EKOLOGIA POLSKA (Ekol. pol.)	31	2	239–256	1983

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ECOLOGICAL CHARACTERISTICS OF LAKES IN NORTH-EASTERN POLAND VERSUS THEIR TROPHIC GRADIENT

I. GENERAL CHARACTERISTICS OF 42 LAKES AND THEIR PHOSPHORUS LOAD. STUDY OBJECTIVES AND SCOPE*

ABSTRACT: The paper contains general information about 42 dimictic and polymictic lakes representative for north-eastern Poland and is an introduction to a series of 12 papers. The main object of these papers is a characteristic of structural and functional relations of lake ecosystems depending on their trophic state and mictic character. Average and maximum phosphorus load for dimictic lakes was 1.1 and 8.8, respectively, and for polymictic lakes 2.6 and 16.8. In 65% of dimictic lakes the visibility of Secchi disc decreased in relation to that recorded 15-28 years ago.

KEY WORDS: Lakes, eutrophication, drainage basin, dimictic lakes, polymictic lakes, hypertrophy.

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* Praca wykonana w ramach problemu międzyresortowego MR II/15 (grupa tematyczna „Ekologiczne podstawy jakości i czystości wód powierzchniowych").

The studies were conducted on 42 lakes[1], representative for lakelands in north-eastern Poland. This is a differentiated hummocky area typical of post-glacial areas.

The studies were carried out by the Department of Hydrobiology, Institute of Ecology, Polish Academy of Sciences and the Department of Hydrobiology, Inland Fisheries Institute in cooperation with the Institute of Geography, University of Warsaw, and the Department of Hydrobiology, University of Warsaw.

The papers give the characteristics of the trophic state and the purity of these lakes including a quantitative analysis of main ecosystem components in order to:

a. draw conclusions about the functioning of lake ecosystems depending on trophic state, pollution and mictic type,

b. determine the characteristics and indices of lakes varying in trophic state,

c. estimate the rate of trophic state changes by comparing with data from other periods.

Geographical and hydrographical aspects of the area and drainage basin of particular lakes (Bajkiewicz-Grabowska 1983) have been analysed, also chemical and physical characters of water and bottom sediments (Zdanowski 1982, 1983a, 1983b, Karabin 1983), phytoplankton and chlorophyll (Spodniewska 1983, Zdanowski 1983c), zooplankton (Ejsmont-Karabin 1983, Karabin 1983) and benthos (Prejs and Papińska 1983, Stańczykowska, Jurkiewicz-Karnkowska and Lewandowski 1983, Wiśniewski and Dusoge 1983). Lakes of a medium size have been chosen - the majority of them having 50-150 ha, and only few deviate from these sizes, the smallest having 24 ha and the largest - 382 ha (the complex of Great Masurian Lakes is the subject of other papers - Gliwicz et al. 1980, data of the Institute of Ecology, Polish Academy of Sciences, in preparation). Only 12 of these lakes have outflows.

All lakes examined are in the same geographical region, on a

[1] In some detailed investigations the number of lakes was even greater - up to 46.

similarly differentiated area and on similar soils. Their individual differences from this point of view are discussed by B a j k i e w i c z - G r a b o w s k a (1983). Loamy-sand soils dominate. Their permeability is not much differentiated, usually average. The lakes differ of course as regards the size of their drainage basin, character of plant cover, the occurrence or not and the amount of sewage point sources. The average declivity of the area for particular lakes is 4-30%. Mean annual precipitation on the whole area is about 550 mm, attaining in some places 650 mm. The highest precipitation is in summer months - July and August, and also in November. Mean outflow per unit of drainage basin area is 3.9-6.88 $l \cdot sec^{-1} \cdot km^{-2}$, usually 5-6, thus being very little differentiated. Ouite high is the per cent of the area without outflow in the direct drainage basin: 0-75%, usually 30-60%. It can be assumed that the values are similar for the total drainage basin (all above data acc. to B a j k i e w i c z - G r a b o w s k a 1983).

Lakes ranging from meso- to hypertrophy have been chosen on purpose, similar number for the dimictic and polymictic group (23 and 19, respectively). More important data describing the lakes are given in Table I.

