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LONG-TERM CHANGES IN PROTECTED LAKES (SOBIBÓR LANDSCAPE PARK, EASTERN POLAND)

ABSTRACT: Analysis of chemical and biological research carried out in the Junes of 1968 and 1995 did not reveal changes in the trophic status of the majority of lakes over the 27-year period. The lack of significant changes in either physico-chemical parameters (SD, conductivity, pH, $N–NO_3$, $N–NO_4$, $P–PO_4$, Fe_{Tot}, Ca and Mg) or biological indices (chlorophyll-a concentration, structure and abundance of phytoplankton) allowed for the classification of the lakes into three groups: dystrophic (Lake Orchowe), moderately eutrophic (Lakes: Spólne, Pereszpa, Koseniec and Brudzieniec) and highly eutrophic (Lake Brudno). Only in Lake Płotycze was a change in status revealed – from moderately eutrophic to dystrophic. The findings allowed conclusions to be drawn regarding the effectiveness of the protection afforded the area to date.

KEY WORDS: eutrophication, lakes, phytoplankton, chlorophyll-a, chemical composition of waters

1. INTRODUCTION

Sobibór Landscape Park takes in the eastern part of the Łęczna-Włodawa Lakeland and lies between 51°22' and 51°30' N and 23°30' and 23°40' E. The Park was founded in 1983 to protect the most valuable areas within the region, which is to say a complex of coniferous and broadleaf forest, alder thiclets, peatlands and forest lakes.

The area supports peatlands of all three types (fens, transitional and raised bogs) with a species-rich vegetation of higher plants including round-leaved sundew (*Drosera rotundifolia*), Siberian iris (*Iris sibirica*), European globeflower

(*Trollius europeus*), many species of sedge (*Carex* sp.) etc. The characteristic feature of the area's lakes is the inaccessibility of their shores as a consequence of locations amongst marshes and swamp forest.

In the beginning of the 1960s the drainage of the whole of the aforementioned Lakeland was performed, as well as the regulation of rivers, including the only larger river – the Tarasienka – which drains the Landscape Park (Fig. 1). The work carried out had a serious impact on water relations in the area. Amongst other things, there was drying and partial degradation of peatland and alder communities, as well as the disappearance of forest marshes. The changes occurring in the biotopes of the Landscape Park began to pose a threat to its protected species of plant and animal, including *Emys orbicularis* of which the Park's population was the largest in Central Europe (J a b ł o ń s k i 1992).

