POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 27(4): 419–431, Y. 2012

WATER QUALITY AND PHYTOPLANKTON OF THE RECREATIONAL USED LAKE SŁAWSKIE*

Anna Kozak, Ryszard Gołdyn, Katarzyna Kowalczewska-Madura, Marcin Zimmer

Department of Water Protection, Faculty of Biology
Adam Mickiewicz University in Poznań

K e y w o r d s: nutrients, phytoplankton abundance, recreational lake.

A b s t r a c t

The main purpose of this study was to determine the water quality parameters, phytoplankton composition and their seasonal variation in the Lake Sławskie. Samples for water quality analyses were collected once a month in the years 2010–2011. According to physico-chemical parameters the ecological status of the Lake Sławskie was moderate. The lake is characterized by thermal and oxygen stratification within a period of summer. Among mineral forms of nitrogen an ammonium nitrogen dominated. In the case of ammonium nitrogen the maximum concentration reached 3.45 mg $N\text{-}NH_4$ l^{-1} in summer 2010 (near the bottom). In winter and early spring periods the participation of nitrate nitrogen increased. Its maximum concentration was noted in February 2010 (1.58 mg $N\text{-}NO_3$ l^{-1}). Participation of nitrite nitrogen in water was low. The concentrations of dissolved phosphates and total phosphorus reached 0.53 mg P l^{-1} and 0.61 mg P l^{-1} near the bottom layer in the summer 2010, respectively.

The qualitative and quantitative structure of phytoplankton were analyzed. The number of algae ranged from 100 org. ml^{-1} to $23.1 \cdot 10^3$ org. ml^{-1}. Domination of cryptophytes, chrysophytes, diatoms, chlorophytes and dinophytes were noted.

JAKOŚĆ WODY I FITOPLANKTON REKREACYJNIE WYKORZYSTYWANEGO JEZIORA SŁAWSKIEGO

Anna Kozak, Ryszard Gołdyn, Katarzyna Kowalczewska-Madura, Marcin Zimmer

Instytut Biologii Środowiska
Uniwersytet im. Adama Mickiewicza w Poznaniu

S ł o w a k l u c z o w e: związki mineralne, liczebność fitoplanktonu, jezioro rekreacyjne.

Address: Anna Kozak, Adam Mickiewicz University, ul. Umultowska 89, 61-614 Poznań, Poland, phone: +48 61 58 78, e-mail: akozak@amu.edu.pl

* The research was supported in part by the grant No NN305 372838 from the Ministry of Science and Higher Education (Poland).

Abstrakt

Celem badań była analiza jakości wody Jeziora Sławskiego na podstawie cech fizyczno-chemicznych, a także określenie składu gatunkowego fitoplanktonu oraz jego zmienności sezonowej. Próbki wody do analiz pobierano co miesiąc w latach 2010–2011. Stan ekologiczny Jeziora Sławskiego określono jako umiarkowany. W okresie letnim Jezioro Sławskie charakteryzowało się dobrze wykształconą stratyfikacją termiczną i tlenową. Analizując udział poszczególnych form azotu mineralnego w wodach badanego jeziora, stwierdzono dominację form azotu amonowego. W okresach letnich odnotowano wzrost jego stężeń, zwłaszcza w strefie naddennej zbiornika, w której wynosiły one do 3,45 mg $N\text{-}NH_4$ l^{-1} w roku 2010. W okresach zimowych i wczesnowiosennych wzrastał udział azotu azotanowego. Jego maksymalną koncentrację stwierdzono w lutym 2010 r. (1,58 mg $N\text{-}NO_3$ l^{-1}). Udział azotu azotanowego w badanym jeziorze był niewielki. Na podstawie analiz ilościowych i jakościowych fitoplanktonu stwierdzono, że liczebność glonów i sinic wynosiła od 100 org. ml^{-1} do $23{,}1 \cdot 10^3$ org. ml^{-1}. W analizowanym okresie stwierdzono dominację kryptofitów, okrzemek, złotowiciowców oraz zielenic i bruzdnic.

Introduction

The Sławskie Lake is the largest lake situated in the area of the Lubuskie Province. This lake is used for recreation and water sports very intensively (International Regatta and Yacht Competitions, Polish Cup Regatta, windsurfing and yachting). The economic development of the city of Sława in the past, particularly the meat industry as well as the rapid development of the tourism, cause the real threat of the sewage inflow and water quality deterioration of the lake. As a result of the enhanced eutrophication process of this lake the strong cyanobacterial blooms were observed. Because of these events, some radical actions were undertaken, targeting on the localization and diversion of untreated sewage from the lake. Because of that the modernization of urban sewage treatment plant in Sława and also diversion of treated sewage from the lake were carried out.

The main aim of this paper was to present the water quality changes as a result of these protection measures of Lake Sławskie.

Materials and Methods

The Lake Sławskie is a gutter, postglacial lake. Its area is 854.67 ha, the maximum depth is 12.3 m and the average depth is 5.2 m. The lake basin runs from the north-west toward south-east, which at the domination of west winds favours the intensive water mixing.