Total phosphorus concentration in the epilimnion in summer was 20-940 $\mu g \cdot l^{-1}$; 20-506 for dimictic lakes and 53-940 for polymictic lakes. The visibility of Secchi disc in summer was 0.3-6.9 m: 0.6-6.9 for dimictic lakes and 0.3-2.4 for polymictic lakes. Trophic state index of Carlson for the summer period was 47.3-103.1 (47.3-94.1 and 61.4-103.1, respectively) according to total phosphorus concentration, 42.2-77.4 (32.2-67.4 and 47.4-77.4) according to the visibility of Secchi disc and 34.8-84.3 (34.8-76.7 and 43.1-84.3) according to chlorophyll concentration.

Thus lakes from the dimictic group had lower trophic state, covering the range from meso- to hypertrophy, whereas the polymictic lakes covered the range from eu- to very high hypertrophy. This was probably mainly due to morphometry and to the connected with it type of matter cycling (K a j a k 1983).

The material from dimictic lakes was taken in 1977, and from polymictic lakes in 1978. Samples were taken twice during the year: during spring circulation (April-May) and at the peak of summer stagnation (July-August).

Table I. Selected characteristics of lakes examined and their drainage basins

Lakes	Maximal depth m	Mean depth m	Surface area ha	Total drainage basin ha	Static degree acc. to Patalas[1]	Schindler's index[2]	Ohle's index[3]	Water exchange rate[4]	The load of P from direct drainage basin[5] $g \cdot m^{-2} \cdot yr^{-1}$	Per cent of point load in the total load	Total P concentration in epilimnion in summer $\mu g \cdot l^{-1}$	SD visibility in summer m	Phytoplankton biomass in summer $mg \cdot l^{-1}$	O_2 concentration at bottom in summer[6] $mg \cdot l^{-1}$	Sources of point load
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dimictic lakes															
Bartąg	15.0	6.4	72	419	III	0.9	6	B	0.1	0	-	2.0	7.2	-	
Czos	43.0	11.1	279	9860	III/IV	3.0	35	0.6	0.24	20	68	1.6	13.5	0.0	municipal
Ełckie	55.8	15.0	382	96690	IV	16.8	253	3.1	4.24	43	202	1.6	7.5	0.0	municipal, industrial
Gim	26.0	7.6	176	1110	III	0.8	6	B	0.07	0	43	5.8	2.2	0.0	
Gromskie	16.0	5.8	240	1108	IV	0.8	5	0.1	0.1	0	-	2.8	6.6	-	
Jaśkowskie	16.0	7.3	152	749	III	0.7	5	0.1	0.1	0	59	2.3	19.9	-	industrial
Juno[7] Północne	27.0	11.9	380	23320	III/IV	5.0	61	1.0	1.73	99	175	1.2	29.8	0.1	municipal
Południowe	33.0				-						282	1.0	14.9	0.0	industrial
Kierzlińskie	44.0	11.7	93	1160	IV	1.5	17	0.3	0.5	0	38	6.9	0.5	2.8	
Kuc	28.0	8.0	98	878	III/IV	-	9	B	0.2	0	40	5.4	0.4	2.9	
Lampackie	38.0	11.1	198	8725	IV	3.9	44	0.8	0.27	35	62	1.3	29.4	0.0	municipal
Lidzbarskie	25.2	10.0	122	36340	IV	46.0	463	8.4	8.8	5	222	1.0	14.9	-	industrial
Małaszewskie	17.0	6.3	202	3810	IV	2.0	19	0.6	0.4	0	137	1.3	11.8	0.0	
Maróz	41.0	11.9	332	21680	III	5.5	65	1.2	0.6	68	44	2.1	7.8	0.0	distillery