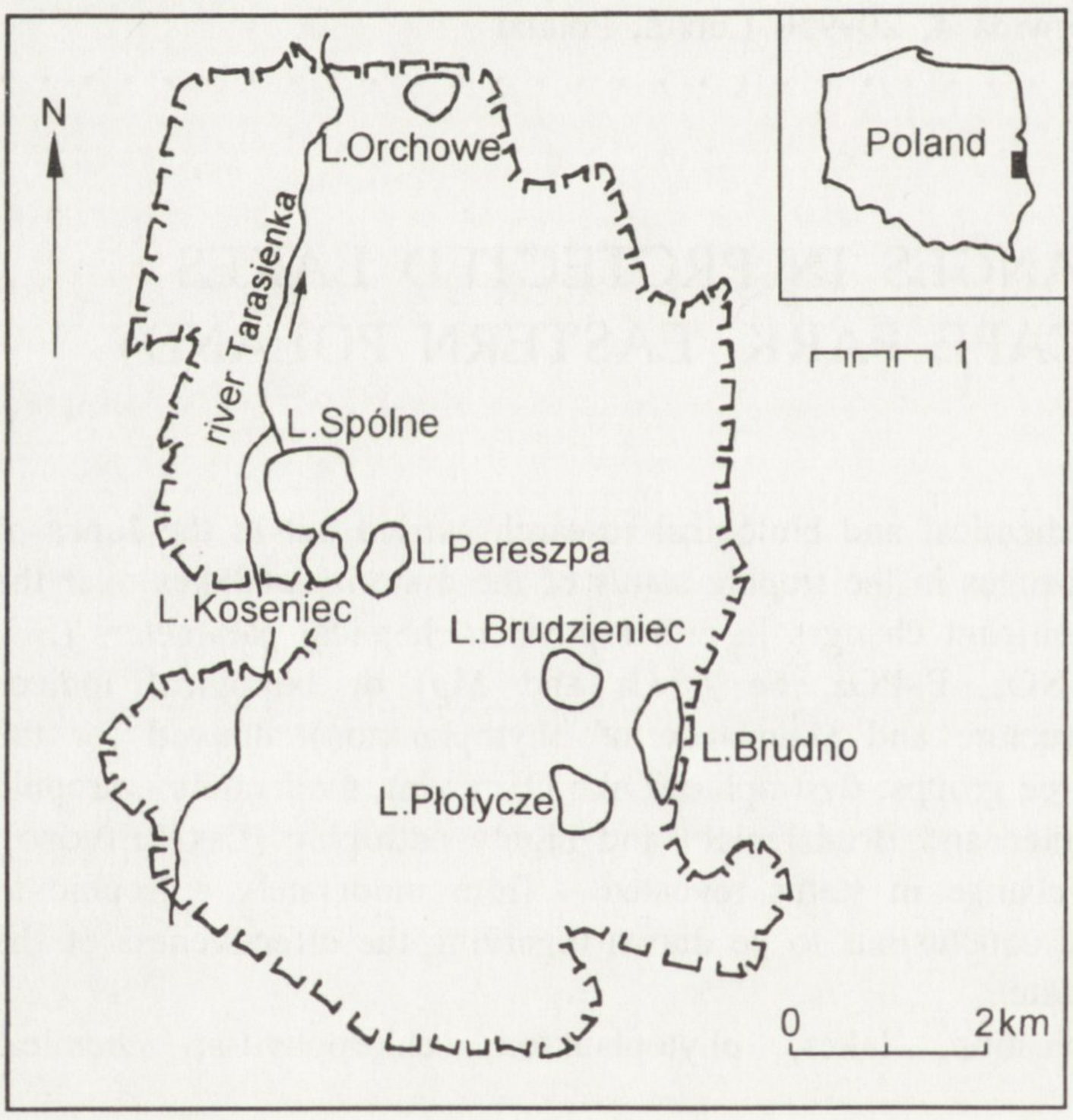

Fig. 1. Location of the lakes within Sobibór Landscape Park
1 – Park boundary

In the years 1966–1969, the lakes within the Park were subject to hydrochemical research (R a d w a n et al. 1971, 1972, 1973), as well as partial research on the zooplankton (R a d w a n 1976, K o w a l c z y k 1979). Work on the phytoplankton was not, however, carried out.

A characterization of the lakes performed by F i j a ł k o w s k i (1959), on the basis of the aquatic vascular vegetation. It was on this basis that Lake Orchowe was assigned to the dystrophic lakes, while Lake Płotycze was included among those with certain unstabilized dystrophic features. The remaining lakes displayed features of moderate eutrophy.

The aim of the work described in this paper was to assess changes in the trophic character of the lakes on the basis of research on their physical and chemical proper-

ties which was carried out 1968 and 1995. To further confirm the present trophic status of the lakes, measurements were also made in relation to chlorophyll concentration and the abundance and composition of the phytoplankton.

2. CHARACTERIZATION OF THE LAKES STUDIED

Sobibór Landscape Park includes the seven lakes whose locations are shown in Fig. 1. One of the lakes – Orchowe – is in the northern part of the Park, while the remainder create the two complexes comprising Lake Pereszpa and the linked lakes Spólne and Koseniec on the one hand, and Lakes Brudno, Brudzieniec and Płotycze on the other.

Established in 1973 was a water/peatland nature reserve taking in the forest Lake Brudzieniec, as well as surrounding fragments of alder carr and marshy coniferous forest. Lakes Spólne, Koseniec and Pereszpa are also within a faunistic reserve – called "Żółwiowe Błota" which was created in 1988 as the reserve for the terrapins. Two further water/peatland reserves are planned: the "Jeziora Brudno-Płotycze" and "Jezioro Orchowe" Reserves. The aim of establishing these reserves is to preserve the many protected species which occur in this area.

The areas and depths of the studied lakes (after Wilgat 1953) are given in Table 1, along with the trophic character as assessed by Fijałkowski (1959). The lakes in question are neither large nor deep and a further feature common to

Table 1. Morphological and trophic characteristics (Wilgat 1953) and plant communities (Fijałkowski 1959) of the lakes of Sobibór Landscape Park

Lake	Surface area (ha)	Depth max. (m)	Trophic status	Plant associations
Orchowe	7.0	0.8	dystrophic	Transitional bog (cl. Scheuzerio-Caricatea fuscae); coniferous forests and scrub (cl. Vaccinio-Picetea)
Płotycze	14.0	3.5	eutrophic	Transitional bog (cl. Scheuzerio-Caricatea fuscae); coniferous forests and scrub (cl. Vaccinio-Picetea)
Brudzieniec	19.0	3.0	eutrophic	Willow-alder forests and scrub (cl. Alnetea glutinosae)
Spólne	77.5	2.3	eutrophic	Willow-alder forests and scrub (cl. Alnetea glutinosae); grass-sedge communities (cl. Molinio-Arrhenatheretea)
Pereszpa	24.3	6.2	eutrophic	Willow-alder forests and scrub (cl. Alnetea glutinosae)
Koseniec	32.6	4.2	eutrophic	Willow-alder forests and scrub (cl. Alnetea glutinosae)
Brudno	42.0	4.5	eutrophic	Sedge communities (cl. Phragmitetea as. Magnocaricion)

all is a location among wet alder carr, marshes and peatlands. The majority of the lakes are eutrophic, with Lake Orchowe standing out as a dystrophic lake with acidic, brown-coloured water. Almost the entire shoreline of this lake is occupied by floating mats of transitional bog.

The shallowness of the lakes ensure that all are considered polymictic. The only exception is Lake Pereszpa, whose maximum depth is prone to thermal stratification, at which times the difference between the temperatures of the surface and bottom layers may be as great as 10° C.

3. METHODS

Samples from all 7 lakes were taken once (in June 1995) for biological and chemical analysis. The results obtained were compared with those from the June 1968 analyses, which had been published by Radwan et al. (1971, 1972, 1973). Sampling in both of these years took place in similar conditions, i.e. in the period of summer stratification with water temperatures being more or less equal (within the range 19.3 to 22.2° C in 1968 (Radwan et al. 1973), and within the range 19.5 to 23.0° C in June 1995). Sampling in both years was carried out near the points of maximum depth, and use was made of a sampler of the Patalas (1954) type with a capacity of 2 dm^3. The samples for chemical analysis were taken from a depth of about 1 m and had volumes of 5 dm^3.

Magnesium was determined with the aid of eriochrome black as an indicator, while total iron concentrations were determined using a colorimetric method with phenanthroin. Determinations for calcium were done with disodium versenate (Hermanowicz et al. 1976), while soluble phosphorus (expressed as the pure element was determined directly in filtered water using the molybdenum method. Ammonium-nitrogen was determined using the method of direct Nesslerization after prior filtering of the water and substraction of the effects of calcium, magnesium and iron, while determinations for nitrate-nitrogen involved a colorimetric method with brucine (Hermanowicz et al. 1976). The concentrations of ammonium- and nitrate-nitrogen were recalculated in terms of the pure ingredients.

