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The occurrence of yeasts in some of the Masurian Lakes

STANISŁAW NIEWOLAK

Institute of Hydrobiology and Water Conservation, Academy of Agriculture and Technology, Olsztyn-Kortowo, Poland

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The results are reported of investigations on the abundance of yeasts in the Kortowskie and Iławskie lakes. The amount and qualitative composition of yeasts was studied in the lakes of the Węgorzewo district. The yeasts were least numerous (up to 82 cells per 1 ml water) in the lakes with relatively unpolluted water and most abundant in bottom deposits with a silty substrate (up to 6200 cells per 1 g dry weight). Net plankton contained up to 15 000 cells in 1 g of fresh weight.

Among the microorganisms living in larger water bodies yeasts are also found. In the water the number of cells is usually small (Salimovska-Rodina, 1940; Rodina, 1950; Hedrick et al., 1964, 1968). They are more numerous in the littoral zone of lakes (Rodina, 1950) where they utilize the excretions of aquatic plants and together with the bacteria of this zone serve as food for the here profusely developing zooplankton and also in the bottom deposits (Rodina 1950; Hedrick and Soygenc, 1965; 1967; Hedrick et al., 1966). Large quantities of yeasts are present in waste waters (Cooke, 1965; Cooke et al., 1960). This prompted some authors (Van Uden, and Ahearn, 1963; Ahearn et al., 1968, 1969, Mayers et al., 1970; Spencer et al., 1970; Simard and Blackwood, 1971 a, b) to search for a relation between their quantity in the water and their qualitative composition and the degree of pollution of the water bodies. The present study was undertaken to investigate the distribution and seasonal changes in the amount of yeasts in several lakes of the Masurian Lakeland, differing in the degree of pollution and to establish the qualitative composition of these microorganisms in the water of the Węgorzewskie lakes.

MATERIAL AND METHODS

Lakes investigated

The studies were undertaken in the period 1966-1971 on the lakes: Kortowskie near Olsztyn, Jeziorak Mały and Jeziorak near Iława and on the Węgorzewo district lakes — Czarna Kuta, Dgał Mały, Piecek and Smolak (Table 1).

The Kortowskie lake near Olsztyn is connected on its northern side by a canal with the large lake Ukiel. On its southern side a stream carries the excess of the lake water to the river Łyna. The bottom is silty.

Jeziorak Mały is a waste reservoir. The northern edge of the lake is overgrown with shrubs and the eastern shore is partly utilized as a landing place for inland navigation. Close to it a canal flows into the lake carrying dairy waste water. The southern side is bordered by a meadow and the western is closed by the grounds of a sawmill from which residues are found on the lake bottom over a wide area. Along the littoral the botom is sandy and in the deeper parts silty. The lake joins the larger Jeziorak by a short and shallow cannal (fig. 1).

Jeziorak is a young trough lake (Lencewicz, Kondracki, 1960). The town Iława has no major influence on the general lake pollution, only in its southern part is a higher degree of eutrophization observed. A canal system connects the lake with Drwęckie lake the river Drwęca and the Elbląg canal. The western border is overgrown with mixed forest, on the eastern side the lake is surrounded by crop fields and partly by coniferous and mixed forest. The bottom along the littoral is sandy and in deeper parts silty. The bottom deposits are of sapropel and "dy" type.

The lake Czarna Kuta lies in terrain of moraine character in a valley surrounded by forests. It is a eutrophic water body of pond type. Its only feeders are a small stream on the eastern side and on the southern a ditch draining the neighbouring meadows and peat bogs. A small stream flows out of it to lake Głęboka Kuta. The bottom sediments are brown of gyttja type (fig. 2).

Dgał Mały lies on moraine terrain in a valley surrounded in three fourths by coniferous and mixed forest, with a hypolimnion classified as cold. Water is supplied from the lake Dgał Wielki by a separate canal. Its outflow joins the lake Dargin. The bottom sediments are black of sapropel type.

Lake Piecek is situated within a bottom and frontal moraine on the north-eastern side. The shores are high but not steep. The outflow on the southern side consists of a small canal with a rapid drop. The lake is surrounded by coniferous and mixed forest as well as crop fields. The bottom sediments are dark brown of "dy" type.