Samples for water quality analyses were collected in the years 2010–2011 (from February to November, once a month) from water column in the deepest part of the lake from the surface and from the depth of 1, 2, 4, 6, 8 and 10 m. Directly in the field the temperature of the water was monitored, the concentration of dissolved oxygen, the conductivity, pH and Secchi disk (SD) visibility

were measured by an instrument WTW 350. In the vertical profile of the lake physico-chemical and biological parameters were analysed, such as concentration of nitrogen (ammonium, nitrite, nitrate, organic nitrogen and total nitrogen) and the phosphorus (dissolved phosphates and total phosphorus). Concentration of chlorophyll-*a* (*Woda i* ścieki. PN-86/C-05560.02) and dry mass of seston (suspended solids) were also measured. All physico-chemical analyses were done according to the Polish Standards (ELBANOWSKA et al. 1999). The qualitative and quantitative composition of phytoplankton was analysed. The phytoplankton samples were collected from the same depth as for chemical analyses and fixed with Lugol's solution. They were analysed under a light microscope, at ×400 magnification. For the quantitative phytoplankton analysis, a Sedgwick-Rafter chamber of 0.67 ml in volume was used. The counting units were cells, colonies, or trichomes.

In both years of research in the summer-time aquatic macrophytes were also explored. Analyses of the arrangement of submerged vegetation were done using the method of transects, localized perpendicularly to the shoreline. They started from the shoreline or from the line of emergent plants and finished at the place of maximal depth at which submerged vegetation occurred. The range of individual plant communities, evaluated on a basis of phytosociological Braun-Blanquet method, was estimated using a special anchor.

Results and Discussion

The lake is characterized by thermal and oxygen stratification within a period of summer. The average water temperature varied from 2.55°C to 21.13°C (July 2010).

Maximum values of water temperature were noted in the summer of the year 2010, when reached 25.9°C in the surface layer. In the following year of research it did not exceed 22.1°C. In remaining months the temperature of water was almost equal in the vertical profile.

The summer oxygen stratification of water of this lake was also observed. In the overdemersal zone the oxygen deficits were noted (Figure 1). In July 2010 the concentration of the dissolved oxygen in water amounted below 2 mg O_2 l^{-1} from the depth of 5 m. In the following year of research the situation rallied and the lowered oxygen layer content appeared only below 7 m in August and October. In the surface layer of water the considerable oxidation were noted, where the oxygenation reached above 198% in first and 150% in the second research year. The highest concentration of dissolved oxygen was noted down in June 2010 at depth of 1 m – 17.18 mg O_2 l^{-1}. In the following year it reached 14.6 mg O_2 l^{-1} in the same layer in October (Figure 1).

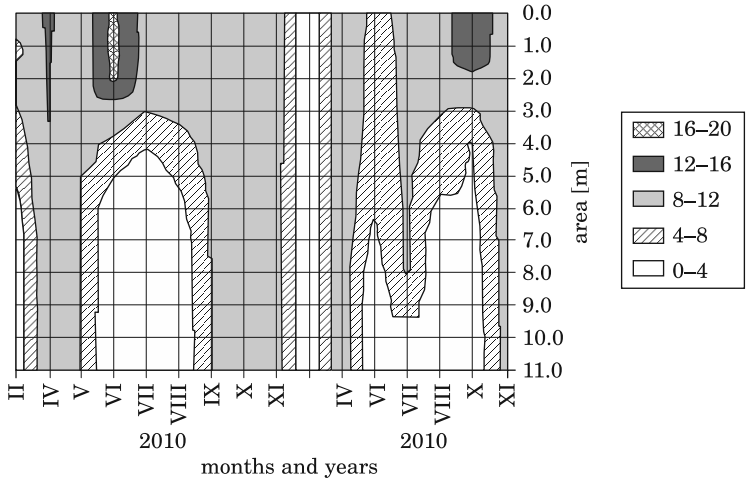

Fig. 1. Changes in the concentration of dissolved oxygen in the water in the vertical profile in the Lake Sławskie in the period of 2010–2011 [mg O_2 l^{-1}]

In the studied period the pH varied from 7.3 to 8.8, maximum values achieving within the period of summer. The conductivity increased in the deepest water layers of the lake, but did not exceed the value of 600 μS cm^{-1}. The water transparency in the Lake Sławskie in analyzed period fluctuated from 1.2 m to 6.4 m. The highest SD value was noted down in winter 2010 and lowest in June 2011. Among mineral forms of nitrogen an ammonium nitrogen dominated. In the case of ammonium nitrogen its concentration reached 3.45 mg $N\text{-}NH_4$ l^{-1} in summer 2010 near the bottom (Figure 2). In the following year, this form of nitrogen concentrations were slightly lower and reached a maximum of 1.9 mg $N\text{-}NH_4$ l^{-1} in November. In winter and early spring periods the participation of nitrate nitrogen increased. Its maximum concentration was found in February 2010, and reached 1.58 mg $N\text{-}NO_3$ l^{-1}. In the summer period (August and September 2010, and in July and August of 2011) the presence of this form of nitrogen was not detected in the water. In the second year of the study a slight decrease in the amount of this form of nitrogen in the water was noted. Participation of nitrite nitrogen was low.