Ołów	40.0	12.9	61	319	IV/III	0.4	5	B	0.1	0	29	3.8	0.4	0.0	
Piłakno	56.0	13.0	259	1080	III/IV	0.3	4	0.1	0.67	98	20	6.4	1.0	3.1	distillery, municipal
Probarskie	31.0	9.2	201	860	IV/III	0.5	4	B	0.1	0	38	5.1	3.0	0.5	
Rzeckie	29.0	7.0	56	1710	IV	4.4	30	0.8	1.0	0	87	0.9	21.5	0.0	
Sarż	15.0	5.8	76	380	IV	0.8	5	B	0.1	0	31	3.6	2.1	0.0	
Skanda	12.0	5.8	51	1080	IV	3.6	21	B	1.0	0	44	4.6	1.7	0.0	
Szeląg Mały	15.0	5.7	84	1440	IV	3.0	17	0.7	0.2	26	68	1.2	12.4	-	municipal, sawmill
Sztumskie[8]	24.0	6.0	50	460	III	1.3	9	0.2	0.3	73	506	2.2	4.6	0.0	industrial, municipal
Wobel	15.0	4.2	23.7	582	IV	6.0	25	0.8	3.6	31	464	0.6	11.6	0.0	dairy, municipal
Range	12.0–56.0	4.2–15.0	23.7–382	319–96690	III–IV	0.3–46.0	4–463	0.1–8.4	0.07–8.8	0–99	20–506	0.6–6.9	0.4–29.8	0.0–3.1	
Polymictic lakes															
Barlewickie	8.5	4.2	63.7	928	II/III	3.4	15	B	0.9	0	940	0.6	87.4	6.0	municipal, industrial
Będze	6.7	2.8	149.9	1210	II	2.8	8	0.4	0.04	0	141	0.5	39.6	9.4	
Brajnickie	5.2	2.7	186.3	3270	II	6.0	18	0.9	0.5	0	157	0.6	68.7	12.4	
Burgale	7.4	4.6	79.0	1260	II/III	3.4	16	0.5	0.4	0	74	1.4	6.2	8.8	
Długie	5.4	2.8	62.0	1700	II	9.7	27	B	2.9	62	285	0.5	16.5	7.9	post-cooling, dairy
Hartowiec	5.2	2.8	69.2	1220	II	6.2	18	1.1	4.05	85	176	0.9	9.8	9.4	distillery
Iławskie	2.8	1.1	154.5	36270	I	204.0	235	36.9	10.1	99	420	0.3	121.9	12.7	municipal, dairy, industrial
Kołowin	7.1	4.0	78.2	2080	II/III	3.0	27	1.3	0.3	0	53	2.4	1.3	9.4	
Kraksy Duże	4.0	1.1	44.2	8760	I	178.0	198	33.7	16.07	96	504	1.5	1.6	1.4	municipal
Liwieniec	2.4	1.2	81.2	34220	I	274.0	421	33.7	3.42	99	321	0.4	46.3	10.4	municipal, distillery
Mój	4.1	2.4	116.5	998	II	3.5	9	B	0.1	0	80	0.9	18.6	7.6	
Rańskie	7.8	3.8	291.3	3130	II/III	2.8	11	0.5	0.72	60	92	1.4	19.4	6.5	dairy, municipal, distillery

Table I (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sambród	4.3	1.9	128.4	5930	II	24.0	46	5.3	1.36	4	161	0.5	17.2	14.0	sawmill
Szoby Małe	3.7	1.6	319.1	35770	I	68.0	112	9.9	5.78	99	142	1.1	35.6	-	rettery, dairy distillery, municipal
Sędańskie	6.1	2.5	168.0	21910	II	51.0	8	7.4	0.05	0	90	1.3	27.5	7.5	
Siercze	2.0	1.0	55.4	242	I	3.6	4	0.7	0.1	0	84	1.6	12.9	7.1	
Stryjewskie	6.2	2.6	67.5	2263	II	13.0	34	2.5	0.07	0	160	0.7	50.5	8.4	
Tuchel	5.1	2.7	42.7	1760	II/III	15.0	41	2.8	1.0	0	357	0.6	100.3	0.06	no data
Warpuńskie	6.5	2.6	49.0	2300	II	18.1	47	3.5	1.5	0	134	0.5	30.0	0.08	
Range	2.0--8.5	1.0--4.6	42.7--291.3	242--36270	I-II/III	2.8--274.0	4-421	0.4--36.9	0.04--16.07	0-99	53-940	0.3--2.4	1.3--121.9	0.06--14.0	