Table 1

Characteristic of the investigated lakes of the Masurian Lakeland in the 1966-1971

Lake	Location	Area (ha)	Depth (m)		Lake type	Pollution		Number of investigated sites
			average	maximum		degree	type	
Kortowskie	Olsztyn	89,7	5,9	17,2	eutrophic	insignificant	storm water, sewage effluent	3
Jeziorak Mały	Iława	26	5,0	6,4	waste water	strong	storm water, sewage effluent, dairy, saw-mill	1
Jeziorak	N of Iława	3230	5,0	11,1	eutrophic	insignificant	sewage effluent	4
Czarna Kuta	SE of Węgorzewo	25,5	2,2	4,5	eutrophic	insignificant	sewage effluent	1 in deep part of lake
Dgał Mały	SE of Węgorzewo	14,2	5,0	16,8	eutrophic	no pollution	—	1 in deep part of lake
Piecek	SE of Węgorzewo	23,6	2,3	8,4	dystrophic	no pollution	—	1 in deep part of lake
Smolak	SE of Węgorzewo	7,0	1,7	5,1	dystrophic	no pollution	—	1 in deep part of lake

Smolak lies in a sandr area among coniferous forests. It is an endorrheic water body with mildly sloping shores. The bottom is overgrown with filamentous algae. The bottom sediments are brown of tyrfopel type.

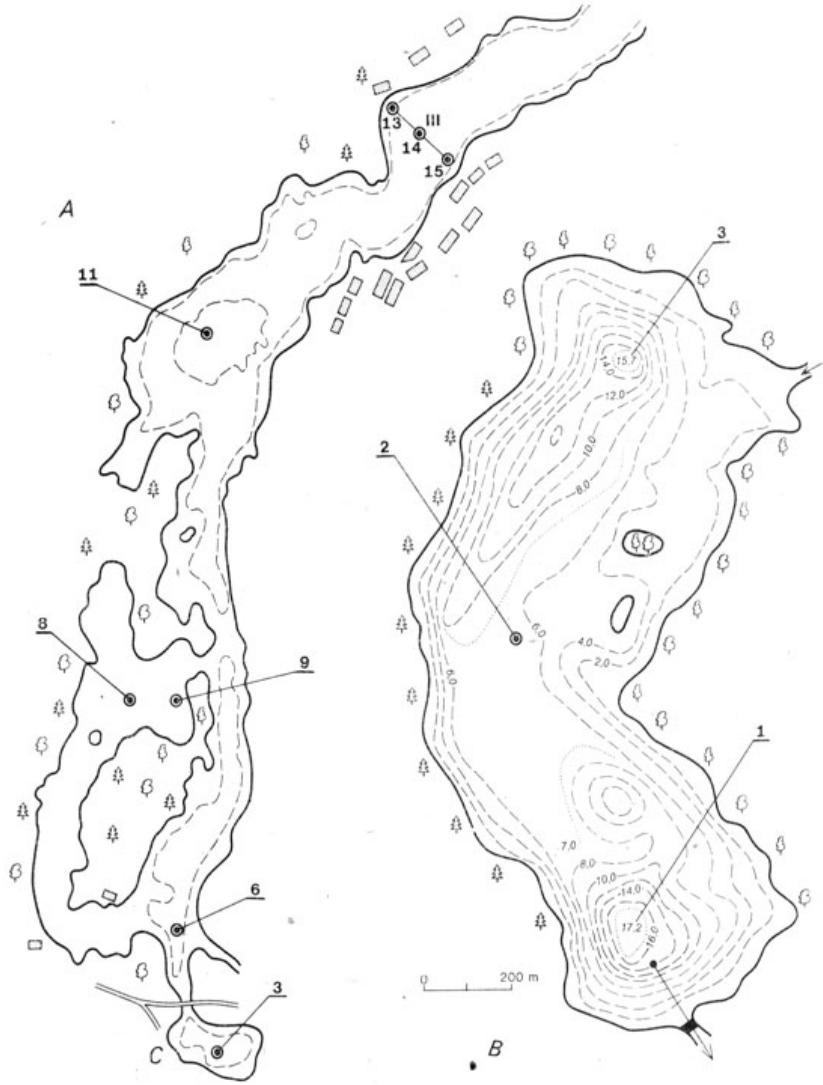

Fig. 1. Location sketch of the investigated Masurian lakes

A — Lake Jeziorak, *B* — Lake Kortowskie, *C* — Lake Jeziorak Mały; *1-15* — sampling sites

Sampling

In the Kortowskie and Węgorzewo lakes the occurrence of yeasts was only studied in the water, while in the Iława lakes water, bottom sediments and net plankton were examined. Water samples from various depths (usually at 1-m intervals) were taken with a sterilized Isachenko apparatus (R o d i n a, 1963). Bottom sediment samples to a depth of 5 cm were collected by Ekman's device. Net plankton was obtained by filtering 10 l. of water through a plankton sampler No. 25.