The similar distribution was found in a case of dissolved phosphates and total phosphorus concentrations. They reached 0.53 mg P l^{-1} and 0.61 mg P l^{-1} near the bottom layer in the summer 2010, respectively (Figure 3).

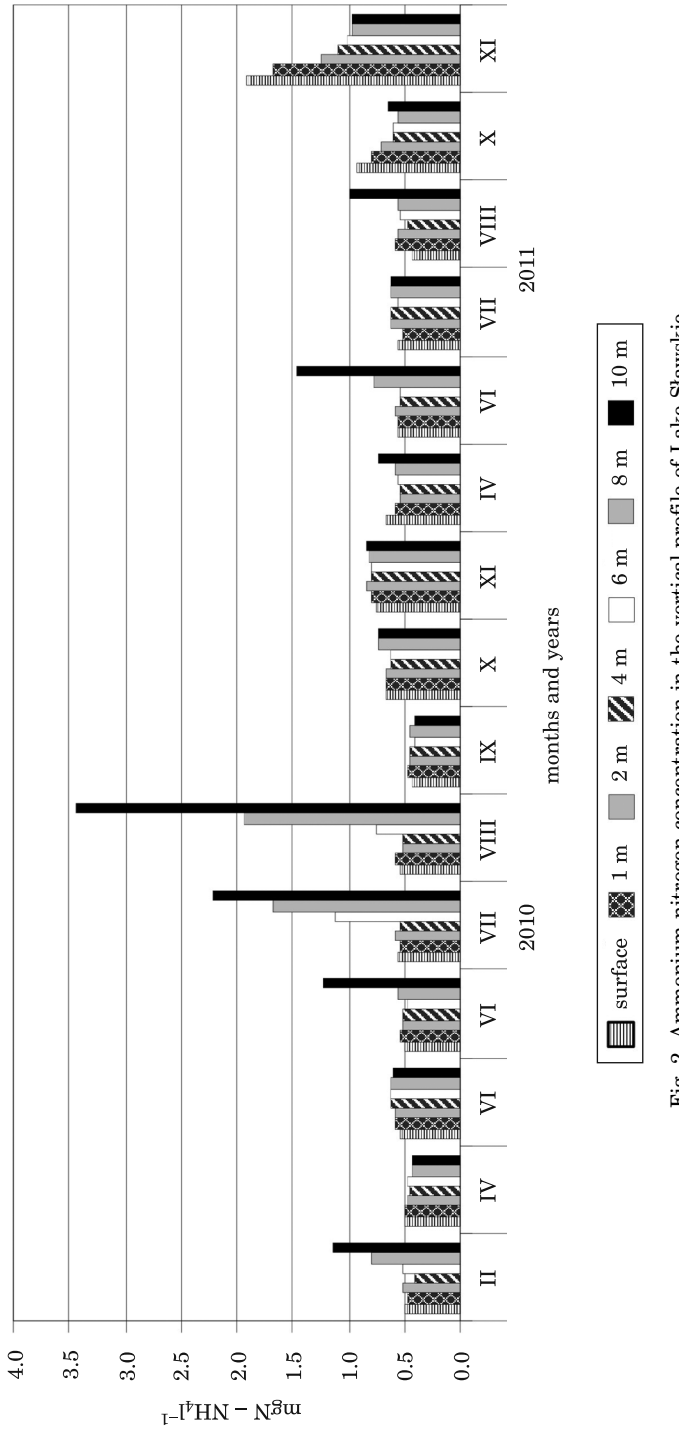

