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SPATIAL AND TIME CHANGES OF SOME ENVIRONMENTAL FACTORS IN THE PELAGIAL OF MIKOŁAJSKIE LAKE

(Ekol. Pol. 20: 541–560). The changes in time and differentiation within the pelagial of Mikołajskie Lake (Masurian Lakeland) of some environmental factors were measured. The following were analysed: visibility, temperature, oxygen, pH, iron, magnesium, calcium, phosphate, potassium, sodium, nitrogen, conductivity.

The aim of the paper was to observe the changes in environmental conditions in the pelagial of Mikołajskie Lake during the annual cycle and to examine the differentiation of these conditions within the lake. The studies were conducted in 1967 and partially in 1968 and 1969 (everyday measurements of the temperature of the surface water layer). Samples for analyses were taken in the deepest part of the lake in vertical 2 m distances from January 27 to November 29, 1967, every 2–4 weeks. Samples for the studies on the spatial differentiation were taken once (August 1, 1967) in few points along the longitudinal lake axis. Everyday temperature measurements were made at the depth of 1 m near the Hydrobiological Station of the Polish Academy of Sciences.

Mikołajskie Lake is the middle link of Mikołajskie Gully divided by narrownesses into 4 lakes: Ryńskie, Tałty, Mikołajskie and Bełdany.
It joins from the south-east by a short narrowness the lake Śniardwy, from the south-west the lake Bełdany, and from the north the lake Tałty. The outflow runs through lake Śniardwy to the river Pisa. Mikołajskie Lake is an elongated water body divided into the northern narrow and deep part and into the southern

one, which is shallower and wide. The lake surface is 460 ha, maximal length – 4945 m, maximal breadth – 1670 m, mean breadth – 907 m, maximal depth – 27.8 m, mean depth – 11.0 m, capacity – 50.57 mln m³ (Catalogue of Polish Lakes 1954, Szczepański 1958, Synowiec 1961). Mikołajskie Lake is a holomictic eutrophic water body of a typical thermal and oxygen stratification (Paschalski 1960).

The analyses were made according to the commonly assumed hydrochemical methods (Just and Hermanowicz 1955)[1].

CHANGES IN TIME

Visibility (Fig. 1). The visibility was measured by the Secchi disc. The greatest visibility values were observed in February (8 m), then a considerable decrease was observed (to 2.5 m after the lake thawing). In summer it does not change much and stays within the range from 1.5 to 2.0 m. In autumn it increases slightly which is undoubtedly due to the decreasing seston amount in water. Visibility measurements conducted by Szczepański (1968) in the years 1954–1956 showed greater values about 1 to 3 m in summer than values presented in this paper. This may be due to the greater eutrophication extent of this lake in the years 1954–1967.

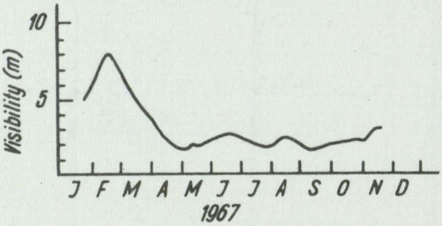

Fig. 1. Visibility (Secchi disc reading) in Mikołajskie Lake

Temperature (Tab. I, Fig. 2). Spring and autumn circulation leads to complete homothermy (Tab. I). The setting of the thermal stratification may be observed in the end of May. In summer the epilimnion is 6–8 m deep, whereas the metalimnion is contained within the layer from 6 to 12 m. The greatest difference in temperatures (10°C) between epilimnion and hypolimnion was observed in between July and August, later on the thermal gradient decreased slowly and gradually. The temperature of hypolimnion in summer does not fall below 10°C, but in winter, at reverse stratification, it slightly surpasses 2°C, and the temperature of top water layers is about 1°C in January and almost 3°C in February. In the latter an almost complete homothermy of lake water masses is then observed. Spring levelling of temperatures takes place at about 5°C, while the autumn one (November 16) at about 9°C.

The highest water temperatures at the depth of 1 m in the period from August 1967 to September 1969 (Fig. 2) were observed in June 1968 (26°C)

[1] Calcium, sodium and potassium were determined using the flame photometer (Zeiss model 3), conductivity with the conductoscope, and pH with the Ridan pH-meter.

Water temperature in various water layers in the deepest part of Mikołajskie Lake

Tab. I

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	1.0	2.5	5.8	8.1	14.2	16.4	17.6	19.5	21.4	21.5	19.8	19.3	18.4	15.8	13.8	11.2	9.5	5.0
1		2.7	5.8	8.1	14.0	16.4	17.2	19.5	21.4	21.5	19.8	19.3	18.4	15.8	13.8	11.2	9.3	5.0
2		2.6	5.5	8.0	14.0	16.3	17.2	19.5	21.5	21.4	19.8	19.2	18.4	15.8	13.8	11.2	9.3	5.0
4		2.6	5.4	8.0	13.9	16.2	16.8	19.5	21.2	21.4	19.8	19.2	18.4	15.8	13.8	11.2	9.3	5.0
6	1.0	2.6	5.2	8.0	13.8	15.7	16.7	18.6	20.3	21.0	19.6	19.1	18.4	15.8	13.8	11.2	9.3	5.0
8			5.1	8.0	13.4	13.2	16.6	17.2	16.8	15.7	19.4	17.6	18.4	15.7	13.8	11.2	9.3	5.0
10	1.2	2.8	5.1	7.9	11.5	10.4	14.3	13.7	12.7	12.5	19.0	12.0	12.0	15.6	13.8	11.2	9.3	5.0
12			5.0	7.8	10.6	9.6	11.1	11.6	11.0	11.3	11.4	11.0	10.7	15.0	13.8	11.2	9.3	5.0
14			5.0	7.8	9.4	9.4	10.0	10.9	10.5	10.7	10.8	10.7	10.7	11.4	13.8	11.2	9.3	5.0
16	1.8	2.8	4.9	8.1	9.0	9.2	9.6	10.1	10.3	10.6	10.7	10.6	10.7	10.7	11.8	11.0	9.3	5.0
18			4.8	8.1	8.8	9.4	9.6	10.1	10.2	10.6	10.6	10.6	10.7	10.5	10.8	10.8	9.3	5.0
20	2.0	2.8	4.8	7.7	8.6	9.4	9.4	9.9	10.2	10.6	10.5	10.6	10.7	10.5	10.8	10.8	9.3	5.0
22			4.8	7.6	8.7	9.4	9.4	9.7	10.0	10.7	10.5		10.7	10.5	10.7	10.6	9.1	5.0
24		2.4	4.8	7.7	8.5	9.0	9.4	9.9			10.5		10.6	10.5	10.6	10.5	9.1	5.0
25	2.3		4.8												10.6	10.4	9.1	4.8
26		2.5			8.6									10.4				