Microbiological investigations

The number of yeast cells was counted on Petri dishes on malt-agar after 5 days of incubation of 1 ml of water or a corresponding dilution of bottom sediment at 25°C. Determinations were replicated 3 times and the results were converted to 1 ml of water, 1 g dry weight of sediment or 1 g of fresh weight of algae. In July and November, 1970 and in February and April, 1971, from water of the Węgorzewo lakes plated on malt-agar all the appearing colonies were transferred to agar slants and when pure cultures were obtained the yeasts were identified (L o d d e r, K r e g e r van R i j, 1952).

RESULTS

Kortowskie lake (Table 2). In lake water yeasts were found mostly in the amount of several to a dozen or so cells/1 ml. They were somewhat more numerous at sampling site 3, in the region of inflowing sewage water from the city of Olsztyn.

Iławskie lakes. Yeasts were most abundant in Jeziorak Mały up to 2310 cells/1 ml at site 3 (Table 3). In the water of Jeziorak they were more numerous only at site 6, around the Iława municipal bathing facilities their number reached 565 cells/1 ml. Their number diminished at sites 8, 9 and 11 with growing distance from the town. Bottom deposits of Jeziorak Mały contained up to 6200 cells per 1 g of dry weight (Table 4 A). In Jeziorak yeasts were more numerous only on silty and sapropel sites (Nos. 6, 8 and 11). They were scarcest on sandy substrate (site 9). In net plankton represented by *Cyanophyceae* of the genus *Anabaena*, *Aphanizomenon* and *Microcystis* (private communication) the number of yeasts reached up to 15 000 cells per 1 g of fresh weight (Table 4 B).

Węgorzewo district lakes (Table 5). In the water of lake Czarna Kuta which showed a somewhat higher degree of pollution the number of yeasts did not exceed 82 cells/1 ml water. They were still less numerous in the lakes with unpolluted water Dgał Mały (up to 65 cells/1 ml water),