Fig. 2. Ammonium nitrogen concentration in the vertical profile of Lake Sławskie

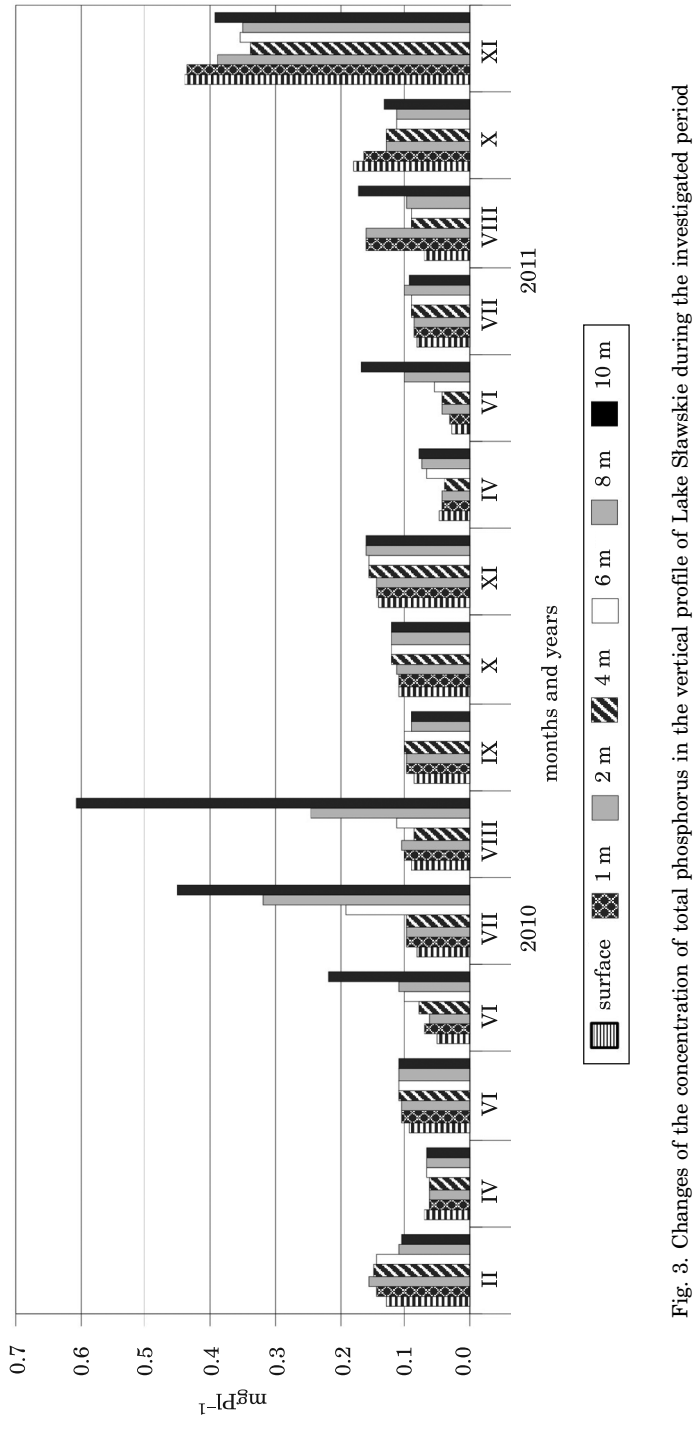

Fig. 3. Changes of the concentration of total phosphorus in the vertical profile of Lake Sławskie during the investigated period