Visibility in the water was determined using a Secchi disc, while conductivity and pH were measured directly in a given lake at a depth of 1 metre, using a conductivity meter and a pH meter respectively.

Water for biological research was taken from the surface to the bottom and poured into joint samples from which samples of 1 dm^3 (from Lake Brudno) to 2 dm^3 (from the other lakes) were taken for determinations of total chlorophyll and separate samples of 0.25 dm^3 for quantitative and qualitative analyses of phytoplankton. The latter samples were fixed in 4% formalin with glycerine.

Analyses for chlorophyll always began on the day of collection of the samples, 1–2 dm^3 of water was filltered through a Whatman GF/C glass-fibre filter and the residue was then homogenized and extracted with boiling 90% ethanol (Nush

1980). Measurements of light absorption in the range 665 and 750 nm (to take account of phaeophytin) were made after 12 hours of extraction with the aid of an EMCO S/E spectrophotometer. The final concentration of chlorophyll-a per dm^3 of water was calculated using the Lorenz formula (after Vollenweider 1969).

The abundance of phytoplankton, calculated per unit volume (dm^3) of water, was defined by Utermöhl's method (after Vollenweider 1969), using an inverted microscope.

4. RESULTS

The basic physical and chemical factors obtained in the Junes 1968 and 1995, were presented in Table 2 and on Fig. 2.

Table 2. Comparison of the Secchi disc visibility, conductivity and pH of lakes in Sobibór Landscape Park in June 1968 and 1995

Lake	Visibility SD (m)		Conductivity ($\mu S \cdot cm^{-1}$)		pH	
	1968	1995	1968	1995	1968	1995
Orchowe	1.25	0.80 (to the bottom)	–	98	7.0	6.65
Płotycze	1.07	1.70	276	104	6.2	7.9
Brudzieniec	0.52	0.50	387	184	6.9	8.0
Spólne	0.85	0.65	–	271	7.7	7.65
Pereszpa	1.96	1.10	–	150	6.9	7.16
Koseniec	0.77	0.80	704	300	7.6	7.06
Brudno	0.45	0.30	397	230	7.4	9.1

The lake of unchanging dystrophic character was Lake Orchowe, with a mildly acidic reaction (pH 6.6), visibility to the bottom (about 1 m) and very low electrolytic conductivity (98 $\mu S\ cm^{-1}$). Values for phosphorus and nitrogen were also low ($P–PO_4$ = 0.013 mg dm^{-3}, and $N–NO_3$ = 0.080 mg dm^{-3}.

Rather divergent from the values typical for dystrophic lakes were the concentrations noted for iron and calcium (0.46 and 23.1 mg dm^{-3}, respectively), although assignment to the dystrophic type was further supported by the low values for chlorophyll 2.6 $\mu g\ dm^{-3}$, and for the abundance and structure of the phytoplankton (Table 3 and Fig. 3, respectively). The phytoplankton was dominated by Chlorophyta (82%), with the dominant species being small green algae such as *Tetraëdon minimum* (Turp.) Breb., *Pediastrum tetras* (Ehr.) Rolfs, *Oocystis lacustris* Chod, and *Crucigenia apiculata* (J. M. Smith) Kom. and others.

The lake defined in the 1960s as moderately eutrophic was Lake Płotycze. Comparison were made between the physico-chemical parameters for this lake for June 1968 and 1995 (Table 2). It was revealed that pH had risen during the period