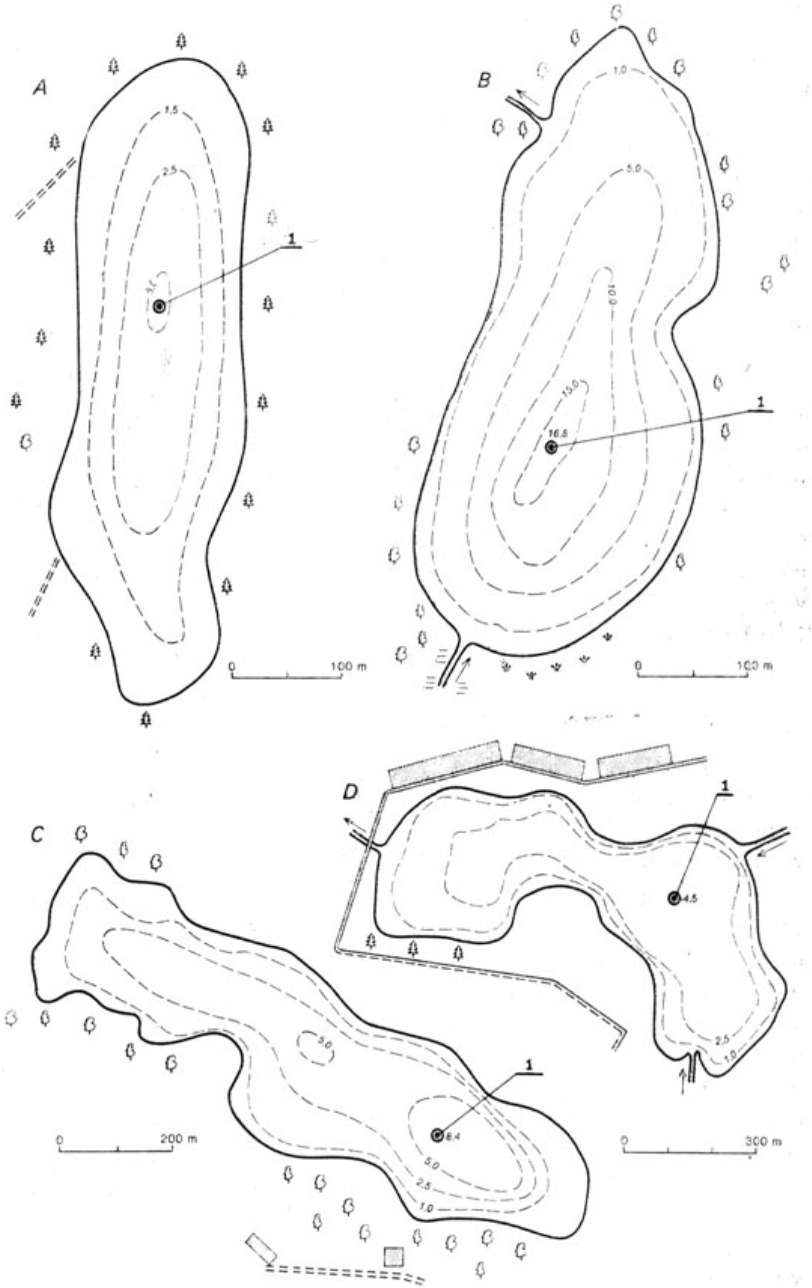

Fig. 2. *A* — Lake Smolak, *B* — Lake Dgal Mały, *C* — Lake Piecek, *D* — Lake Czarna Kuta; *1* — sampling sites

Table 2

Numbers of yeasts cells in Kortowskie Lake in the period Apr. 27th 1966-Apr. 17th 1968
(average values of 3 replications, per 1 ml water)

Sampling site	Depth m	1966											1967														1968			
		27 IV	21 V	21 VI	5 VII	9 VIII	23 VIII	9 IX	23 IX	7 X	24 X	14 XI	15 IV	29 IV	16 V	2 VI	19 VI	4 VII	27 VII	9 VIII	5 IX	20 IX	2 X	24 X	7 XI	21 XI	5 XII	10 I	20 II	21 III	17 IV
1	0	17	17	26	3	5	15	0	4	3	2	3	2	12	1	4	0	0	5	—	4	0	2	3	3	2	5	45	10	10	185
	0,3	18	20	15	4	6	15	2	9	2	4	6	2	0	3	5	0	0	6	10	7	10	2	1	4	5	15	10	10	1	50
	1	18	3	—	0	8	4	1	9	4	0	8	2	0	5	1	1	3	2	—	1	1	1	10	2	5	5	—	2	15	54
	2	11	4	10	6	0	8	5	7	1	0	24	1	0	2	4	0	0	—	—	3	0	2	3	2	5	4	5	3	6	48
	4	12	22	16	2	4	0	0	12	1	0	1	1	0	1	3	1	2	8	5	2	0	3	12	7	5	5	3	4	0	50
	6	18	7	8	5	2	0	2	9	0	0	1	5	0	1	9	1	17	6	8	1	0	1	2	2	5	3	2	3	24	35
	8	5	6	5	8	7	1	4	6	0	0	5	1	0	2	16	0	1	7	6	2	0	2	3	0	8	5	2	0	2	50
	10	3	5	5	7	5	0	8	10	2	1	1	1	0	1	2	3	1	1	3	14	0	2	3	1	6	4	2	1	0	17
	12	16	12	5	0	1	6	7	3	1	1	1	1	0	1	8	0	0	3	4	3	1	2	30	2	5	3	2	7	3	24
	14	10	2	3	8	2	8	2	5	4	3	1	1	1	1	3	33	7	3	2	2	0	1	6	1	—	2	—	6	3	50
	16	10	25	8	5	8	20	4	9	5	3	4	0	0	4	24	0	1	3	5	1	0	3	2	3	6	3	0	8	3	103
2	0	28	5	12	—	—	—	—	1	5	1	3	—	1	4	0	0	2	15	6	0	2	22	13	3	13	5	132	—	—	—
	0,3	10	3	8	6	4	11	4	2	5	1	3	—	4	4	5	2	3	10	12	10	1	3	6	60	3	10	8	1	7	48
	1	12	1	7	—	—	—	—	3	6	1	3	—	5	4	12	3	6	8	4	5	0	2	1	4	7	9	6	2	62	—
	2	12	4	2	—	—	—	—	2	4	2	2	—	0	4	20	—	0	5	3	1	1	4	2	1	9	11	5	7	15	90
	4	16	0	8	—	—	—	—	2	2	1	2	—	2	1	9	—	0	2	4	2	0	1	2	4	0	6	1	2	1	155
	6	36	2	2	8	5	8	2	2	1	1	2	—	4	2	16	0	1	1	4	2	0	1	2	1	3	7	1	2	1	15
3	0	18	8	0	3	6	8	3	0	10	0	5	—	0	4	5	0	4	3	6	1	3	8	2	3	5	7	85	5	12	21
	0,3	14	3	6	2	5	10	4	0	20	1	2	3	1	5	3	2	2	2	6	2	0	1	7	20	11	7	25	23	28	46
	1	—	—	—	4	4	6	1	0	21	0	1	—	0	7	2	0	8	1	3	10	0	3	2	15	136	2	14	21	50	23
	2	42	6	1	2	0	3	6	1	18	0	1	—	2	4	5	0	3	20	4	2	1	1	4	4	5	1	7	8	28	210
	4	20	6	1	0	0	0	3	3	12	1	3	—	1	2	13	0	2	30	6	1	1	1	2	2	5	5	2	5	23	260
	6	20	4	7	5	9	12	7	3	2	0	2	—	1	2	6	1	6	20	8	3	1	—	6	4	3	10	2	2	2	46
	8	10	5	5	7	8	6	2	2	0	0	5	—	0	0	9	1	1	4	5	1	1	1	1	2	8	3	1	5	4	55
	10	6	2	1	9	4	8	1	3	1	0	0	—	0	3	7	0	2	4	2	2	0	2	40	3	5	—	2	9	0	45
	12	34	9	4	8	6	5	8	2	1	0	2	—	0	—	12	0	2	3	2	2	0	2	6	2	2	8	2	5	1	245
	14	68	18	5	3	4	6	3	3	2	1	5	4	7	1	14	6	2	20	10	3	0	2	2	3	11	15	6	15	2	260