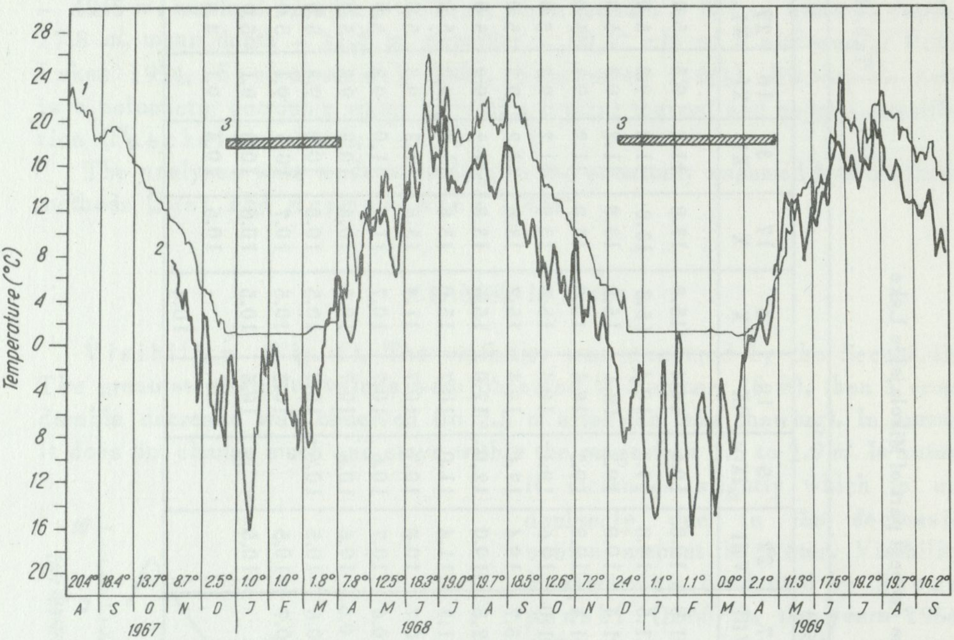

Fig. 2. Water temperature of Mikołajskie Lake at the depth 1 m and air temperature measured at 7 a.m.

1 – water temperature, *2* – air temperature, *3* – freezing period
The numbers at the bottom present the mean monthly water temperatures

and in June of the following year (23.6°C). The highest mean monthly temperatures were in August. In summer (June-August) the water temperatures stay within the range 11.1–26.0°C, and the smallest temperature fluctuations are observed in August (differences not greater than 5°C), and the highest in June (in 1968 these differences were 13.4°C, and in 1969 – 12.6°C). The water heating in spring is very uneven, violent temperature fluctuations of both water and air are observed. Cooling of water in autumn has a considerably more even character.

Oxygen (Tab. II–III). The oxygenation of pelagial waters shows a regular for a eutrophic lake pattern of changes both in time and as regarding the depth. All the time during the investigations the oxygen content is quite considerable in the surface water layers, but in winter and spring months it is greater than in summer, which is undoubtedly due to the changes in water temperature. A visible spring homooxygenation is still observed two months after the lake thawing at full water saturation with oxygen, whereas the spring one – at incomplete water saturation in the second half of October. In the first days

Oxygen content (mg/l O_2) in various water layers in the deepest part of Mikołajskie Lake

Tab. II

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	13.35	12.51	14.21	14.61	11.70	10.70	11.35	9.74	10.43	8.44	8.92	9.90	9.50	9.02	9.02	9.52	9.62	11.62
1		12.11	13.75	14.20	11.32	10.15	10.17	9.10	9.91	8.21	8.52	9.40	9.03	8.79	8.55	9.53	9.58	11.27
2		12.20	13.70	13.25	11.28	9.95	10.88	9.11	9.84	8.27	8.43	9.32	9.15	8.66	8.40	8.58	9.23	11.37
4		12.20	12.75	13.60	11.28	9.90	10.58	10.39	9.37	7.89	8.25	9.28	9.42	9.20	8.52	8.42	9.27	11.25
6	12.35	12.30	12.71	13.60	11.45	9.35	10.58	7.71	5.60	6.66	8.07	9.23	8.84	8.50	8.52	8.50	9.36	11.22
8			13.30	13.55	11.17	8.65	10.48	5.70	1.03	0.64	8.18	3.74	8.15	8.48	8.54	8.41	9.43	11.39
10	12.71	12.20	12.05	13.58	11.08	7.40	6.82	2.85	0.96	0.77	8.49	0.32	0.16	8.34	8.55	8.43	9.47	11.29
12			13.00	13.52	11.12	6.99	5.36	2.28	0.72	0.76	0.58	0.30	0.07	7.10	8.72	8.48	10.39	11.16
14			13.23	13.55	10.71	6.80	3.59	1.64	0.30	0.46	0.39	0.31	n.f.	0.15	9.09	8.88	10.01	11.48
16	9.75	9.69	13.04	14.03	10.53	6.77	3.84	0.31	0.45	0.43	0.32	0.30	0.07	n.f.	0.66	8.56	9.35	11.12
18			13.38	14.97	10.67	6.95	3.40	0.24	0.45	0.44	0.30	0.23	n.f.	n.f.	0.15	8.57	9.54	11.27
20	8.76	6.92	12.75	13.32	10.02	6.40	3.16	0.61	0.15	0.43	0.36	0.22	n.f.	n.f.	0.29	8.73	9.40	11.10
22			13.05	13.10	9.93	5.92	3.04	0.16	0.45	0.43	0.36		n.f.	n.f.	0.14	6.83	8.30	10.32
24		3.24	12.55	13.21	9.95	4.47	1.38	0.38			0.32		traces	n.f.	n.f.	1.52	8.90	11.19
25	4.79		10.93												0.16	n.f.	9.55	11.78
26		2.65			8.93									n.f.				