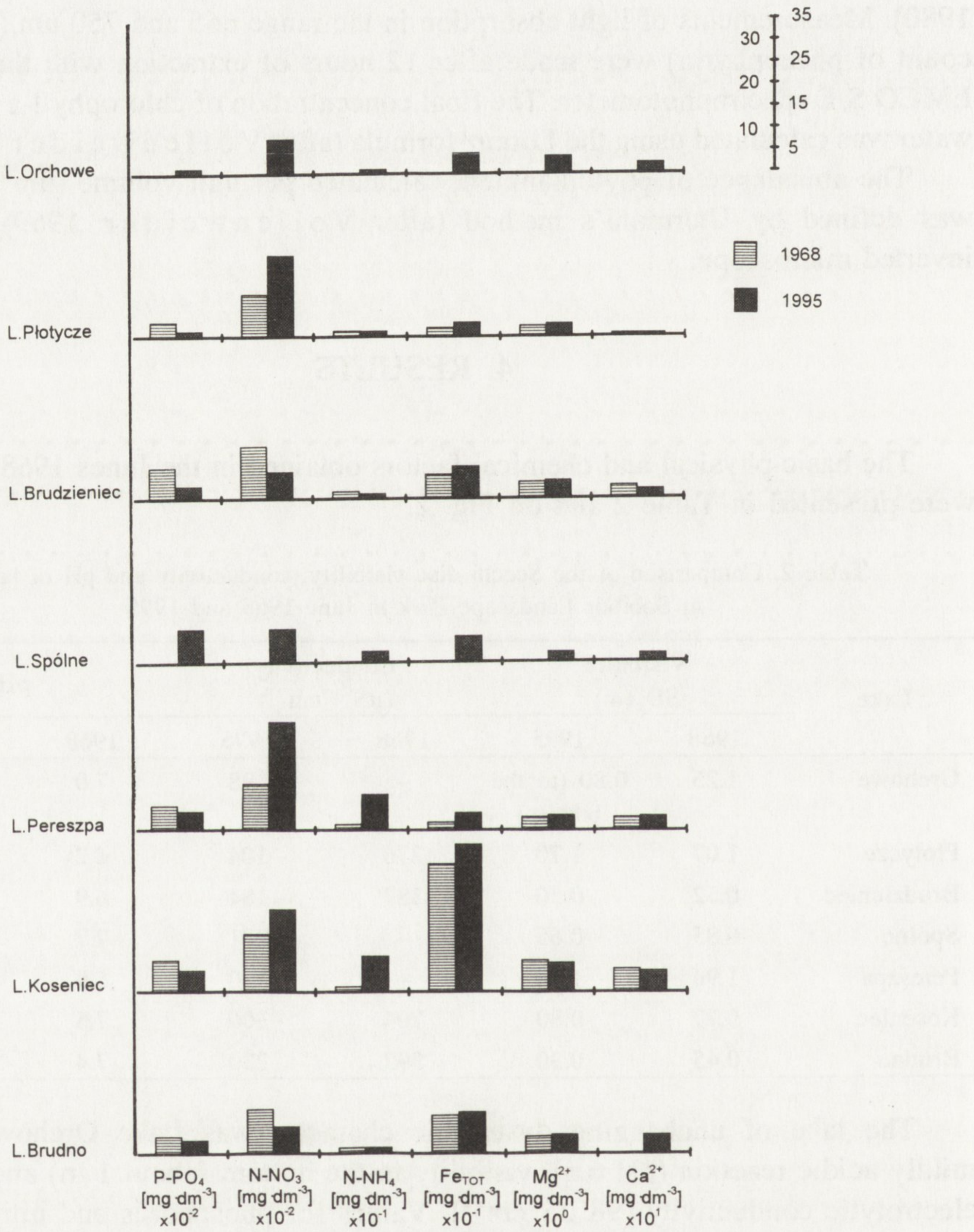

Fig. 2. Values of some indicators of the trophic status of lakes of Sobibór Landscape Park, as measured in June 1968 and June 1995

from 6.2 to 7.8, while visibility had risen from 1.07 to 1.70 m and electrolytic conductivity had decline from 276 to 104 μS cm^{-1}. In contrast, in the 27-year period the concentrations of phosphorus and nitrogen remained low with $P–PO_4$ between 0.013–0.033 mg dm^{-3}, and $N–NO_3$ between 0.097 and 0.186 mg dm^{-3}. Also low were the concentrations of iron, magnesium and calcium, as well as of chlorophyll (2.78 μg dm^{-3}). In addition, the structure of the phytoplankton was very similar to that occurring in dystrophic Lake Orchowe. Analysis of the parameters suggested that the lake be classified amongst dystrophic water bodies rather than eutrophic

Table 3. Abundance of phytoplankton and concentration of chlorophyll-a (June 1995) in lakes of Sobibór Landscape Park (mean for the water column)

Lake	Number ($N \cdot 10^3 \cdot dm^{-3}$)	Chlorophyll-a ($\mu g \cdot dm^{-3}$)
Orchowe	1 100	2.6
Płotycze	12 200	2.8
Brudzieniec	11 100	7.8
Spólne	3 300	25.6
Pereszpa	3 500	9.2
Koseniec	3 200	12.0
Brudno	97 900	23.8

ones. This change was influenced probably by the transitional bog and coniferous forest in the immediate surroundings of the lake.

The moderately eutrophic lakes which had not undergone further eutrophication in the period of almost 30 years were lakes Spólne, Koseniec and Pereszpa, as well as Lake Brudzieniec. Comparisons of the 1968 and 1995 data revealed that the pH of the water was either maintained at a constant level throughout, or showed an upward trend (Table 2). For example, the pH of Lake Brudzieniec rose from 6.9 to 8.0, while that of Lake Pereszpa increased from 6.9 to 7.1. Visibility measured by Secchi disc also showed minimal variation (Table 2), while the relatively low values for electrolytic conductivity displayed a downward trend. Conductivity fell from 387 to 184 $\mu S\ cm^{-1}$ in Lake Brudzieniec and from 704 to 300 $\mu S\ cm^{-1}$ in Lake Koseniec.

The aformentioned lakes were also characterized by rather high concentrations of calcium (above 20 $mg\ dm^{-3}$). Indeed a values as high as 50 $mg\ dm^{-3}$ was recorded for Lake Koseniec. Values for iron were generally low (at 0.2 to 0.7 $mg\ dm^{-3}$), with the one exception being Lake Koseniec, where a concentration of 3.0 $mg\ dm^{-3}$ was recorded.

Concentrations of phosphates ($P–PO_4$) and nitrate-nitrogen ($N–NO_3$) were not higher than in 1968 either, although the concentration of the latter was higher at Lake Pereszpa (0.248, as opposed to 0.106 $mg\ dm^{-3}$).

The group of lakes under discussion had apparently been characterized by an upward trend where concentrations of ammonium-nitrogen were concerned (Fig. 2).

The concentration of chlorophyll and the abundance and structure of the phytoplankton confirm the status of the lakes as moderately eutrophic (Table 3, Fig. 3).

In lakes Spólne, Koseniec and Pereszpa concentrations of chlorophyll that varied between 9.2 and 25.6 $\mu g\ dm^{-3}$ were revealed and the abundance of phytoplakton (around $3 \cdot 10^6$ individuals per dm^3) was very similar. An important (25–50%) percentage role in part the phytoplankton of all the lakes was played by nannoplanktonic Cryptophyceae species (Fig. 3). About 40% of the phytoplankton of Lake Pereszpa was constituted by Euglenophyta (principally *Trachelomonas volvocina* Ehr.), and a further 16% was accounted for by blue-green algae (principally the filamentous species of the genera *Oscillatoria* and *Lyngubya* which are characteristic of eutrophic lakes). A significant (25–50%) share of the phytoplankton in Lakes Koseniec and Spólne was also taken by diatoms, with the dominant species in this case being *Cyclotella comta* (Ehr.) Kütz., which often occurs in large numbers