Table 3

Numbers of yeasts cells in Ilawa Lakes in the period Apr. 30th 1967-March 26th 1969
(average values of 3 replications, per 1 ml water)

Lake	Sampling site	Depth m	1967									1968												1969	
			30 IV	26 V	30 VI	26 VII	29 VIII	27 IX	20 X	8 XI	6 XII	24 I	20 II	11 III	23 IV	30 V	28 VI	29 VII	22 VIII	9 IX	4 X	9 XI	5 XII	15 I	26 III
Jezio-rak Mały	3	0	—	—	—	—	—	—	—	—	—	—	—	—	0	0	300	35	21	7	60	195	0	0	11
		0,3	47	61	6	—	2	25	18	63	20	14	16	32	0	0	565	55	32	7	100	61	2	10	17
		1	26	38	8	5	1	—	12	32	18	5	8	12	0	0	48	16	13	2	92	42	2	8	15
		2	18	42	2	20	4	—	16	14	15	4	5	18	0	1	96	16	10	4	84	16	2	2	3
		3	25	18	12	10	5	—	8	13	9	7	13	5	1	0	120	20	8	18	39	25	1	0	4
		4	8	29	18	16	2	—	0	12	13	12	1	2	0	0	180	22	12	20	65	12	0	7	2
		5	5	75	63	68	1	28	28	38	34	40	40	10	1	3	2310	75	43	36	114	65	2	29	10
Jezio-rak	6	0	—	—	—	—	—	—	—	—	—	—	—	—	0	2	104	32	12	—	13	6	1	1	44
		0,3	9	61	6	20	1	244	65	38	17	2	5	3	0	1	565	10	8	37	6	13	1	0	2
		1	0	22	4	13	0	150	30	32	12	1	4	2	1	2	48	2	8	20	8	10	0	0	3
		2	1	18	2	18	0	40	26	40	16	2	0	5	0	0	52	11	10	18	3	18	1	0	0
		3	2	9	1	6	0	62	32	30	18	3	3	0	0	0	31	8	6	24	3	7	2	2	5
		4	0	30	2	15	0	70	30	24	13	0	2	0	2	0	19	16	2	6	5	6	0	0	0
		5	2	72	3	30	1	140	42	32	14	8	3	1	0	1	46	30	16	12	12	9	2	5	1
	8	0	—	—	—	—	—	—	—	—	—	—	—	—	0	0	25	15	11	11	1	2	4	2	2
		0,3	9	1	16	—	2	35	18	20	14	5	6	4	0	0	8	22	18	7	1	5	6	1	5
		1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		2	7	—	8	—	2	50	12	8	12	—	8	4	0	0	8	16	20	12	3	5	5	0	1
	9	0	—	—	—	—	—	—	—	—	—	—	—	—	0	0	27	21	18	10	2	4	9	0	9
		0,3	7	98	17	35	2	24	15	26	20	11	12	11	0	0	7	57	32	8	2	6	8	0	2
		1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		2	15	75	9	16	—	100	52	23	7	10	18	15	0	0	25	15	8	33	1	4	6	0	1
	11	0	—	—	—	—	—	—	—	—	—	—	—	—	1	3	16	32	24	85	7	3	0	0	3
		0,3	1	20	4	58	0	22	12	42	7	3	7	2	0	2	20	6	16	60	2	1	1	2	5
		1	—	18	1	22	2	17	—	16	10	5	3	0	0	0	16	11	12	45	0	2	0	1	1
		2	—	10	2	30	5	12	—	25	4	2	2	0	0	2	10	6	18	38	0	0	0	0	0
		4	6	16	4	—	2	23	—	8	12	6	0	1	0	3	15	17	13	70	1	3	1	0	0
		6	2	20	3	14	15	28	—	8	6	6	2	0	2	2	20	10	12	—	0	0	0	3	0
		8	3	160	2	24	4	65	—	10	8	6	1	1	0	1	27	12	10	75	0	9	1	2	1
		10	8	150	2	24	2	42	20	14	9	35	42	187	0	1	25	15	20	64	2	4	1	—	0