[1]Static degree (acc. to Patalas 1960 after Zdanowski 1983a) assumes the lowest value (I) at constant mixing, the highest value (IV) at very well developed stratification. [2]Schindler's index - ratio of total drainage basin surface area to the volume of the lake. [3]Ohle's index - ratio of total drainage basin surface area to lake surface area. [4]Water exchange rate - ratio of annual outflow to the lake volume. B - lakes without inflows. [5]Estimated lake loads are only for the direct drainage basin; for lakes with a high water exchange rate the real loads are of course greater, but difficult to determine as measurements of water amount and phosphorus concentrations in outflows are not made frequently. All lakes obtain also a load from the atmosphere (about 0.005 $g \cdot m^{-2} \cdot yr^{-1}$ - Hillbricht-Ilkowska, Goszczyńska and Planter - in press), which is not included in above calculations, and some lakes obtain also the difficult to estimate sewage from animal farms. Point loads are frequently too low; e.g., phosphorus load from "industrial wastes" is not considered if in the data of the Centre of Investigations and Environment Control the character of industry is not stated precisely, or if there are no data on P concentrations for a given kind of industry; this concerns lakes: Ełckie, Jaśkowskie, Juno, Lidzbarskie, Sambród, Szeląg Mały. As regards lakes Barlewickie and Sztumskie, although it is known that they obtain a load of municipal and industrial wastes there are no data. Lake Tuchel is undoubtedly polluted, but no data are available on the kind and amount of sewage. For Lake Liwieniec it has been assumed that mean total P concentration for municipal, distillery and slaughterhouse wastes are 20 $mg \cdot l^{-1}$; for lake Długie having post-cooling and dairy wastes the phosphorus concentration has been assumed as for dairy wastes. For the Iławskie Lake it has been assumed that the dairy wastes are not treated. [6]O_2 was measured in the deepest place, about 1 m above the bottom, and in the lake > 30 m deep at the depth of 30 m, because of the limited length of the cable of the oxygen meter. [7]Lake Juno was treated as a whole from the point of its geographical and drainage basin character, and as two separate parts (northern and southern) as regards its hydrochemical and biological character, because of the great difference in phosphorus concentration in epilimnion in summer. [8]For the Sztumskie Lake it was assumed (on the basis of data of Januszkiewicz 1969) 100 $m^3 \cdot 24\ hr^{-1}$ for mixed sewage (municipal and slaughterhouse) and the phosphorus concentration 11.4 $g\ P_{tot} \cdot m^{-3}$ (as for municipal wastes).

This series of publications is a first attempt of elaborating the material as a whole.

The load of phosphorus to lakes from the drainage basin varied considerably - 0.04-16.1 g $P \cdot m^{-2} \cdot year^{-1}$, but usually did not exceed several $g \cdot m^{-2} \cdot year^{-1}$ (Table I).

The load of phosphorus (as the basic factor deciding generally, and also in the area examined, about the trophic status of lakes - Kajak 1979, Zdanowski 1982), to lakes was calculated as a sum of point and areal sources, assuming an annual outflow in $kg \cdot ha^{-1} \cdot year^{-1}$ from forests - 0,05, meadows - 0.1, fields 0.4 and areas with buildings - 1.0. These values were assumed as average and most probable for these areas according to numerous literature sources (review: Kajak 1979, Reckhow and Simpson 1980, Reckhow, Beaulac and Simpson 1980). The areas of particular types of plant cover are taken from the paper by Bajkiewicz-Grabowska (1983).

The assumed values are much higher than those given by Hillbricht-Ilkowska, Goszczyńska and Planter (in press) for 7 small (0.3-2.3 km^2) partial drainage basins of the river Jorka, drained by small unpolluted streams. But the values given by these authors are very low (0.007-0.06 $kg \cdot ha^{-1} \cdot year^{-1}$) and are at the bottom of the range of literature data (review: Kajak 1979). For a stream running across an area with buildings the value given by these authors is 0.23 kg $P \cdot ha^{-1} \cdot year^{-1}$. These studies have not taken into consideration the export of matter by waters from showers, which, as it is known, take out considerable amounts of matter.

In estimations of the phosphorus load from the drainage basin, it has been assumed that it comes from the whole area, including that without surface outflow. This can result in some overestimations of the areal load, but such simplification has been considered as necessary at rough calculations, because a number of areas without a surface outflow acc. to the map may have some outflows in reality, due to land reclamations, ditches, etc.