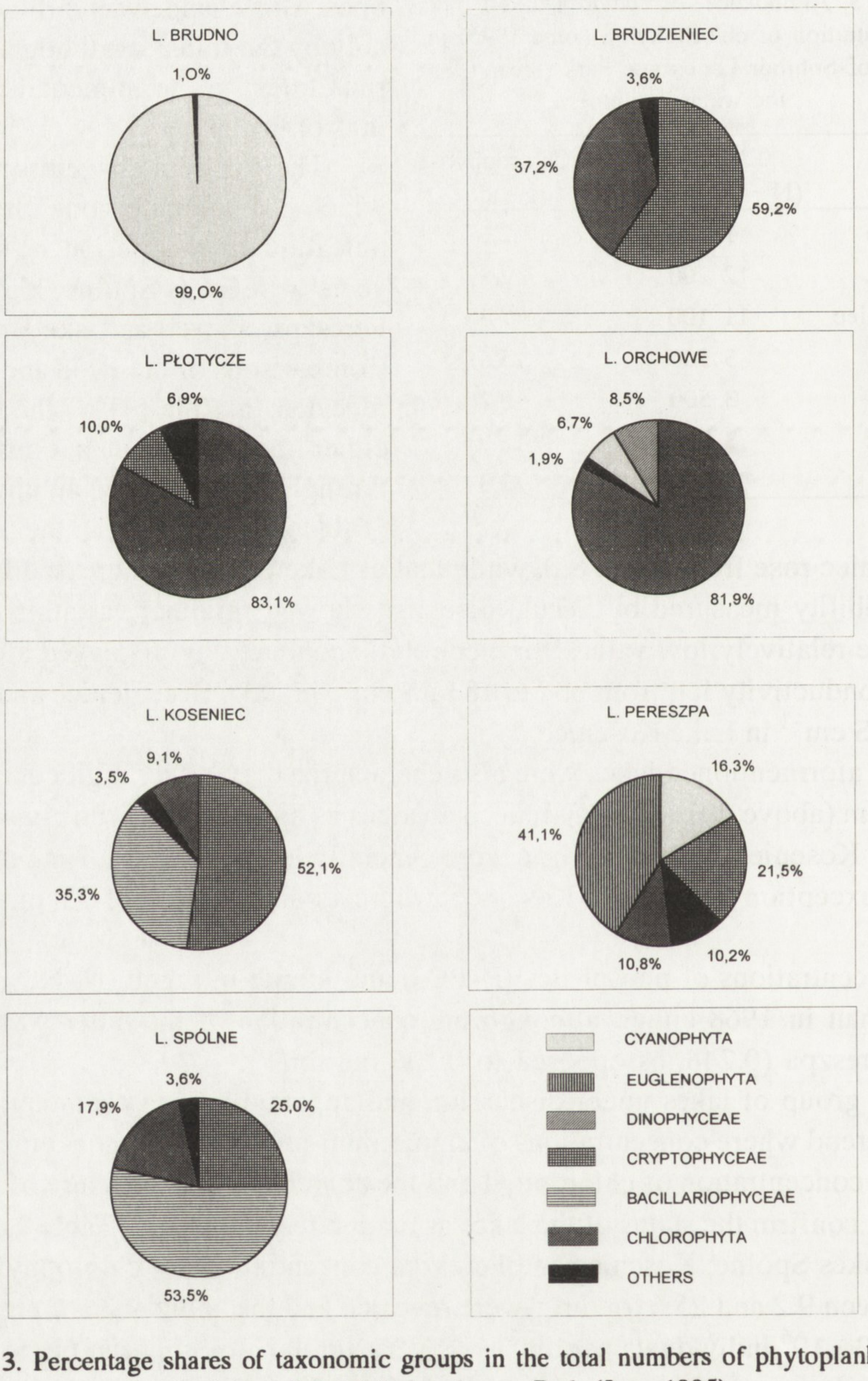

Fig. 3. Percentage shares of taxonomic groups in the total numbers of phytoplankton in the lakes of Sobibór Landscape Park (June 1995)

in the spring phytoplankton of eutrophic water bodies. Lake Brudzieniec was characterized by a rather high value for the abundance of phytoplankton (11,000,000 individuals per dm^3) and a simultaneously low concentration of chlorophyll (at 7.8 μg dm^{-3} Cryptophytes and chlorophytes accounted respectively for 60 and 37% of the total numbers of phytoplankton, with the latter group being very species-rich (having about 30 species in the June sample).

Of the seven lakes studied, only Lake Brudno displayed a more advanced stage of eutrophication as indicated by its physico-chemical and biological parameters. A 1996 pH of 9.1 was significantly greater than the 1968 value of 7.4, and transparency was lower (with visibility down from 0.45 to 0.30 m) (Table 2). The concentration of calcium was high (at 43.0 mg dm^{-3}), while that of ammonium-nitrogen was at the enhanced level of 0.13 mg dm^{-3}. the advancement of eutrophication was also confirmed by the chlorophyll concentration (24 μg dm^{-3}), as well as by the abundance and structure of the phytoplankton (Table 3, Fig. 3). The 1995 value for the abundance of phytoplankton was as high as 98,000,000 individuals per dm^3, as a consequence of the blooming of the filamentous blue-green *Oscillatoria planctonica* Wolosz. The mass appearance of blue-green algae (and especially filamentous species thereof) is characteristic for lakes that have stabilized eutrophic character.

5. DISCUSSION

Most of the lakes discussed in the present work were characterized in the 1950s as moderately eutrophic (Fijałkowski 1959) (Table 1). The only exceptions were Lake Orchowe – defined as dystrophic – and Lake Płotycze, which was considered by Fijałkowski (on the basis of the vascular plants) to show features of unstabilized dystrophy.