Oxygen saturation (%) in various water layers in the deepest part of Mikołajskie Lake

Tab. III

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	93.6	91.6	113.2	123.2	113.0	108.2	117.2	105.0	116.5	94.5	96.6	106.1	100.2	90.0	81.6	85.2	83.9	90.7
1		89.1	109.5	119.9	109.1	102.6	104.5	98.0	110.7	91.9	92.3	100.7	95.2	87.7	77.3	84.5	83.0	87.9
2		89.4	108.3	111.5	108.5	100.2	111.9	98.3	110.2	92.4	91.3	99.9	96.5	86.4	76.0	77.6	80.0	88.6
4		89.4	100.5	114.2	108.2	99.7	107.9	113.0	104.2	88.2	89.4	99.5	99.4	91.8	77.1	76.3	80.2	87.8
6	86.7	90.0	99.7	114.2	109.6	93.0	107.5	81.6	61.3	73.8	87.2	98.8	93.3	84.9	77.1	77.0	81.0	87.6
8			104.2	113.9	105.9	82.0	106.3	58.6	10.5	6.4	87.9	38.8	91.6	84.5	77.3	76.2	81.7	88.8
10	94.5	90.0	94.4	113.7	101.0	65.8	66.0	27.3	8.9	7.2	90.6	2.9	1.5	83.0	77.4	76.3	82.0	88.0
12			101.3	113.2	99.4	61.0	48.4	20.8	6.5	6.9	5.3	2.7	0.6	69.8	78.9	76.8	90.0	87.2
14			103.2	113.4	93.1	59.1	31.6	14.7	2.7	4.1	3.5	2.8	0.0	1.4	82.2	80.5	86.8	89.5
16	74.1	71.5	101.5	118.5	90.6	58.6	33.5	2.7	3.9	3.8	2.9	2.7	0.6	0.0	5.9	77.2	81.0	87.0
18			104.0	124.8	91.5	60.3	29.6	2.1	3.9	3.9	2.7	2.0	0.0	0.0	1.3	77.0	82.7	87.8
20	70.3	51.1	99.1	111.5	85.5	55.6	27.4	5.4	1.3	3.8	3.2	2.0	0.0	0.0	2.6	78.3	81.3	86.6
22			101.5	109.0	84.9	51.4	26.4	1.4	3.9	3.8	3.2		0.0	0.0	1.2	61.0	71.7	80.7
24		23.6	97.5	110.4	84.6	38.5	12.0	3.3			2.8		0.0	0.0	0.0	13.5	76.8	87.3
25	39.3		85.0												1.4	0.0	82.4	91.5
26		19.4			76.1									0.0				

of June the oxygen stratification is beginning to form. As shown by the changes in the oxygen content and saturation of water during the summer stagnation the homooxygenation of top water layers reaches the 6 m water layer, i.e. slightly smaller layer than the epilimnion range in this lake (Tab. I, Paschalski 1960). During the summer stagnation the hypolimnion is void of oxygen.

Iron total (Tab. IV). During the summer stagnation a visible enrichment of the deep layers is observed. This is probably due to the reduction in sediments, in oxygen-free conditions, of ferric ions into ferrous ions and their passage to the near bottom water layers.

Magnesium (Tab. V). It is found in the epilimnion all the year in considerable quantities. During the stagnation of waters higher concentration of this component is observed at the bottom, however, in comparison with the surface layers it is not too high.

Calcium (Tab. VI). The abundance of waters in calcium compounds shows a suprisingly small variability in the vertical section. During the summer stagnation, a very slight enrichment of ground layers in calcium is observed, most probably due to the biological decalcification of epilimnion waters, although in the latter a visible decrease of content is not observed. There are also no visible changes in the annual cycle. Studies of the calcium content conducted earlier in the annual cycle in the surface layer of deposits of Mikołajskie Lake (Rybak 1969) also did not display more distinct variations in the amounts of this element.

Phosphate (Tab. VII). Surface water layers are not abundant in this component. Its greater amounts are found during the summer stagnation (especially in its final stage) in deeper water layers. It probably reaches the water by being washed out of dead plankton. Lower phosphate concentration in all layers during the circulation of water masses of the lake is most probably due to the precipitation of phosphate in the form of hardly soluble ferric phosphate. But as the stagnation proceeds the phosphates in near bottom layers become soluble.

Potassium (Tab. VIII). It is found in slightly greater concentrations in deeper water layers in the final period of summer stagnation as compared with the surface layers. However, during the winter stagnation a very low concentration of this component is observed in the deep layers.

Sodium (Tab. IX). As the summer stagnation proceeds and afterwards during the autumn circulation sodium is found in small quantities but evenly distributed in particular water levels. During the winter and spring circulation greater amounts of this element are observed. This is especially visible in the surface layers at the beginning of stagnation.