The estimated loads from the direct drainage basin are only a part of total load for lakes with a high coefficient of water exchange, where the main load comes from the indirect drainage basin. Greater inflows, especially those running across villages, usually have water with high concentrations of total phosphorus (data for March and August), e.g., the Krutynia river at its mouth to the Lampackie Lake - 0.36 and 0.29 mg P $\cdot$ l^{-1}, respectively, the inflow near Miłuki to the same lake - 1.2 and 1.3 mg P $\cdot$ l^{-1}, the Iławka river at its mouth to lake Kraksy - about 0.3 mg $\cdot$ l^{-1} at both dates (B o r o w s k i et al. 1976, 1978).

Data on the character and the volume of sewage point sources have been taken mainly from the work by G i e r c u s z k i e w i c z - B a j t l i k and J a b ł o ń s k i (1977), assuming (analogously as G i e r c u s z k i e w i c z - B a j t l i k and G ł ą b s k i (1981)) the phosphorus concentration in mg $\cdot$ l^{-1} in municipal sewage 11.4, from distillery 88.0, from slaughterhouses 7.6, from dairies 2.5, from retteries 26.0, and the reduction of concentration at mechanical cleaning by 20%, and at mechanical-biological cleaning by 40%. The seasonal character of sewage sources has been taken into consideration giving 220 days for the distillery campaign and 120 days for the tourist season in holiday centres.

Phosphorus load to polymictic lakes is on the average higher than to dimictic ones both for mean values for these two groups of lakes (2.6 and 1.1 g P_{tot} $\cdot$ m^{-2} $\cdot$ $year^{-1}$, respectively) and the maximal ones (Table I).

Phosphorus load to lakes, and total phosphorus and nitrogen concentration in epilimnion in summer correlated positively with the density of river network in the drainage basin and also with the ratio of the surface area of drainage basin to the surface area and volume of the lake (Table II).

Some of these lakes were investigated in the years 1950-1963 (O l s z e w s k i and P a s c h a l s k i 1959, P a t a l a s 1965, O l s z e w s k i et al. 1978). The data on the visibility of Secchi disc and the oxygen concentration at the bottom were compared for these years and for own data for years 1977-1978 (Table III). In the majority of dimictic lakes (11 out of 17) the visibility of Secchi disc decreased in summer. In some lakes the oxygen deficit at the near-bottom hypolimnion layers increased. But out of 11 polymictic lakes only three had lower visibility. However, it has to be taken into consideration that absolute values of the visibility of Secchi disc many years ago (measurements of O l s z e w s k i and P a s c h a l s k i 1959, P a-

Table II. Relationship between the phosphorus and nitrogen concentration in the lake epilimnion in summer and the chosen parameters of the drainage basin (only lakes without a through flow and without sewage inflow were considered)
Mean values and the range are given. Lakes of a network density in the drainage basin: < 0.5 km^{-1}: Ołów, Sarż, Gromskie, Bartąg, Probarskie, Kołowin, Siercze, Bądze; 0.5–2.0 km: Kierzlińskie, Kuc, Małaszewskie, Burgale, Mój, Warpuńskie, Brajnickie

Elements compared	Numerical values	
Density of water network, $km \cdot km^{-2}$ (and the number of lakes)	<0.5 (8)	0.5–2.0 (7)
Ohle's index	8.0 4–27	19.3 9–47
Schindler's index	1.6 0.4–3.6	4.9 1.5–18.1
P_{tot} load, $g \cdot m^{-2} \cdot yr^{-1}$	0.1 0.04–0.3	0.5 0.1–1.55
P_{tot} concentration, $\mu g \cdot l^{-1}$	63.1 29–141	94.3 38–157
N_{tot} concentration, $\mu g \cdot l^{-1}$	1074 620–2460	1456 1110–1860

t a l a s 1965) were much greater in dimictic lakes – on the average 2.9 m (0.4–6.3 m) – than in polymictic ones: 1.1 m (0.4–2.8 m). The polymictic lakes were already then much more eutrophic than the dimictic lakes.