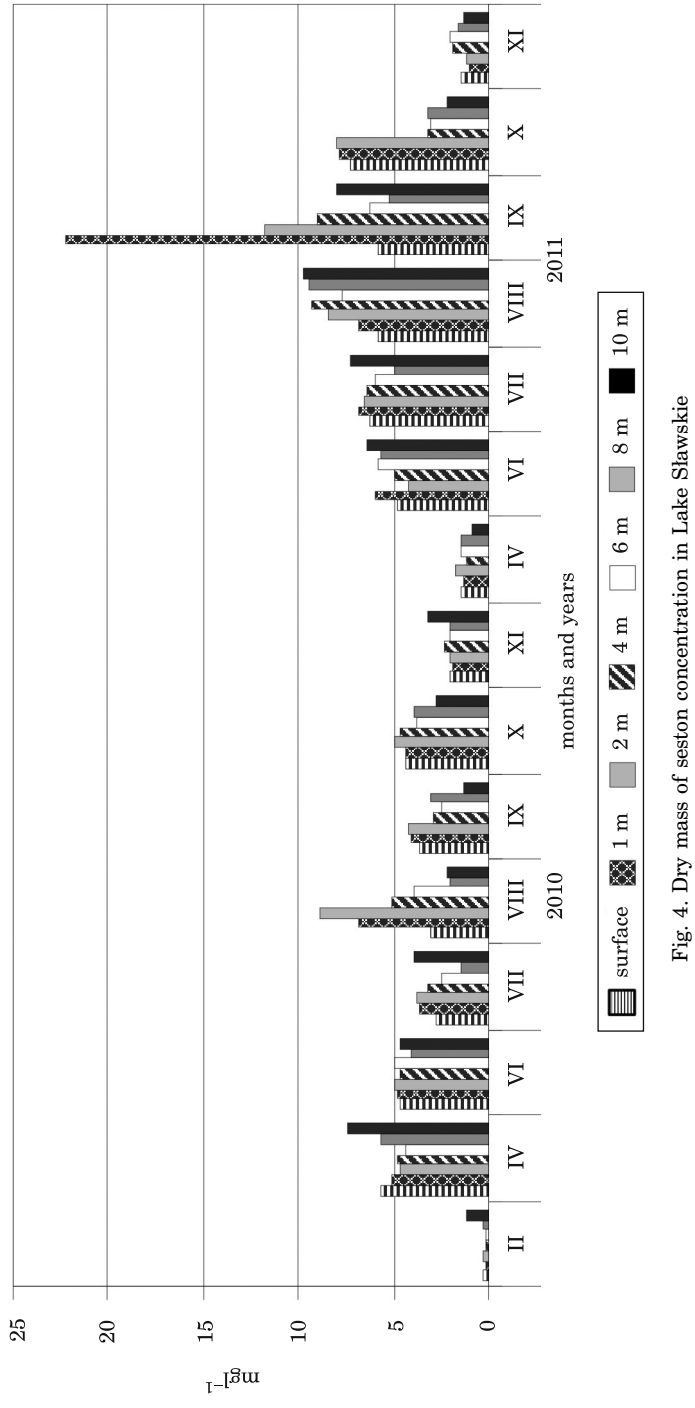

Fig. 4. Dry mass of seston concentration in Lake Sławskie

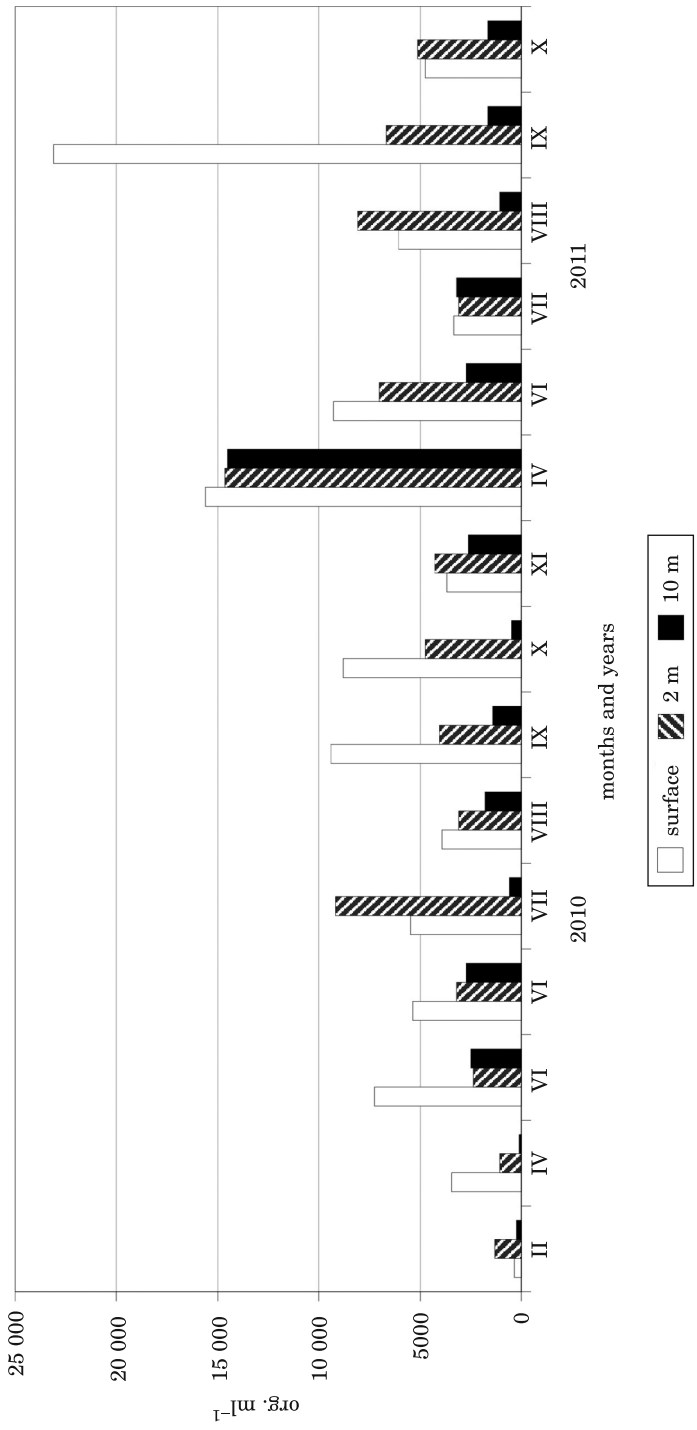

Fig. 5. Abundance of organisms belonging to individual taxonomic groups present in Lake Sławskie (examples from the surface and depth of 2 and 10 m)