Table 4

Number of yeasts in two Iława Lakes bottom deposits in the period Apr. 30th 1967-March 26th 1969 (A) and in net plankton in 1968 (B) (Average values of 3 determinations, in 1 g dry wt. of bottom deposits and in 1 g wet wt. of net plankton)

Date		Lake			
		Jeziorak Mały	Jeziorak		
		Sampling site			
		3	8	9	11
A. 30.IV	1967	3600	28	10	82
26.V		6200	92	32	90
30.VI		2100	840	16	124
26.VII		1200	650	14	130
29.VIII		920	393	8	150
27.IX		600	120	28	240
20.X		300	420	48	820
8.XI		420	68	18	420
6.XII		280	18	12	110
24.I	1968	120	0	12	42
20.II		92	8	4	20
11.III		320	10	12	44
23.IV		5900	18	7	36
30.V		3200	235	—	45
28.VI		23400	1270	0	88
29.VII		150	428	12	92
22.VIII		185	98	42	110
9.IX		300	42	40	385
4.X		640	1600	50	1000
9.XI		500	90	16	340
5.XII		50	2	10	75
15.I	1969	280	3	0	53
26.III		20	0	0	15
B. 29.VI	1968	4000	950	1500	2000
9.IX		410	490	4400	15000
4.X		150	150	150	900

Piecek (up to 30 cells/1 ml water), and Smolak (up to 60 cells/1 ml water). Almost one half of the identified yeasts produced carotenoid pigments. As regards qualitative composition, species of the genus *Rhodotorula* prevailed (Table 6).

Table 5

Number of yeast cells in Węgorzewo Lakes water, in the period May 6th 1970-Apr. 15th 1971 (average values of 3 determinations, per 1 ml water)
a — total; b — „pink yests"