Nitrogen (Tab. X–XII). Observed increase of ammonia concentration (Tab. X) in near bottom layers in the final period of summer stagnation at

Iron content (mg /l Fe$^{\cdot\cdot\cdot}$) in various water layers in the deepest part of Mikołajskie Lake

Tab. IV

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	0.57	0.05	0.07	0.05	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	0.04
1		0.03	0.06	0.05	n.f.	n.f.	n.f.	0.07	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
2		n.f.	traces	0.05	n.f.	n.f.	n.f.	0.06	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
4		traces	0.06	0.02	n.f.	n.f.	n.f.	0.06	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
6	0.03	0.02	0.06	n.f.	n.f.	n.f.	n.f.	0.08	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
8			0.05	n.f.	n.f.	n.f.	n.f.	0.05	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.	n.f.
10	0.05		0.06	n.f.	0.05	n.f.	n.f.	0.05	0.03	0.10	n.f.	0.12	0.11	n.f.	n.f.	n.f.	n.f.	0.04
12			0.07	n.f.	0.05	0.03	0.07	0.07	0.04	0.16	0.15	0.21	0.26	n.f.	n.f.	n.f.	n.f.	n.f.
14			0.06	0.04	0.09	0.03	0.11	0.07	0.15	0.22	0.22	0.24	0.24	0.18	n.f.	n.f.	n.f.	n.f.
16	0.06	0.05	0.06	0.03	0.12	0.03	0.16	0.10	0.14	0.26	0.21	0.24	0.27	0.31	0.08	n.f.	n.f.	0.04
18			0.06	0.05	0.08	0.03	0.17	0.08	0.11	0.28	0.26	0.28	0.27	0.32	0.26	n.f.	n.f.	n.f.
20	0.08	0.07	0.05	n.f.	0.10	0.05	0.17	0.07	0.14	0.36	0.28	0.27	0.28	0.38	0.33	n.f.	n.f.	n.f.
22			0.05	n.f.	0.10	0.10	0.21	0.10	0.19	0.27	0.28		0.27	0.38	0.38	0.03	n.f.	n.f.
24		0.09	0.04	n.f.	0.12	0.57	0.37	0.10			0.35		0.30	0.38	0.39	0.36	n.f.	n.f.
25	0.17		0.04												0.40	0.64	n.f.	n.f.
26		0.09			0.17									0.37				

Magnesium content (mg/l Mg••) in various water layers in the deepest part of Mikołajskie Lake

Tab. V

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	15.56	14.35	12.16	12.52	13.50	10.46	15.56	9.97	7.78	10.46	11.19	9.97	8.36	11.67	12.16	12.16	14.35	13.50
1		12.16	12.16	13.38	13.38	11.31	16.90	11.31	8.63	10.46	11.19	11.31	11.31	11.31	11.67	12.16	14.35	13.50
2		11.80	15.20	12.52	14.35	10.46	16.05	11.31	8.63	9.97	10.46	11.31	11.67	11.31	12.16	12.52	14.35	13.50
4		16.54	11.67	12.16	13.86	12.04	15.20	12.16	8.63	10.46	10.34	11.31	11.67	12.16	13.86	14.35	14.35	13.50
6	16.54	12.52	12.52	13.38	14.71	12.04	14.35	12.16	8.63	11.31	11.07	10.82	11.67	11.31	14.71	15.20	14.35	13.50
8			12.52	14.35	13.86	11.67	14.71	11.31	9.97	11.31	11.31	12.52	11.67	12.52	13.50	14.35	14.35	13.50
10	16.05	15.20	12.16	13.86	16.05	11.31	16.54	11.31	9.97	14.71	11.19	14.84	17.39	12.52	13.50	13.50	14.35	13.50
12			13.50	13.38	15.20	11.31	17.39	13.50	11.67	13.01	13.13	14.84	16.90	12.16	14.71	15.20	14.35	13.86
14				12.52	15.56	12.04	20.43	13.86	12.52	12.52	14.47	14.84	16.90	16.90	13.86	14.35	14.35	13.50
16	15.56	14.35	12.16	13.50	14.71	11.31	17.39	13.50	11.67	13.50	15.32	15.20	16.90	16.54	13.50	14.35	14.35	13.50
18			13.38	13.38	15.20	11.31	18.24	12.52	12.52	13.50	14.96	14.84	16.90	16.90	13.01	14.35	14.35	13.50
20	19.58	14.71	13.38	13.38	14.35	12.04	22.23	11.31	12.16	13.01	13.98	13.86	15.56	16.54	12.16	13.86	14.35	13.50
22			15.20	13.50	14.35	11.31	18.60	12.16	13.01	16.05	13.50		14.71	16.54	13.50	14.35	14.35	13.50
24		14.71	12.52	13.38	14.35		20.79	13.86			13.50		15.56	16.54	19.58	19.09	14.35	12.52
25	16.90		13.50												21.28	21.28	12.16	13.50
26		14.35			15.56									16.54				

Calcium content (mg/l CaO) in various water layers in the deepest part of Mikołajskie Lake

