskie Lake did not change. Phytoplankton was dominated by *Melosira* and *Stephanodiscus*.

Phytoplankton of Konińskie lakes (total biomass, community structures and nannoplankton share) is determined by two groups of antagonistic factors. The first group consists of increased water temperature and trophy which stimulated algal growth. They result in development of abundant diatom-cryptophyte communities in early spring, in the entire cooling system. The second group consists of high flow rate which interferes with the effect of high temperature and trophy in summer. High flow rate within and between the lakes is an important limiting factor for blue-green and dinoflagellate nuisance blooms, which are stimulated by warm water and high

nutrient concentrations. High temperature of discharge waters causes increased mortality of algae, as suggested by reduced numbers in the discharge channels.

It seems that despite some degree of "homogeneity" of Konińskie lake phytoplankton (the same dominants, lack of statistically significant differences in total algal biomass within and between the lakes), some individual characteristics of the lakes could be observed that caused strong blue-green, green and dinoflagellate growth in Licheńskie, and abundant diatom growth in Ślesińskie Lake.

These characteristics were: different seasonal pattern and level of heating and mixing of the two lakes and of particular sites, different trophy and rate of organic matter accumulation, related, among others, to lake morphometry. Thus, it is probable that also the dominating species of algae might have been determined by these factors. Such an effect was observed on a much larger scale by Lavrientieva (1990) who studied phytoplankton communities in two cooling reservoirs situated in different climatic zones: subpolar and subtropical. In these water bodies cosmopolitic, eutrophic, mesosaprobic and euryhaline species predominated. Community structures were determined by the phytoplankton broght in with the supplying rivers, and characteristics of the lakes themselves. No significant influence of increased water temperature (up to 32.0-34.0°C) was observed on the domination structure in both reservoirs heated for 4-10 years. These results are similar to the observations on phytoplankton composition in Konińskie lakes, in which the dominating taxa were the same as in natural waters with normal thermal regime. Mass development of algae in the lakes in 1993 should be a warning and should remind how non-stable is the system subjected to various human activities: heated water discharge, cage fish culture, domestic sewage discharge, recreation. It also shows how easily and "unnoticeably" a thershold may be exceeded, beyond which the mechanisms preventing eutrophication will no more operate. Phytoplankton proved to be a sensitive indicator of the changes in water ecosystems and in the adjacent watershed.

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STRESZCZENIE

PRZESTRZENNE I SEZONOWE ZRÓŻNICOWANIE FITOPLANKTONU W JEZIORACH LICHEŃSKIM I ŚLESIŃSKIM KOŁO KONINA W LATACH 1991–1993

Badania fitoplanktonu prowadzone w jeziorach konińskich (rys. 1, tab. 1) w latach 1991–1993 potwierdziły tendencję w rozwoju planktonu roślinnego, stwierdzoną w końcu lat 80. Wyrazem tej tendencji był wzrost ogólnej biomasy glonów do 40% w latach 1991–1993 w odniesieniu do jej wartości notowanych w latach 1987–1990 w jeziorach Pątnowskim, Licheńskim i Ślesińskim (tj. od 5,0 do 6,0 mg dm^{-3}) (tab. 2, 3, 4).

Zaobserwowano także malejący udział frakcji nanoplanktonowej w fitoplanktonie badanych zbiorników, zwłaszcza w Jeziorze Licheńskim (20% w 1993 r.), w wyniku rozwoju w sezonie letnim populacji dużych nitkowatych sinic i bruzdnic o znacznych rozmiarach komórek oraz w sezonie wiosennym - licznych osobników kryptofitów o wymiarach komórek większych od 30 μm.

W latach 1991–1993 sukcesja sezonowa zbiorowisk fitoplanktonu w Jeziorze Licheńskim, włączonym w obieg chłodzenia przez cały rok, podobnie jak w końcu lat 80., była charakterystyczna dla żyznych wód jeziornych. Oznaczało to, że wiosenne zbiorowisko okrzemkowo-kryptofitowe zastępowane było latem przez ugrupowania sinic i bruzdnic wespół z towarzyszącymi im taksonami z pozostałych grup systematycznych (rys. 2, 3). W Jeziorze Ślesińskim, okresowo włączanym w obieg chłodzenia, przez cały sezon wegetacyjny dominowały okrzemki, niemniej w strukturze fitoplanktonu w sezonach chłodnych znaczący był udział kryptofitów, a w okresie letnim - sinic, bruzdnic i zielenic (rys. 4, 5)

Pomimo pewnego podobieństwa planktonu roślinnego w jeziorach konińskich (te same dominanty, brak statystycznie istotnych różnic w wartościach ogólnej biomasy glonów pomiędzy stanowiskami w obrębie jezior Licheńskiego i Ślesińskiego oraz pomiędzy badanymi jeziorami i kanałami) można jednak wskazać na indywidualne cechy ekologiczne zbiorników, warunkujące rozwój w nich określonych grup glonów, np. kryptofitów w północnej rynnie Jeziora Licheńskiego wiosną, zielenic w Jeziorze Licheńskim latem, czy też okrzemek w Jeziorze Ślesińskim przez cały sezon wegetacyjny.

Duży przepływ wody pomiędzy jeziorami podgrzanymi oraz intensywne jej mieszanie w każdym ze zbiorników w sezonie letnim, pomimo dużej już żyzności jezior konińskich, jest w dalszym ciągu ważnym czynnikiem ograniczającym intensywny rozwój fitoplanktonu, w tym populacji sinic uciążliwych z punktu widzenia czystości wody i jej zdolności chłodzenia urządzeń energetycznych.

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