Jezioro Lake	Depth m	1970																1971			
		6.V		3.VI		8.VII		5 VIII		3.IX		7.X		4.XI		3.XII		11.II		15.VI	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Czarna Kuta	0	2	0	1	0	3	2	3	3	3	3	18	10	40	18	15	10	31	15	5	3
	1	0	0	0	0	0	0	0	0	0	0	5	4	16	6	—	—	—	—	—	—
	2	1	0	0	0	2	0	4	1	2	2	1	0	20	9	—	—	—	—	—	—
	3	5	3	0	0	82	32	12	5	12	5	2	0	80	16	3	0	8	2	2	0
Dgał Mały	0	0	0	0	0	12	6	2	2	35	22	18	12	65	30	12	10	1	1	2	2
	1	0	0	0	0	0	0	1	0	10	3	13	7	—	—	20	8	3	2	0	0
	2	0	0	0	0	0	0	0	0	5	0	2	0	—	—	4	1	0	0	1	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	—	—	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	2	0	5	5	—	—	0	0	0	0	0	0
	5	0	0	0	0	1	0	0	0	1	0	6	4	—	—	5	2	1	0	0	0
	6	0	0	2	0	1	0	0	0	1	0	1	0	—	—	0	0	0	0	0	0
	7	0	0	1	0	5	3	0	0	0	0	0	0	—	—	0	0	0	0	0	0
	8	0	0	0	0	0	0	2	1	2	0	3	0	—	—	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	2	0	1	0	—	—	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	1	0	—	—	0	0	0	0	0	0
	11	0	0	0	0	1	0	0	0	3	0	2	0	—	—	0	0	0	0	0	0
	12	0	0	0	0	0	0	0	0	6	2	9	2	—	—	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	8	3	6	3	—	—	6	1	0	0	0	0
	14	0	0	0	0	9	5	3	0	28	12	26	12	42	18	8	2	0	0	2	0
Piecek	0	1	0	2	2	0	0	1	1	15	12	9	5	15	12	6	6	3	2	1	0
	1	0	0	0	0	0	0	0	0	4	3	4	2	3	2	5	3	0	0	1	0
	2	0	0	2	0	0	0	2	2	1	0	1	0	1	0	2	0	0	0	0	0
	3	0	0	1	1	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0
	4	1	0	4	2	4	3	1	0	2	0	3	0	2	0	1	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
	6	0	0	0	0	0	0	1	0	3	0	1	0	1	0	2	0	0	0	0	0
	7	2	1	0	0	0	0	0	0	0	0	0	0	0	0	6	4	0	0	0	0
	8	5	3	11	5	0	0	2	1	30	6	2	0	8	4	12	4	0	0	0	0
Smolak	0	0	0	0	0	0	0	60	42	12	5	8	3	4	3	10	8	6	4	0	0
	1	0	0	0	0	0	0	4	2	9	2	2	1	2	1	6	3	2	0	0	0
	2	0	0	1	0	0	0	2	2	3	1	0	0	1	0	3	2	2	1	1	0
	3	0	0	2	0	2	2	1	0	4	0	0	0	0	0	2	0	5	4	0	0
	4	0	0	0	0	0	0	0	0	8	3	4	3	0	0	4	0	1	0	0	0
	5	0	0	38	12	0	0	5	2	24	6	11	2	1	0	12	5	8	3	0	0

DISCUSSION

The quantitative composition and distribution of yeasts in the lakes of the Masurian Lakeland depended in the period of the investigations on the supply with inflowing water of allochtonic organic matter and is amount produced in the water bodies themselves. The absence of these fungi or their minimal quantity in the water of Dgał Mały, Piecek and Smolak situated far from larger human settlements indicate that these

Table 6

Frequency of occurrence of some yeast species in the water of lakes in the Węgorzewo distriet

Yeasts	Czarna Kuta				Dgał Mały				Piecek				Smolak			
	1970		1971		1970		1971		1970		1971		1970		1971	
	8 VII	4 XI	11 II	15 IV	8 VII	4 XI	11 II	15 IV	8 VII	4 XI	11 II	15 IV	8 VII	4 XI	11 II	15 IV
Sporobolomyces sp.	1	0	0	1	0	3	1	0	0	1	1	0	0	1	1	0
Sporobolomyces roseus Kluyver et van Niel	0	8	0	0	0	1	0	0	0	5	1	0	0	1	3	0
Rhodotorula glutinis (Fres.) Harrison	15	25	8	4	2	13	0	2	1	5	0	0	2	2	2	0
Rhodotorula mucilaginosa (Jörg.) Harrison	2	5	0	0	2	2	0	1	0	0	0	0	0	0	2	0
Rhodotorula rubra (Demme) Lodder	16	16	0	0	5	18	2	0	2	7	0	0	0	0	4	0
Rhodotorula flava (Saito) Lodder	0	0	9	0	5	3	0	0	0	0	0	0	0	0	0	0
Candida sp.	21	21	6	0	5	14	1	1	1	7	0	2	0	3	3	1
Cryptococcus albidus (Saito) Skinner	11	22	4	0	3	12	0	0	0	6	0	0	0	0	1	0
Cryptococcus luteolus (Saito) Skinner	1	7	0	0	0	5	0	0	0	0	0	0	0	0	2	0
Torulopsis sp.	19	18	8	2	3	22	0	1	0	0	1	0	0	0	4	0
Debaryomyces sp.	1	5	0	0	4	3	0	0	0	1	0	0	0	1	0	0
Saccharomyces sp.	0	9	2	0	0	4	0	0	0	0	0	0	0	0	0	0
Hansenula sp.	0	4	1	0	0	2	0	0	0	0	0	0	0	0	0	0
Pichia sp.	0	6	1	0	0	1	0	0	0	0	0	0	0	0	0	0