Analysis of basic physico-chemical aspects was carried out at the lakes in 1960s (Radwan et al. 1971, 1972, 1973) and it was confirmed that the trophic characters of the lakes had been maintained. Research on the physico-chemical and biological characteristics of the lakes was done again in June 1995, and the comparison with the earlier data revealed that the largely inaccessible forest lakes of Sobibór Landscape Park had shown considerable trophic stability with all changes noted having occurred at a very slow rate.

On the basic of their trophic characteristics, the lakes in question may be classified into three groups.

The first group includes lakes Orchowe and Płotycze whose concentrations of calcium and magnesium and low electrolytic conductivity allow for their characterization as disharmonic water bodies. Similar relationships were indeed noted in the disharmonic lakes of Wigry Landscape Park in north-eastern Poland (Zdanowski et al. 1992).

An important factor characterizing the trophic status of a lake is the concentration of phosphorus compounds. In the cases of the two aformentationed lakes, the values for this indicator were low in comparison with those noted for other lakes in Poland (Zdanowski 1983, Zdanowski et al. 1992). The dystrophic nature of the lakes was also confirmed by the low concentration of chlorophyll (2.5–2.8 μg dm^{-3}) as well as by phytoplankton dominated by green algae of the group Chlorococcales. Similar biological properties have been shown to characterize dystrophic lakes in other parts of Poland (Oleksowicz 1988, Hutorowicz et al. 1992).

The second group was made up of moderately-eutrophic lakes and included the lakes: Spólne, Koseniec and Pereszpa, as well as the Lake Brudzieniec (Fig. 1). The reaction of the water in these lakes oscillated within the pH range 7.0–7.7, and only in Lake Brudzieniec was a higher value of 8.0 recorded. The moderate degree of eutrophy was also confirmed by the rather low values noted for electrolytic conductivity and concentrations of $P–PO_4$, $N–NO_3$ and $N–NH_4$, as well as by the biological parameters. Concentration of chlorophyll varied between 7.8 and 25.6 $\mu g\, dm^{-3}$ and thus did not exceed those values characteristic for moderately-eutrophic lakes in other regions of Poland (Hillbricht-Ilkowska and Kajak 1986, Hillbricht-Ilkowska 1990).

The abundance and structure of the phytoplankton was also characteristic for moderately fertile water bodies (Kožova et al. 1975). The lakes in question had phytoplankton with a rather diverse species composition and different taxonomic groups of algae displaying considerable species richness. In Lake Pereszpa 30 species were identified which was the highest species diversity among the four analysed lakes. Euglenophyta played a significant (41%) role in the numbers of individuals at this lake, although this was mainly due to the abundant occurrence of the flagellate *Trachelomonas volvocina*, which occurs in large numbers in waters that are little polluted (Turoboyski 1970).

Comparison of the physico-chemical parameters noted in 1968 and 1995 also attest to the great stability of the ecosystems studied and hence to the maintenance of the trophic status recorded in the 1960s. The lack of change may well reflect the relative isolation of the lakes among forests and wetlands.

The greatest degree of eutrophication was noted in the case of Lake Brudno, which had maintained this character from the beginning of the 1960s. Of the seven lakes studied, it was Lake Brudno which had the lowest visibility (down to 0.30 m) and the most alkaline reaction (of pH 9.1). The 97,000,000 phytoplanktonic individuals noted per dm^3 was the highest value recorded in June 1995 and is in line with other figures given for eutrophic lakes in late May or June (Wojciechowska 1986). The structure of the phytoplankton was also indicative for eutrophy, with 99% of individuals being of the filamentous blue-green algae *Oscillatoria planctonica* Wolosz. A dominance of this blue-green species has been shown for eutrophic lakes by Ravena and Vollenwelder (1968), Spodniewska (1978) and Szyszka (1992) among others.

The maintenance of unchanged trophic status over almost thirty years does show the lakes of Sobibór Landscape Park to be worthy of protection, along with the surrounding peatland, alder carr and marsh communities (Cieślak et al. 1987). Together, these are valuable biotopes with many protected species. The confirmation of this occurred, among other ways, through the creation in 1988 of a faunistic reserve for *Emys orlicularis* including Lakes Spólne, Koseniec and Pereszpa. It is also planned that two aquatic-peatland reserves be established shortly with the names "Jezioro Orchowe" and "Jezioro Brudno i Płotycze".

6. SUMMARY

In June 1995, the lakes of Sobibór Landscape Park (Fig. 1) were subject to research concerning the physico-chemical properties of their waters as well as their phytoplankton abundance, chlorophyll concentration and species composition. Table 1 gives the morphometric data for the lakes and details their trophic characters.

To trace the long-term changes in the trophic characters of the lakes, the physico-chemical parameters noted for June 1995 were compared with data from June 1968 (Radwan et al. 1971, 1972, 1973). The two sets of results are shown in Table 2 and Fig. 2. It emerged on the basis of this analysis that Lake Orchowe had been and remained a dystrophic lake (with pH 6.6, electrolytic conductivity of 98 $\mu S\ cm^{-1}$ and concentrations of $P–PO_4$ and $N–NO_3$ at 0.013 and 0.080 mg dm^{-3} respectively). The lake in question also had low values for the abundance of phytoplankton and the concentration of chlorophyll (Table 3).

Lake Płotycze had been considered moderately eutrophic in the 1960s and may by considered dystrophic on the basic of the latest data given here. Over the 27-year period there was an apparent increase in visibility, a decline in conductivity and continued low values for concentrations of calcium, magnesium, phosphorus and nitrogen (Table 2, Fig. 2). The 1995 concentrations of chlorophyll (Table 3) and phytoplanktonic structure (Fig. 3) are also indicative of a lake dystrophic in character.