Tab. VI

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	51.7	53.2	61.9	63.0	59.5	65.8	56.0	63.0	62.3	56.0	56.3	56.7	60.2	57.4	58.1	58.1	54.6	56.7
1		47.6	62.2	63.7	58.5	65.8	53.2	61.6	62.3	56.0	56.3	56.0	56.0	57.7	57.4	57.7	54.6	56.7
2		59.5	63.0	64.7	57.4	65.8	56.7	62.3	62.3	57.4	56.0	56.0	57.4	57.7	57.8	57.4	54.6	56.7
4		51.8	63.0	63.7	58.1	65.8	58.8	62.3	62.3	56.0	56.1	56.0	57.4	57.7	58.1	57.4	54.6	56.7
6	51.8	60.9	63.0	64.4	57.6	66.5	59.1	61.6	63.7	56.0	56.0	56.7	57.4	57.7	57.8	57.4	54.6	56.7
8			63.0	63.0	58.1	65.1	60.2	62.3	67.2	65.1	56.0	57.0	57.4	57.4	59.5	57.4	54.6	56.7
10	51.4	55.3	62.2	62.6	57.0	66.5	56.3	64.4	68.6	60.2	56.1	62.3	56.0	57.4	57.4	57.4	55.3	57.4
12			61.2	63.0	57.0	66.5	56.0	63.5	67.2	64.4	61.6	61.9	57.4	58.1	58.1	57.4	55.3	57.4
14				63.0	57.6	65.8	55.3	62.3	67.2	65.1	60.7	62.0	57.4	59.5	58.1	57.4	55.3	57.4
16	52.5	56.7	62.2	62.6	57.6	67.2	56.0	63.0	67.2	62.4	60.7	60.9	57.4	59.5	59.5	56.7	55.3	57.4
18			61.6	63.7	57.6	67.8	55.6	63.0	65.8	62.4	61.6	61.6	57.4	59.5	60.2	57.4	54.9	57.4
20	53.2	56.0	62.2	63.7	57.4	66.5	59.5	65.8	65.8	62.4	61.8	61.6	60.2	59.5	59.8	56.0	54.9	57.5
22			61.2	63.0	56.6	66.5	54.6	65.8	64.4	63.0	63.0		60.2	59.5	59.5	56.7	54.9	57.5
24		60.2	60.9	64.0	56.6		54.3	60.9			63.0		60.2	59.5	59.5	60.2	55.3	58.8
25	53.5		60.9												59.5	58.8	61.6	58.8
26		60.2			56.3									59.5				

Phosphate content (mg/l PO_4''') in various water layers in the deepest part of Mikołajskie Lake

Tab. VII

Depth m	Date (1967) 27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	0.265	0.101	0.250	0.372	0.067	n.f.	0.064	0.295	0.075	0.162	0.048	0.077	0.109	0.098	0.130	0.190	0.320	0.160
1		0.151	0.237	0.081	0.067	n.f.	0.058	0.175	0.100	0.156	0.045	0.084	0.135	0.098	0.114	0.280	0.327	0.245
2		0.175	0.243	0.073	0.062	n.f.	0.058	0.185	0.087	0.220	0.077	0.039	0.109	0.130	0.114	0.240	0.272	0.260
4		0.235	0.245	0.081	0.067	n.f.	0.063	0.215	0.105	0.232	0.090	0.035	0.060	0.098	0.110	0.255	0.310	0.260
6	0.325	0.240	0.260	0.081	0.073	n.f.	0.048	0.250	0.090	0.161	0.110	0.059	0.060	0.114	0.114	0.255	0.290	0.185
8			0.237	0.059	0.090	n.f.	0.074	0.295	0.137	0.365	0.094	0.094	0.117	0.114	0.101	0.255	0.290	0.255
10	0.255	0.165	0.265	0.060	0.059	n.f.	0.160	0.380	0.225	0.550	0.094	0.465	0.700	0.136	0.122	0.250	0.272	0.250
12			0.255	0.060	0.084	n.f.	0.415	0.520	0.420	0.900	0.566	0.690	1.010	0.156	0.141	0.310	0.290	0.175
14			0.245	0.060	0.081	n.f.	0.560	0.620	0.465	0.955	0.760	0.720	0.975	1.010	0.131	0.290	0.300	0.180
16	0.235	0.215	0.277	0.060	0.087	n.f.	0.480	0.630	0.540	0.910	0.805	0.760	1.125	1.475	0.939	0.320	0.290	0.175
18			0.265	0.060	0.087	n.f.	0.795	0.750	0.540	0.910	0.860	0.760	1.175	1.560	1.240	0.290	0.290	0.200
20	0.265	0.190	0.265	0.060	0.089	n.f.	0.760	0.685	0.625	1.225	1.075	0.850	1.010	1.675	1.380	0.290	0.237	0.240
22			0.280	0.060	0.089	n.f.	0.660	0.880	0.660	0.895	1.110		1.375	1.700	1.700	0.435	0.265	0.225
24		0.320	0.265	0.060	0.085	traces	0.585	0.885			1.250		1.250	1.800	1.690	2.800	0.310	0.210
25	0.382		0.270												1.570	4.450	0.310	0.245
26		0.280			0.200									2.000				

Potassium content (mg/l K˙) in various water layers in the deepest part of Mikołajskie Lake

Tab. VIII

Depth m	Date (1967) 27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	3.18	2.55	4.10	2.57	2.35	2.55	3.10	2.50	2.45	2.60	2.40	2.30	2.35	2.15	2.45	2.45	2.40	2.45
1		2.27	3.22	2.57	2.38	2.55	2.20	2.47	2.50	2.60	2.43	2.30	2.25	2.25	2.25	2.45	2.40	2.45
2		2.55	2.65	2.52	2.30	2.55	2.10	2.50	2.60	2.60	2.32	2.28	2.25	2.15	2.30	2.45	2.40	2.45
4		2.55	2.75	2.57	2.30	2.55	2.45	2.45	2.45	2.65	2.32	2.50	2.20	2.15	2.45	2.45	2.40	2.45
6	3.05	2.55	2.75	2.52	2.30	2.55	2.50	2.50	2.40	2.55	2.32	2.35	2.20	2.15	2.25	2.45	2.40	2.45
8			2.75	2.52	2.30	2.62	2.80	2.53	2.70	2.65	2.43	2.70	2.15	2.15	2.45	2.45	2.40	2.45
10	2.90	2.50	2.57	2.52	2.38	2.55	2.25	2.45	2.55	2.60	2.54	2.65	2.40	2.15	2.45	2.45	2.40	2.45
12			2.65	2.57	2.50	2.55	2.15	2.45	2.50	2.55	2.43	2.50	2.40	2.25	2.45	2.45	2.40	2.45
14				2.52	2.50	2.55	2.10	2.45	2.50	2.55	2.51	2.62	2.50	2.45	2.30	2.45	2.40	2.45
16	2.20	2.05	2.60	2.45	2.50	2.55	2.15	2.47	2.50	2.55	2.54	2.65	2.50	2.45	2.60	2.20	2.45	2.45
18			2.65	2.52	2.50	2.55	2.10	2.32	2.45	2.55	2.54	2.65	2.50	2.45	2.60	2.35	2.40	2.45
20	2.10	2.05	2.70	2.57	2.45	2.55	2.25	2.63	2.45	2.55	2.54	2.50	2.50	2.45	2.60	2.35	2.40	2.45
22			2.70	2.62	2.50	2.57	2.10	2.63	2.45	2.55	2.54		2.50	2.45	2.60	2.35	2.50	2.45
24		2.07	2.70	2.57	2.50	2.87	2.10	2.45			2.54		2.50	2.45	2.60	2.80	2.50	2.45
25	2.20		2.70												2.60	2.80	2.55	2.50
26		2.07			2.50									2.45				