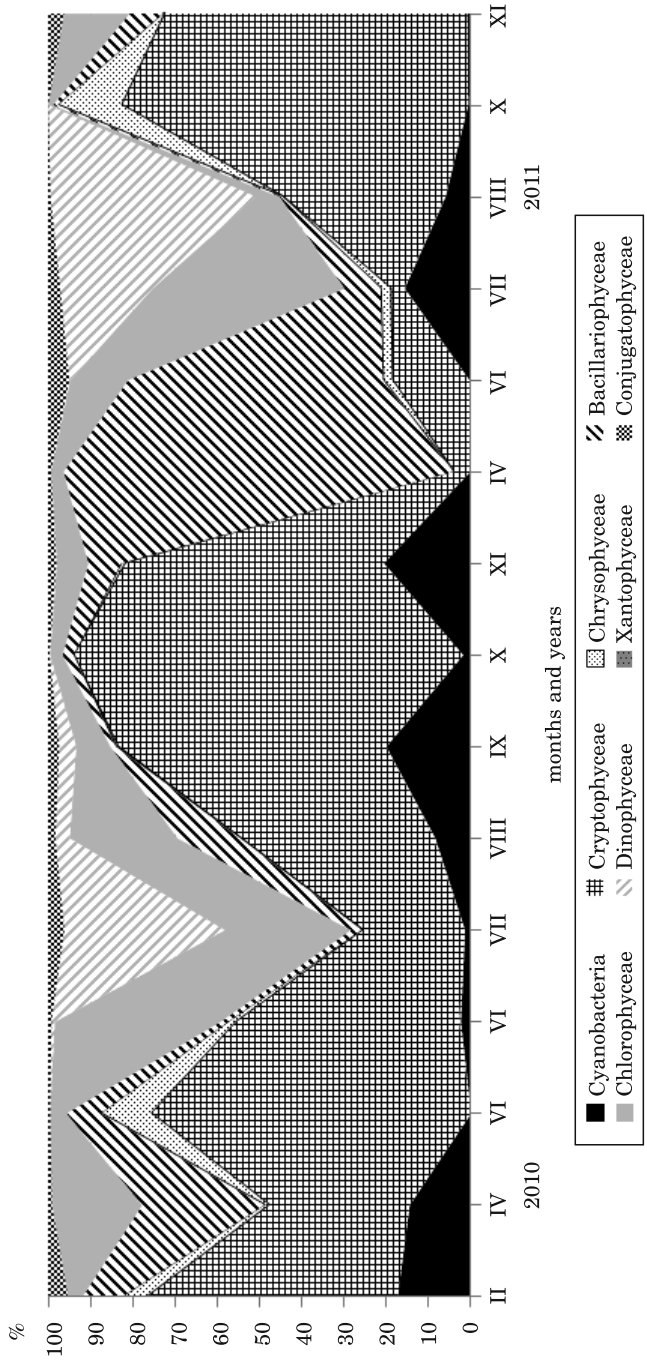

Fig. 6. Share of taxonomic groups in the total abundance of phytoplankton (example from a depth of 1 m)

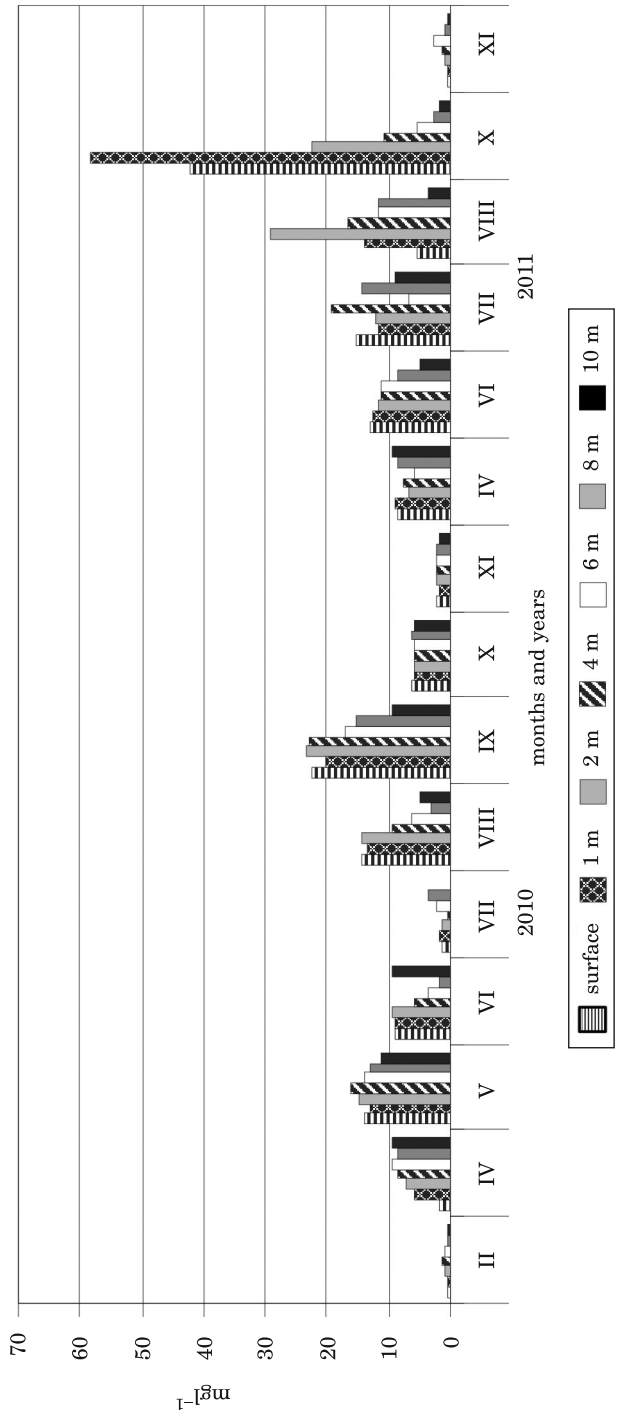

Fig. 7. Concentration of chlorophyll-a in the vertical profile of Lake Slawskie

The dry mass of seston concentration ranged from 0.1 to 22.2 mg l^{-1}. The largest value was noted in August 2011 (Figure 4). Taking into account such indicators as chlorophyll-a, conductivity, transparency, oxygen concentration in the hypolimnion, total nitrogen and phosphorus, the ecological status of Lake Sławskie was determined to be moderate.