Lakes Spólne, Koseniec, Pereszpa and Brudzieniec were moderately eutrophic in the 1960s and have not seen eutrophication further in the subsequent years. These lakes show rather high concentration of calcium (over 20 mg dm^{-3}) and a slightly higher concentrations of ammonium-nitrogen (Fig. 2). Moderate eutrophy is also confirmed by appropriate concentration of chlorophyll, and by the level of abundance and structure of the phytoplankton.

The only lake with advanced eutrophication was Lake Brudno, where in 1995 pH of 9.1 was compared with a 1968 value of 7.4. Visibility was also lower in 1995 (0.30 m as opposed to 0.45 m) and the phytoplankton was seen to be dominated by the blue-geen alga *Oscillatoria planctonica* Wołosz.

Analysis of biological and physico-chemical parameters from the years 1968–1995 revealed the very considerable trophic stability of the ecosystems studied. This may result from their isolation (a location amongst forests and wetlands), as well as from their effective protection to date.

7. POLISH SUMMARY

W czerwcu 1995 roku w jeziorach Sobiborskiego Parku Krajobrazowego (rys. 1) badano właściwości fizyko-chemiczne wody oraz fitoplankton, uwzględniając liczebność, koncentrację chlorofilu i strukturę jakościową. Dane morfometryczne jezior i ich charakter troficzny przedstawiono w tabeli 1.

W celu prześledzenia długoterminowych zmian charakteru troficznego zbiorników parametry fizyko-chemiczne z czerwca 1995 roku porównano z analogicznymi z czerwca 1968 roku (Radwan i in. 1971, 1972, 1973) i przedstawiono je w tabeli 2 i na rysunku 2. Na podstawie tych analiz okazało się, że zbiornikiem o niezmieniającym się charakterze dystroficznym było jezioro Orchowe (pH 6,6, przewodnictwo elektrolityczne 98 $\mu S\ cm^{-1}$, wartości fosforu $P–PO_4$ – 0,013 mg dm^{-3} i azotu $N–NO_3$ – 0,080 mg dm^{-3}). Niska była też w tym zbiorniku liczebność fitoplanktonu i zawartość chlorofilu (tab. 3).

Jeziorem, które w latach sześćdziesiątych było charakteryzowane jako umiarkowanie eutroficzne, a na podstawie obecnych badań zostało zakwalifikowane do dystroficznych było Płotycze. Na przestrzeni 27 lat wzrosła widzialność, zmalała przewodowość oraz niskie były zawartości wapnia, magnezu, fosforu i azotu (tab. 2, rys. 2). Koncentracja chlorofilu (tab. 3). i struktura fitoplanktonu (rys. 3) potwierdziły jego dystroficzny charakter.

Do jezior umiarkowanie eutroficznych, które w okresie niemal trzydziestu lat nie zwiększyły stopnia eutrofizacji należały Spólne, Koseniec, Pereszpa i Brudzieniec. Wymienione zbiorniki charakteryzowały się dość dużymi ilościami wapnia (powyżej 20 mg dm^{-3}) i małą tendencją wzrostową dotyczącą wartości azotu amonowego (rys. 2). Umiarkowaną eutrofię potwierdziła też koncentracja chlorofilu, liczebność i struktura fitoplanktonu.

Jedynym zbiornikiem o zaawansowanej eutrofii było jezioro Brudno, w którym pH wzrosło od 7,4 do 9,1, przezroczystość zmalała z 0,45 do 0,30 m, a fitoplankton zdominowany był (99%) przez nitkowatą sinicę *Oscillatoria planctonica* Wołosz.

Analiza parametrów fizyko-chemicznych z lat 1968–1995 oraz parametry biologiczne wskazują na dużą stabilność troficzną badanych ekosystemów, co może wynikać z ich pewnej izolacji (położenie wśród lasów i mokradeł) oraz skuteczności dotychczasowej ochrony tych zbiorników.

8. REFERENCES

1. Cieślak M., Krzywińska E., Gacka-Grzesikiewicz E. 1987 – Szata roślinna [Plant associations] (W: Sobiborski Park Krajobrazowy [In: Sobibór Landscape Park], ed. E. Gacka-Grzesikiewicz) – PWN Warszawa, 37–54.
2. Fijałkowski D. 1959 – Szata roślinna Jezior Łęczyńsko-Włodawskich i przylegających do nich torfowisk [Plan associations of lakes situated between Łęczna and Włodowa and of peat-bogs adjacent to these lakes] – Annls Univ. Mariae Curie-Skłodowska, B, 14: 131–206.
3. Hermanowicz W., Dożańska W., Dojlido J., Koziorowski B. 1976 – Fizyczno-chemiczne badania wody i ścieków [Physical and chemical investigation of water and wastewater] – Arkady, Warszawa, 846 pp.
4. Hillbricht-Ilkowska A. 1990 – Assessment of the trophic impact on the lake environment in Poland: a proposal and case study (In: Ecological risks – perspectives from Poland and the United States, eds. W. Grodziński, E. Cowling, A. Breymayer) – Nat. Acad. Press, Washington, 283–296.
5. Hillbricht-Ilkowska A., Kajak Z. 1986 – Parametry i wskaźniki przydatne do kontroli zmian funkcjonalnych i strukturalnych w ekosystemach jeziornych ulegających procesowi eutrofizacji [Parameters and indexes useful in controlling structure and functional changes in eutrophicated lake systems] (W: Monitoring systemów jeziornych [In: Lake systems monitoring], ed. A. Hillbricht-Ilkowska) – Ossolineum, Wrocław, 23–45.
6. Hutorowicz A., Spodniewska I., Krzywosz W. 1992 – Fitoplankton w jeziorach Wigierskiego Parku Narodowego [Phytoplankton in lakes of Wigry National Park] (W: Jeziora Wigierskiego Parku Narodowego. Stan eutrofizacji i kierunki ochrony [In: Lakes of Wigry National Park. Trophic status and protection directions], ed. B. Zdanowski) – Ossolineum, Wrocław, Zesz. Nauk. Komitetu "Człowiek i Środowisko", 3: 79–100.
7. Jabłoński A. 1992 – Próba aktywnej ochrony żółwia błotnego *Emys orbicularis* (L.) [A test of the active protection of *Emys orbicularis* (L.)] (W: Czynna ochrona zwierząt [In: The active protection of animals], eds. R. Olaczek, L. Tomiałojć) – PWN Warszawa, 107–115.
8. Kowalczyk Cz. 1979 – Fauna skorupiaków jezior Pojezierza Łęczyńsko-Włodawskiego na tle warunków limnologicznych. Część III. Jeziora o IV stopniu degradacji [Crustacean fauna of the Łęczna-Włodawa Lake District against the background of limnological factors. Part III. The lakes of the 4th degree of degradation] – Annls Univ. Mariae Curie-Skłodowska, C, 34: 261–278.
9. Kožova O. M., Zagorenko G. F., Ladejščikova E. N. 1975 – Osobennosti fitoplanktona ozera Chubsugut w miežgodorom i sezonnom aspektach [The phytoplankton of Lake Chubsugut and its seasonal and multi-annual variations] – Gidrobiol. Ž. 11: 77–82.
10. Nush E. A. 1980 – Comparison of different methods for chlorophyll and pheopigment determination – Arch. Hydrobiol. Beih. Ergebn. Limnol. 14: 14–36.