Sodium content (mg/l Na') in various water layers in the deepest part of Mikołajskie Lake

Tab. IX

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	7.70	7.42	6.87	6.32	6.10	6.49	9.02	7.32	7.20	7.15	6.92	6.63	6.50	6.43	6.95	6.82	7.08	6.56
1		6.76	6.87	6.46	5.94	6.49	6.82	7.32	7.02	7.15	6.76	6.63	6.63	6.43	6.95	6.82	7.08	6.56
2		7.59	6.73	6.32	5.94	6.49	6.71	7.32	6.78	7.15	6.76	6.63	6.63	6.43	6.43	6.82	7.08	6.56
4		8.10	6.87	6.46	5.94	6.49	8.47	7.32	6.78	7.15	7.05	8.19	6.56	6.43	6.56	6.82	7.08	6.56
6	8.41	7.59	6.87	6.32	6.40	6.60	10.12	7.32	6.78	7.15	6.76	6.89	6.63	6.43	6.43	6.82	7.08	6.56
8			6.87	6.46	6.10	6.60	9.13	7.32	7.20	7.15	6.92	7.02	6.50	6.56	6.95	6.82	7.08	6.56
10	8.00	7.92	6.60	6.32	6.60	6.38	6.82	7.80	7.20	7.15	6.92	6.89	6.50	6.56	6.43	6.82	7.08	6.56
12			6.60	6.46	6.60	6.38	7.01	7.08	6.78	7.15	6.92	6.63	6.50	6.56	6.43	6.82	7.08	6.56
14				6.60	6.60	6.49	6.60	7.08	6.90	7.15	6.92	7.15	6.63	6.56	6.43	6.82	7.08	6.56
16	6.29	6.40	6.87	6.32	7.01	6.38	6.16	7.08	6.78	7.28	6.76	6.89	6.63	6.56	6.95	6.50	7.15	6.56
18			6.87	6.32	7.01	6.38	6.49	7.08	6.78	7.28	6.92	7.02	6.50	6.56	6.95	6.50	7.15	6.56
20	6.29	6.76	6.87	6.60	7.01	6.49	7.37	9.60	6.78	7.28	6.92	6.89	6.50	6.56	7.15	6.50	7.15	6.56
22			6.87	6.60	7.01	6.49	6.27	9.60	6.66	7.28	6.92		6.63	6.56	6.76	6.50	7.15	6.56
24		6.76	6.87	6.60	7.31	6.93	6.16	6.84			6.92		6.50	6.76	6.76	7.02	7.21	6.56
25	6.95		6.87												6.56	7.02	7.28	6.89
26		6.76			7.01									6.76				

Ammonia content (mg/l N_{NH_4}) in various water layers in the deepest part of Mikołajskie Lake

Tab. X

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	0.04	0.04	0.02	0.02	0.02	0.04	0.04	0.04	0.06	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.08	0.08
1		0.05	0.02	0.04	n.f.	0.04	0.04	0.04	0.06	0.06	0.04	0.04	0.04	0.04	0.08	0.06	0.06	0.06
2		0.04	0.04	0.04	0.02	0.04	0.06	0.04	0.06	0.06	0.04	0.04	0.04	0.04	0.08	0.06	0.06	0.08
4		0.04	0.04	0.04	0.02	0.04	0.06	0.04	0.08	0.06	0.04	0.04	0.06	0.04	0.06	0.06	0.06	0.06
6	0.06	0.05	0.04	0.04	0.02	0.04	0.06	0.04	0.08	0.04	0.04	0.04	0.06	0.04	0.08	0.06	0.06	0.06
8			0.04	0.04	0.02	0.04	0.06	0.04	0.06	0.06	0.04	0.04	0.06	0.04	0.08	0.06	0.06	0.06
10	0.06	0.05	0.04	0.04	0.10	0.06	0.06	0.03	0.06	0.08	0.04	0.20	0.34	0.04	0.06	0.06	0.08	0.06
12			0.04	0.04	0.02	0.10	0.06	0.03	0.08	0.12	0.18	0.40	0.60	0.04	0.08	0.06	0.08	0.06
14			0.04	0.04	0.02	0.10	0.12	0.03	0.08	0.12	0.18	0.40	0.60	0.60	0.08	0.06	0.06	0.06
16	0.04	0.04	0.04	0.04	0.02	0.12	0.16	0.03	0.10	0.20	0.18	0.40	0.50	0.60	0.34	0.06	0.06	0.06
18			0.04	0.04	0.04	0.14	0.24	0.04	0.16	0.24	0.18	0.40	0.50	0.60	0.44	0.06	0.06	0.06
20	0.04	0.06	0.04	0.04	0.04	0.14	0.24	0.05	0.10	0.24	0.18	0.40	0.50	0.80	0.34	0.06	0.06	0.05
22			0.04	0.04	0.04	0.18	0.24	0.08	0.12	0.20	0.18		0.48	0.80	0.40	0.06	0.06	0.05
24		0.08	0.04	0.04	0.08	0.22	0.24	0.12			0.20		0.58	0.80	0.44	0.96	0.06	0.06
25	0.14		0.04												0.44	0.96	0.06	0.06
26		0.10			0.06									1.00				