In the majority of dimictic lakes the phosphorus load was not extremely high – about or below 1 g $P \cdot m^{-2} \cdot year^{-1}$, and in several lakes only (Juno Północne, Juno Południowe, Lidzbarskie, Ełckie, Wobel) it was several $g \cdot m^{-2}$. (Of course, it exceeded as a rule the permissible and even dangerous concentration according to criteria of V o l l e n w e i d e r 1968.) Thus the deteriorating water purity expressed by worse visibility of the Secchi disc was the result of poor defence mechanisms of the lake. It should be pointed out that in almost all dimictic lakes, and only in some polymictic lakes of a P_{tot} concentration in summer over 60 $\mu g \cdot l^{-1}$, although polymictic lakes had usually greater phosphorus load than dimictic ones, the water purity deteriorated. This is undoubtedly due to higher average trophic state of polymictic lakes than dimictic ones. In the group above 60 mg $P \cdot l^{-1}$

Table III. Changes after 14–29 years in the visibility of Secchi disc and O_2 concentration at the bottom in dimictic (D) and polymictic (P) lakes

Oxygen data – the same dates as for the visibility data. Underlined lakes are those with a decrease in the visibility of Secchi disc after some 20 years. Dash – no data, t – traces. Data for years 1950–1963 – acc. to Olszewski et al. (1978) or Patalas (1965), data for years 1977–1978 – acc. to Karabin (1983) and Zdanowski (1983a). Considered were only lakes with data recorded many years ago. The lakes are given in the order of increasing P_{tot} concentration in summer 1977 or 1978

Lakes	Mictic type	Depth m	P_{tot} in summer $\mu g \cdot l^{-1}$	Date	Visibility m	O_2 at the bottom $mg \cdot l^{-1}$
1	2	3	4	5	6	7
Piłakno		56.0	20	Sept. 1959	5.9	4.3–4.9
				Aug. 1961	6.3	4.6–5.9
				July 1977	6.4	3.1
Ołów		40.0	29	Aug. 1950	1.9	0.6
				July 1977	3.8	0
Probarskie		31.0	38	Sept. 1950	3.8	t
				July 1977	5.1	t
Skanda		12.0	44	Aug. 1962	4.6	0
				July 1956	1.6	
				July 1977	1.6	0
Bartąg	D	15.2	–	Sept. 1959	2.75	0
				July 1977	2.0	–
Maróz		41.0	44	July 1951	2.2	2.9
				July 1977	2.1	0
Gromskie		16.0	66	Aug. 1952	3.8	"oxygen to the bottom"
				July 1977	2.8	
Czos		43.0	68	Sept. 1950	2.8	0.2
				Aug. 1962	2.8	
				July 1977	1.6	0
Szeląg Mały		15.0	68	Aug. 1961	3.0	–
				July 1977	1.2	–
Lampackie		38.0	73	Sept. 1959	3.4	0.4–0.8
				July 1977	1.3	–
Rzeckie		29.0	87	Aug. 1960	2.8	–
				July 1977	0.9	0
Małaszewskie		17.0	137	Aug. 1952	3.7	0
				July 1977	1.3	0
Juno Północne		27.0	175	Sept. 1950	2.3	0
				July 1977	1.2	0.1

Table III (continued)

1	2	3	4	5	6	7
Ełckie		56.0	202	Sept. 1950 Aug. 1951 July 1977	1.7* 0.4 1.6	 0 0
Lidzbarskie		25.2	222	Aug. 1963 July 1977	1.2 1.0	0.9 -
Juno Południowe		33.0	282	Sept. 1950 July 1977	2.2 1.0	0 0
Wobel		15.0	464	Aug. 1950 July 1977	0.7 0.6	0 0
Kołowin		7.2	53	Aug. 1962 Aug. 1959 July 1978	2.8 1.2 2.4	7.9-8.1 9.4
Mój		4.1	80	Aug. 1962 July 1978	0.75 0.9	7.7-7.9 7.6
Sędańskie		6.1	90	Sept. 1959 July 1978	0.75 1.3	8.1-12.1 7.5
Rańskie		7.8	92	Aug. 1952 July 1978	2.2 1.4	0 6.5
Warpuńskie	P	6.5	134	Aug. 1964 July 1978	0.8 0.8	8.9-9.1 6.9
Brajnickie		5.2	157	Aug. 1952 July 1978	0.4 0.6	0 12.4
Stryjewskie		6.2	160	Aug. 1963 July 1978	0.75 0.7	8.2 8.4
Hartowiec		5.2	176	Aug. 1963 Aug. 1959 July 1978	0.7 0.5 0.9	8.0-8.8 - 9.4
Długie		5.4	285	Sept. 1963 July 1978	0.75 0.5	- 7.9
Tuchel		5.1	357	Aug. 1963 July 1978	0.7 0.6	6.7-8.8 t
Kraksy Duże		4.0	504	Aug. 1962 July 1978	0.9 1.5	16.7-17.4 1.4