The phytoplankton abundance in the investigated period varied from 100 org. ml^{-1} in March 2010 up to $23.1 \cdot 10^3$ org. ml^{-1} in October 2012 (Figure 5). The highest density of phytoplankton was especially caused by cryptophytes ($18 \cdot 10^3$ org. ml^{-1}). Also important were chrysophytes although less numerous in this period (Figure 6). These groups were usually present in the cold water periods (JACQUET et al. 2005, KOZAK 2009). The most numerous were *Rhodomonas lacustris* Pascher et Ruttner and *Cryptomonas marssonii* Skuja. These species were also the most numerous in many Polish lakes eg. Lake Strzeszyńskie in Poznań (SZELĄG-WASIELEWSKA 2006). In the same time in Lake Sławskie maximum chlorophyll-*a* concentration was noted reaching 58.4 μg l^{-1}. In remaining months it did not exceed 25 μg l^{-1} (Figure 7).

In Lake Sławskie the phenomenon of the self-restoration was observed. After the diversion of sewage inflow the improvement of water transparency was found. Some decrease in the abundance of cyanobacteria was noted in the phytoplankton. They reached only $1.7 \cdot 10^3$ org. ml^{-1} in September 2010. The most numerous species among cyanobacteria were *Aphanizomenon flos-aquae* (L.) Ralfs, *Cuspidothrix issatschenkoi* (Usachev) Rajaniemi and *Pseudanabaena limnetica* (Lemmermann) Komarek. These species are quite common indicators of high trophic level (SZELĄG-WASIELEWSKA 2006, BURCHARDT et al. 2007). They were noted in many eutrophic dam reservoirs and lakes (KOZAK 2005, BURCHARDT et al. 2007). There are among the number of species (about forty) of cyanobacteria belonging to different genera, which are potential toxin producers (PAWLIK-SKOWROŃSKA et al. 2004).

In the summer 2010 and 2011 the most abundant in Lake Sławskie were green algae and dinophytes, especially *Ceratium hirundinella* (O.F. Müller) Bergh. This species was the most numerous in August 2011. It is regarded as an indicator of meso-eutrophic waters (ROSEN 1981). It was also abundant in summer in many other lakes such as Lake Ostrowiec (GOŁDYN and SZELĄG-WASIELEWSKA 2004), Lake Łuknajno (JAWORSKA and KRUK 2007) and in restored Lake Głęboczek (JAWORSKA et al. 2009).

The group characterized by the greatest species richness was Chlorophyta. Its representatives were noted in all over the season. The highest density in this group was noted in July 2010 ($6.1 \cdot 10^3$ org. ml^{-1}). This is the most numerous group in many lakes and reservoirs (KOZAK 2005, 2009).

In spring centric diatoms (*Cyclotella* sp., *Stephanodiscus* sp.) grew in the reservoir. Their density reached $14.9 \cdot 10^3$ org. ml^{-1}. These genera favor

a turbulent environment such as water mixing and low light conditions. The domination of small centric diatoms is usually observed in the phytoplankton of eutrophic floodplain lakes (WOJCIECHOWSKA et al. 2007).

The bottom of the lake was covered by numerous molluscs (e.g. *Dreissena polymorpha*). Their influence on the water transparency was favourable due to the phytoplankton filtration.

Macrophytes as an effective factor improving water quality, were also monitored. The species of submerged plants such as *Batrachium circinatum, Najas marina*, *Ceratophyllum demersum* and *Myriophyllum spicatum* were present and increased the surface of their patches in the succeeding years. Macrophytes play a great role in the lake ecosystem e.g. create specific habitats (refuge) that support zooplankton proliferation (CELEWICZ-GOŁDYN et al. 2010, PATURA et al. 2012). What is more, the species richness of zooplankton increases along with an increase in habitat heterogeneity (KUCZYŃSKA-KIPPEN 2006). The macrofilter feeders are responsible for controlling the development of phytoplankton and improvements of water transparency (KOZAK and GOŁDYN 2004). The domination of macrophytes favor regression of phytoplankton including harmful cyanobacteria.

Conclusions

Lake Sławskie water studied in the period of 2010–2011 have had good quality. On the basis of physico-chemical variables of the water this lake was categorized as mezo-eutrophic. Taking into account such indicators as chlorophyll-a, conductivity, transparency, oxygen concentration in the hypolimnion, total nitrogen and phosphorus, the ecological status of the Sławskie Lake was determined to be moderate.