Nitrate content (mg/l N_{NO_3}) in various water layers in the deepest part of Mikołajskie Lake

Tab. XI

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	0.12	0.12	0.09	0.02	0.02	n.f.	0.01	n.f.	0.01	0.01	n.f.	n.f.	n.f.	0.01	0.01	0.02	0.02	0.03
1		0.11	0.09	0.02	0.02	0.01	0.01	0.01	0.01	0.01	n.f.	0.01	n.f.	0.01	0.01	0.02	0.02	0.03
2		0.11	0.10	0.02	0.02	n.f.	0.01	n.f.	0.01	0.01	n.f.	0.01	n.f.	0.01	0.01	0.02	0.02	0.03
4		0.10	0.09	0.02	0.02	n.f.	0.01	n.f.	0.01	0.01	n.f.	0.01	n.f.	0.01	0.02	0.02	0.02	0.03
6	0.10	0.10	0.10	0.02	0.02	n.f.	0.01	0.01	0.01	0.01	n.f.	0.01	n.f.	0.01	0.02	0.04	0.02	0.03
8			0.10	0.01	0.02	0.01	0.01	n.f.	0.01	0.01	n.f.	0.01	n.f.	0.01	0.01	0.04	0.02	0.03
10	0.10	0.10	0.10	n.f.	0.02	0.02	0.03	0.03	0.03	0.02	n.f.	0.01	0.01	0.01	0.01	0.02	0.02	0.03
12			0.09	n.f.	0.02	0.02	0.06	0.08	0.03	0.02	n.f.	0.01	0.01	0.02	0.01	0.02	0.02	0.03
14			0.10	0.01	0.03	0.02	0.07	0.08	0.03	0.02	n.f.	0.01	0.01	0.01	0.01	0.02	0.02	0.03
16	0.10	0.12	0.10	0.02	0.03	0.02	0.06	0.08	0.03	0.02	n.f.	0.01	0.01	0.01	0.02	0.02	0.02	0.03
18			0.10	0.02	0.03	0.02	0.07	0.08	0.03	0.04	n.f.	0.01	0.01	0.02	0.03	0.02	0.02	0.03
20	0.10	0.12	0.10	0.02	0.02	0.02	0.07	0.06	0.03	0.04	n.f.	0.01	0.01	0.01	0.03	0.02	0.02	0.02
22			0.09	0.04	0.02	0.01	0.07	0.08	0.03	0.03	0.01		0.01	0.02	0.03	0.02	0.02	0.03
24		0.12	0.10	0.04	0.02	0.01	0.07	0.08			n.f.		0.01	0.02	0.03	0.04	0.02	0.02
25	0.10		0.09												0.03	0.02	0.02	0.02
26		0.12			0.02									0.02				

Nitrite content (mg/l N_{NO_2}) in various water layers in the deepest part of Mikołajskie Lake

Tab. XII

Depth m	Date (1967)																	
	27 I	23 II	11 IV	6 V	20 V	6 VI	19 VI	5 VII	24 VII	7 VIII	22 VIII	5 IX	19 IX	4 X	17 X	3 XI	16 XI	29 XI
0	0.002	0.002	0.001	0.002	0.003	0.003	0.002	0.002	0.002	0.001	0.001	n.f.	n.f.	n.f.	0.003	0.003	0.009	0.010
1		0.004	0.001	0.002	0.003	0.003	0.002	0.002	0.002	0.001	0.001	n.f.	0.001	n.f.	0.003	0.003	0.010	0.010
2		0.002	0.001	0.002	0.002	0.003	0.002	0.002	0.002	0.001	0.001	n.f.	0.001	n.f.	0.003	0.003	0.009	0.010
4		0.002	0.002	0.002	0.002	0.003	0.002	0.003	0.002	0.002	0.001	n.f.	0.001	n.f.	0.003	0.003	0.010	0.012
6	0.002	0.002	0.002	0.002	0.002	0.004	0.002	0.003	0.002	0.002	0.001	n.f.	0.001	n.f.	0.003	0.003	0.009	0.012
8			0.002	0.002	0.002	0.005	0.003	0.004	0.003	0.009	0.001	n.f.	0.001	n.f.	0.003	0.003	0.010	0.015
10	0.002	0.003	0.002	0.002	0.002	0.008	0.009	0.004	0.037	0.100	0.001	n.f.	0.001	n.f.	0.003	0.003	0.010	0.017
12			0.002	0.003	0.005	0.008	0.010	0.004	0.040	0.100	0.040	n.f.	0.001	n.f.	0.003	0.003	0.009	0.008
14			0.002	0.003	0.005	0.008	0.008	0.005	0.035	0.100	0.040	n.f.	0.001	n.f.	0.003	0.003	0.010	0.008
16	0.002	0.002	0.002	0.003	0.006	0.010	0.008	0.010	0.028	0.100	0.040	n.f.	0.001	n.f.	0.002	0.003	0.010	0.010
18			0.002	0.003	0.006	0.008	0.008	0.005	0.018	0.100	0.040	n.f.	0.001	n.f.	0.002	0.003	0.009	0.010
20	0.002	0.002	0.002	0.003	0.006	0.008	0.008	0.008	0.018	0.076	0.040	n.f.	0.001	n.f.	0.002	0.003	0.009	0.010
22			0.002	0.004	0.006	0.009	0.008	0.010	0.020	0.100	0.030		0.001	n.f.	0.002	0.003	0.009	0.012
24		0.008	0.002	0.003	0.006	0.010	0.012	0.010			0.030		0.001	n.f.	0.002	0.002	0.008	0.010
25	0.003		0.002												0.002	0.002	0.008	0.012
26		0.008			0.007									0.002				