*Heavy water bloom.

total phosphorus concentration was 204 (80-504) and 168 (66-464) $mg \cdot l^{-1}$, respectively. Many years ago the visibility of Secchi disc was within this group much lower in polymictic lakes (on the average 0.8 m at the range 0.4-2.2 m) than in dimictic lakes (on the average 2.4 m at the range 0.4-3.8 m). As it is known

(K a j a k 1979, 1983), at higher total phosphorus concentration (from several tens up to about 100 $\mu g \cdot l^{-1}$) it is no longer a limiting factor. Therefore, lakes which in earlier investigations had a higher trophic state (mainly polymictic lakes) showed smaller decrease in visibility than lakes which then had a lower trophic state.

It has to be taken into consideration that sometimes the visibility of Secchi disc may be high (due to small seston amount) as a result of unfavourable conditions for phytoplankton growth - e.g., occurrence of toxic substances or the not fully explained mechanisms causing that the plankton is poor in "winter-kill" lakes (review of literature, K a j a k 1981) the latter occurring most probably in Lake Kraksy (Table III).

Chemical qualities of lakes examined (apart from the concentration of biogenic substances - Table I) are quite similar.

The organic matter content in bottom sediments in summer in dimictic lakes is between 20 and 48% (only in lake Gim 74%), and in polymictic lakes - between 21 and 57%.

ACKNOWLEDGMENTS: The authors wish to acknowledge (on their own behalf and of all authors of papers presented in this volume) Dr. R. J. Wiśniewski for cooperation in the choice of lakes for investigations, Dr. R. J. Wiśniewski and Dr. K. Dusoge for organizing supplementary parts of the expedition and material sampling from the lakes, A. Karabin, M.Sc., and S. Sumiński for participation in technical arrangements, measurements of visibility, temperature, O_2 concentration, and sampling of other materials, M. Matusiak, A. Bilski and A. Krasiński for providing transport and technical help during the expedition.

SUMMARY

The paper provides general information on complex studies conducted on 42 lakes (23 dimictic and 19 polymictic lakes) which are representative for the lakelands in north-eastern Poland. The studies were carried out by the Department of Hydrobiology, Institute of Ecology, Polish Academy of Sciences and the Inland Fisheries Institute in cooperation with the Institute of Geography and Department of Hydrobiology of the University of Warsaw.

Detailed data concerning various investigations and general conclusions are presented in other papers of this volume.

The main object was the characteristic of trophic state and the purity of lakes and a quantitative analysis of the main ecosystem components as a basis for determining: (1) characteristics and indices for lakes of various trophic state, (2) the functioning of lake ecosystems depending on trophic state, pollution, and degree of mixing, (3) the rate of trophic state changes by comparing with data from other periods. On the area examined sandy-loamy soils of an average permeability dominated. The area declivity was 4-30%. Mean precipitation was 550 mm, average outflow per unit of area was usually 5-6 $l \cdot sec^{-1} \cdot km^{-2}$. Areas without outflows covered usually 30-60% of the drainage basin. The surface area of the majority of lakes was 50-150 ha. Total phosphorus concentration in epilimnion in summer was 20-940 $\mu g \cdot l^{-1}$, the visibility of Secchi disc 0.3-6.9 m.

On the basis of the surface area of the drainage basin, the type of soil utilization, and the data on the amount and kind of sewage, the literature data on phosphorus export from land, the phosphorus load to lakes was estimated. Mean and maximal load for dimictic lakes was 1.1 and 8.8, respectively, and for polymictic lakes 2.6 and 16.1 $P_{tot} \cdot m^{-2} \cdot year^{-1}$ (Table I), thus exceeding considerably (from several up to a hundred times) the permissible load according to criteria of Vollenweider (1968).