The lake was characterized by thermal and oxygen stratification within a period of summer. An ammonium nitrogen dominated among mineral forms of nitrogen. It reached 3.45 mg $N\text{-}NH_4$ l^{-1} in summer 2010 in the bottom layer. Both dissolved phosphates and total phosphorus concentrations reached 0.53 mg P l^{-1} and 0.61 mg P l^{-1} near the bottom layer in the summer 2010. In summer-time the least visibility was noted (1.2 m noted in June 2011). The highest density of phytoplankton was especially caused by cryptophytes, chrysophytes and diatoms. Cyanobacteria did not exceed 20% among phytoplankton groups. The presence of macrophytes and the increasing range of submerged plant communities in the succeeding years favour the restriction of the abundance of phytoplankton and the improvement of light transparency.

Translated by ANNA KOZAK

Accepted for print 15.10.2012

References

CELEWICZ-GOŁDYN S., KLIMKO M., KUCZYŃSKA-KIPPEN N., NAGENGAST B. 2010. *Relationship between plankton assemblages and habitat characteristics of stands of Typha angustifolia and Chara hispida in Lake Wielkowiejskie*. Oceanol. Hydrobiol. Stud., 39: 127–135.

BURCHARDT L., MARSHALL H., KOKOCIŃSKI M., OWSIANNY P.M. 2007. *Blooms of Aphanizomenon flos-aquae associated with historical trophic changes occurring in Lake Świętokrzyskie, Poland*. Oceanol. Hydrobiol. Stud. 36 Suppl., 1: 261–266.

ELBANOWSKA H., ZERBE J., SIEPAK J. 1999. *Fizyczno-chemiczne badania wód*. PWN, Poznań.

GOŁDYN R., SZELĄG-WASIELEWSKA E. 2004. *Changes in the phytoseston of a river-lake system in Drawieński National Park*. Oceanol. Hydrob. Stud., 33(2): 17–28.

JACQUET F., BRIAND J.F., LEBOULANGER CH., AVOIS-JACQUET C., OBERHAUS L., TASSIN B., VINÇON-LEITE B., PAOLINI G., DRUART J.C., ANNEVILLE O., HUMBERT J.F. 2005. *The proliferation of the toxic cyanobacterium Planktothrix rubescens following restoration of the largest natural French lake (Lac du Bourget)*. Harmful Algae, 4: 651–672.

JAWORSKA B., GAWROŃSKA H., ŁOPATA M. 2009. *Changes in the phytoplankton community of a lake restored with phosphorus inactivation (Lake Głęboczek, northern Poland)*. Oceanol. Hydrobiol. Stud., 38(1): 93–101.

JAWORSKA B., KRUK M. 2007. *Temporal changes in the phytoplankton structure in a shallow, macrophyte-dominated lake (Lake Łuknajno, northeast Poland)*. Oceanol. Hydrob. Stud., 36 (Supl. 1): 213–220.

KOZAK A. 2005. *Seasonal changes occurring over four years in a reservoir's phytoplankton composition*. Pol. J. Environ. Stud., 14(4): 451–465.

KOZAK A. 2009. *Community structure and dynamics of* phytoplankton in Lake Uzarzewskie. Teka Kom. Ochr. Kszt. Środ. Przyr., 6: 146–152.

KOZAK A., GOŁDYN R. 2004. *Zooplankton versus phyto- and bacterioplankton in the Maltanski Reservoir (Poland) during an extensive biomanipulation experiment*. J. plankton res. 26(1): 37–48.

KUCZYŃSKA-KIPPEN N. 2006. *Changes in the zooplankton community of ponds as a result of macrophyte cover transformation in a pastoral water body*. Teka Kom. Ochr. Kszt. Środ. Przyr., 3: 87–95.

PATUREJ E., GUTKOWSKA A., DURCZAK K. 2012. *Biodiversity and indicative role of zooplankton in the shallow macrophyte-dominated Lake Łuknajno*. Pol. J. Natur. Sc., 27(1): 53–66.

PAWLIK-SKOWROŃSKA B., SKOWROŃSKI T., PIRSZEL J., ADAMCZYK A. 2004. *Relationship between Cyanobacterial bloom composition and anatoxin-a and microcystin occurrence in the eutrophic dam reservoir (SE Poland)*. Pol. J. Ecol., 52(4): 479–490.

ROSÉN G. 1981. *Phytoplankton indicators and their relations to certain chemical and physical factors*. Limnologica 13(2): 263–290.

SZELĄG-WASIELEWSKA E. 2006. *Trophic status of lake water evaluated using phytoplankton community structure. Change after two decades*. Pol. J. Environ. Stud., 15(1): 139–144.

Woda i ścieki. Badania zawartości chlorofilu w wodach powierzchniowych. Oznaczanie chlorofilu alfa w glonach planktonowych metodą spektrofotometryczną monochromatyczną z poprawką na feopigmenty alfa. PN-86/C-05560.02.

WOJCIECHOWSKA W., PASZTALENIEC A., SOLIS M. 2007. *Diversity and dynamics of phytoplankton in floodplain lakes (Bug River, Eastern Poland)*. Oceanol. Hydrobiol. Stud., Suppl. 34(1): 199–208.