simultaneous decrease in these layers of nitrate amounts (Tab. XI) proves about the intensification of ammonification and decomposition processes in the deep lake zones in that time. During the autumn circulation as the lake water masses become oxygenated the amount of ammonia strongly decreases (Tab. X), but the nitrite (Tab. XII) and nitrate (Tab. XI) concentrations increase. The violent increase of nitrite in the hypolimnion in July and August is typical. Earlier (at the beginning of summer stagnation) the nitrate concentration increases in deeper zones, but decreases in surface layers during the vegetation season, probably being used up by phytoplankton.

SPATIAL DIFFERENTIATION

Studies of spatial differentiation of some environmental elements were conducted once during the summer stagnation. The analysis was made on 7 stations of Mikołajskie Lake along the longitudinal lake axis. Water temperature, O_2, PO_4''' content, conductivity and pH (Tab. XIII) were measured in the vertical

Spatial changes of some environmental factors in the pelagial of Mikołajskie Lake (August 1, 1967)

Tab. XIII

Depth m	Number of measurement points	Range (from-to)				
		pH	Oxygen (mg O_2/l)	Phosphate (mg/l PO_4''')	Conductivity ($K_{18}\cdot 10^6$)	Temperature (°C)
0	7	8.4–8.6	10.7–12.2	0.140–0.280	220–256	21.8–22.8
2	7	8.5–8.7	9.8–12.3	0.084–0.256	220–256	21.3–22.6
4	7	8.0–8.7	6.8–12.2	0.112–0.300	218–256	20.2–22.6
6	6	7.8–8.3	3.9–6.5	0.108–0.384	230–245	18.4–19.7
8	6	7.5–7.8	0.3–3.5	0.115–0.456	245–258	15.7–18.2
10	6	7.5–7.6	0.2–1.2	0.332–0.592	245–270	12.0–13.4
12	3	7.4–7.5	0.2–0.8	0.430–0.700	260–270	11.2–11.8
14	3	7.4–7.5	0.2–0.4	0.540–0.885	260–270	10.5–10.8
16	1	7.5	0.2	0.625	260	10.7
18	1	7.4	0.1	0.724	260	10.5
20	1	7.4	n.f.	0.808	260	10.4

section. The differentiation of the analysed factors is not great on particular stations. This concerns especially temperature, oxygen and pH. Slightly different from this pattern are the stations close to the confluences of Mikołajskie Lake with lakes Śniardwy and Bełdany, where slightly higher values of these indices may be observed. The other components show greater differentiation.

At total increase of PO_4 content together with the depth some differentiation is observed in particular points of the lake. Changes in conductivity (increasing together with the depth on all stations) in the epilimnion of the lake form a regular sequence – decrease of values is observed on successive stations in the direction of the confluences with lakes Śniardwy and Bełdany.

CONCLUSIONS

The pattern of spatial differentiation, the course of changes in time as well as the values of particular indices are typical for eutrophic type of lakes of central and northern Poland (Olszewski 1951, 1953, Olszewski and Paschalski 1959, Patalas 1960a, 1960b, Paschalski 1962, 1965, Januszkiewicz 1964). The magnesium content considerably differs from this typical pattern. As compared with the content of this component in waters of other lakes the several times greater concentration of this component is striking. This concerns especially the near bottom water layers during stagnation, when considerable accumulation of this component was observed, which is typical for strongly stratified lakes (Januszkiewicz 1964).

The strikingly small differences in the calcium amount on particular pelagial depths of the examined lake might prove about the insignificant biological process of water decalcification so characteristic for many lakes (Thomas 1956, Stangenberg et al. 1957, Januszkiewicz 1964, Ruttner 1965).

The examined lake does not display a visible spatial differentiation (in various points of the lake) from the point of the examined environmental elements of water. The conditions at the confluence with lakes Śniardwy and Bełdany are only slightly different. This is probably due, on one hand, to the influence of water masses of lake Śniardwy (vast and shallow, strongly mixed), and on the other hand, to the considerable narrowness in these places and therefore greater influence of the basin on conditions existing in the water.

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ZMIANY PRZESTRZENNE I CZASOWE NIEKTÓRYCH CZYNNIKÓW ŚRODOWISKOWYCH W PELAGIALU JEZIORA MIKOŁAJSKIEGO

Streszczenie

Przeprowadzono badania zmian warunków środowiskowych w pelagialu Jeziora Mikołajskiego w cyklu rocznym i zróżnicowania tych warunków w obrębie jeziora. Badania przeprowadzono w 1967 r. i częściowo w latach 1968 i 1969 (codzienne pomiary temperatury powierzchniowej warstwy wody).

Analizowano: widzialność (fig. 1), temperaturę wody (tab. I, fig. 2), tlen (tab. II–III), żelazo ogólne (tab. IV), magnez (tab. V), wapń (tab. VI), fosforany (tab. VII), potas (tab. VIII), sód (tab. IX), azot (tab. X–XII) – w cyklu rocznym oraz temperaturę,

tlen, fosforany, przewodnictwo elektrolityczne i pH (tab. XIII) – zróżnicowanie przestrzenne.

Stwierdzono, że wartości większości wskaźników są typowe dla jezior eutroficznych środkowej i północnej Polski. Nie stwierdzono wyraźnego zróżnicowania przestrzennego (w różnych punktach jeziora), za wyjątkiem połączeń z jeziorami Śniardwy i Bełdany.

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