Phosphorus load and also total phosphorus and nitrogen concentration in epilimnion in summer correlated positively with the density of river net in the drainage basin and with the ratio of surface area of the drainage basin to the surface area and volume of lake (Table II).

In 28 lakes examined 15-29 years ago the visibility decreased, mainly (in 11 out of 17, i.e., in 65%) in dimictic lakes. In some lakes the oxygen deficits in the hypolimnion were greater (Table III). The greater per cent of dimictic lakes, where changes were observed as compared with the state some years ago, was undoubtedly due to the fact that the trophic status of these lakes was and is lower on the average than that of polymictic lakes, and therefore these lakes are more sensitive to the increasing load and concentration of nutrients.

POLISH SUMMARY

Praca zawiera ogólne informacje o kompleksowych badaniach 42 jezior (23 dymiktycznych i 19 polimiktycznych) reprezentatywnych dla pojezierzy na północnym wschodzie Polski. Badania prowadził zespół Zakładu Hydrobiologii Instytutu Ekologii Polskiej Akademii Nauk i Instytutu Rybactwa Śródlądowego z udziałem Instytutu Geografii oraz Zakładu Hydrobiologii Uniwersytetu Warszawskiego. Dane szczegółowe z poszczególnych zakresów badań oraz podsumowanie całości są zawarte w następnych pracach niniejszego tomu.

Celem prac była charakterystyka stanu trofii i czystości jezior oraz ilościowa analiza głównych składników ekosystemu jako podstawa do: 1) określenia cech charakterystycznych i wskaźników dla jezior różnej trofii, 2) wnioskowania o funkcjonowaniu ekosystemów jezior, zależnie od trofii, zanieczyszczenia, stopnia miksji, 3) oceny tempa zmian trofii przez porównanie z danymi z innych okresów. Na badanym terenie dominowały gleby piaszczysto-gliniaste o średniej przepuszczalności. Spadek terenu kształtował się w granicach 4-30%. Średni opad wynosił 550 mm, średni spływ jednostkowy najczęściej 5-6 $l \cdot sek^{-1} \cdot km^{-2}$. Obszary bezodpływowe stanowiły najczęściej 30-60% powierzchni zlewni. Większość jezior miała powierzchnię 50-150 ha. Stężenie fosforu całkowitego w epilimnionie latem zawierało się w granicach 20-940 $\mu g \cdot l^{-1}$, widzialność krążka Secchi'ego 0,3-6,9 m.

Na podstawie wielkości zlewni, charakteru użytkowania ziemi oraz danych o ilości i rodzaju ścieków i przyjętych na podstawie piśmiennictwa danych o spływach obszarowych fosforu oszacowano ładunki fosforu do jezior i ich obciążenie fosforem ze zlewni bezpośredniej. Obciążenie średnie i maksymalne wynosiło odpowiednio dla jezior dymiktycznych 1,1 i 8,8, zaś dla polimiktycznych 2,6 i 16,1 g $P_{całk} \cdot m^{-2} \cdot rok^{-1}$ (tab. I), przekraczało więc znacznie (od kilku do ponad 100 razy) obciążenia dopuszczalne wg kryteriów V o l l e n w e i d e r a (1968).

Obciążenie fosforem a także stężenie fosforu i azotu całkowitego w epilimnionie latem korelowały pozytywnie z gęstością sieci rzecznej w zlewni oraz ze stosunkiem powierzchni zlewni do powierzchni i objętości jeziora (tab. II).

Dla 28 jezior badanych 15-28 lat temu stwierdzono spadek widzialności, głównie (w 11 na 17, a więc w 65%) w jeziorach dymiktycznych. W niektórych jeziorach stwierdzono także większe deficy-

ty tlenowe w hypolimnionie (tab. III). Większy procent jezior dymiktycznych, w których stwierdzono zmiany w stosunku do stanu sprzed wielu lat, wynika niewątpliwie z faktu, że stan trofii tych jezior był i jest jeszcze przeciętnie niższy niż jezior polimiktycznych i że wobec tego jeziora te bardziej reagują na wzrost ładunku i stężeń substancji biogennych.

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