11. Oleksowicz A. S. 1988 – Dynamika zbiorowiska glonów w troficznie zróżnicowanych jeziorach Pojezierza Kaszubskiego [The dynamics of algal communities in the trophically-diverse lakes of the Kaszuby Lakeland] – Univ. M. Kopernika, Toruń, 84 pp.
12. Patalas K. 1954 – Porównawcze badania nad nowym typem samoczynnego czerpacza planktonowego i hydrochemicznego [Comparative studies on a new type of automatic planktonic and hydrochemical sampler] – Ekol. pol. A, 2: 231–241.
13. Radwan S. 1976 – Planktonic rotifers as indicators of lake trophy – Annls Univ. Mariae Curie-Skłodowska, C, 21: 227–235.
14. Radwan S., Podgórski W., Kowalczyk Cz. 1971 – Materiały do hydrochemii Pojezierza Włodawskiego. Część I. Stosunki mineralne [A contribution to the hydrochemistry of the Łęczna and Włodawa Lake District. Part I. Mineral relations] – Annls Univ. Mariae Curie-Skłodowska, C, 26: 31–39.
15. Radwan S., Podgórski W., Kowalczyk Cz. 1972 – Materiały do hydrochemii Pojezierza Włodawskiego. Część II. Substancje organiczne i związki azotowe [A contribution to the hydrochemistry of the Łęczna and Włodawa Lake District. Part II. Organic substances and nitrogen compounds] – Annls Univ. Mariae Curie-Skłodowska, C, 27: 17–30.
16. Radwan S., Podgórski W., Kowalczyk Cz., Fall J. 1973 – Materiały do hydrochemii Pojezierza Włodawskiego. Część III. Właściwości fizyczne i chemiczne [A contribution to the hydrochemistry of the Łęczna and Włodawa Lake District. Part III. Physical and chamical properties] – Annls Univ. Mariae Curie-Skłodowska, C, 28: 97–116.
17. Ravera O., Vollenweider R. A. 1968 – *Oscillatoria rubescens* D. C. as an indicator of Lago Maggiore eutrophication – Schweiz. Z. Hydrol. 30: 374–380.
18. Spodniewska I. 1978 – Phytoplankton as the indicator of lake eutrophication. I. Summer situation in 34 Masurian Lakes in 1973 – Ekol. pol. 26: 53–70.
19. Szyszka T. 1992 – Dynamics of phytoplankton in a hypertrophic lake – Wyd. Nauk. Uniw. W. Mickiewicza, Poznań, Ser. Biol. 47: 40 pp.
20. Turoboyski L. 1970 – Listy organizmów wskaźnikowych najczęściej spotykanych w wodach Polski [Lists of indicatory organisms most often encountered in surface waters in Poland] – Mat. Bad. Inst. Gosp. Wodn., Warszawa, 77 pp.
21. Vollenweider R. A. 1969 – A manual to methods for measuring primary production in aquatic environments – Blackwell, Oxford-Edinburg, 213 pp.
22. Wilgat T. 1953 – Jeziora Łęczyńsko-Włodawskie [Łęczyńsko-Włodawskie lakes] – Annals Univ. Mariae Curie-Skłodowska, B, 8: 37–132.
23. Wojciechowska W. 1986 – Phytoplankton fluctuations in pond lake Bikcze – Ekol. pol. 34: 133–143.
24. Zdanowski B. 1983 – Ecological characteristics of lakes in North-Eastern Poland versus their trophic gradient. III. Chemistry of the water in 41 lakes – Ekol. pol. 31: 287–308.
25. Zdanowski B., Karpiński A., Prusik S. 1992 – Warunki środowiskowe wód Wigierskiego Parku Narodowego [Environmental parameters of waters in Wigry National Park] (W: Jeziora Wigierskiego Parku Narodowego. Stan eutrofizacji i kierunki ochrony [Lakes of Wigry National Park. Trophic status and protection directions], ed. B. Zdanowski) – Ossolineum, Wrocław, Zesz. Nauk. Komit. Nauk. "Człowiek i Środowisko", 3: 35–62.

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