lakes are not polluted. Similar quantities of yeasts are also reported by Van Uden and Ahearn (1963) for the lake Duglas in Michigan State (U.S.A.). Hedrick et al. (1964) for the little polluted lake Michigan, Ahearn et al. (1968) for the water bodies of the Miami region and Meyers et al. (1970) for the relatively unpolluted lake Champlain (U.S.A.). Somewhat greater numbers of yeasts in the lake Czarna Kuta were due to the sewage water from a village on the edge of the lake.

A more pronounced influence of pollution on the increase in the number of yeasts was noted in spring on site 3 of the Kortowskie lake where storm runoff and sewage water from Olsztyn flowed in, and in general during the entire vegetation season in the lake Jeziorak Mały polluted with sewage from Iława. The number of yeasts found periodically (up to 260 cells/1 ml water in the Kortowskie lake, 2310 cells/1 ml water in Jeziorak Mały and 564 cells/1 ml water at site 6 of Jeziorak) exceed the values for polluted waters in other countries (Cooke 1965; Ahearn et al., 1968; Ahearn et al., 1969; Spencer et al., 1970; Simard, 1971; Simard and Blackwood, 1971 a, b).

The waste water character of Jeziorak Mały was the cause of the lack of regularity in the seasonal occurrence of yeasts in this water body. The dynamics of seasonal variations in the abundance of these fungi in the water of the remaining lakes depended above all on the presence of available sources of carbon and energy. Maximal numbers of yeasts at the sampling sites in the Kortowskie lake, Jeziorak and the lakes of the Węgorzewo District were found in spring, probably owing to the development of phytoplankton and utilization of the excretions of algae. This could be concluded from the large quantities of yeasts in the net plankton of the Iława region lakes. In general yeasts appear in the water not in the form of singly floating cells (Meyers et al., 1970), but bound with larger plankton organisms and detritus on which they find more profuse food. The possibility of utilization of alga intravital secretions by these fungi has been experimentally confirmed (Niewolak, 1971) in a joint culture of *Chlorella vulgaris* and *Scenedesmus obliquus* with *Rhodotorula* sp. isolated from the lake Jeziorak. The increase of the number of yeasts in the water of the lakes in autumn may be explained by the richer content in the water of organic matter derived from dying plants, indispensable for these microorganisms.

The vertical distribution of yeasts in the water of the Masurian lakes and its character depended largely on the type of water body and the season. Moreover, in the particular lakes there were differences in the distribution of these organisms at various sites. In general, a more abundant occurrence of yeasts in the surface water of the lakes was probably due to the more profuse development of phytoplankton which serves for them as source of nutrition. Similar observations were reported by

Ahearn et al. (1969) and Meyers et al. (1970) from the lake Champlain. Among the yeasts present in the surface waters of the Węgorzewo lakes pigmented strains were more numerous including *Rhodotorula glutinis*. This species shows a high resistance to ultraviolet radiation which, according to Kamšylov (1965), is probably adsorbed on the cell surface of *Rhodotorula glutinis* and stimulates its development.

It is possible that in the development of yeasts in the surface water of the Węgorzewo lakes a certain role was played by the vicinity of the border of the water-air phases, since it is a source of carbon and nitrogen and also of other elements from the soil dust and other particles of land origin settling on the surface. Maximal amounts of yeasts sporadically found in the thermocline of the Kortowskie and Jeziorak lakes may be explained by the differences in temperature and specific weight of the water and the retention in it of dead plankton suspensions. The increase in the number of yeasts in the benthic water of all the lakes might have been the result of action of convection currents and the rise with them of the upper bottom deposits rich in organic matter and of accumulation of detritus at the bottom.

The distribution of yeasts in the bottom sediments of the Iława lakes (the substrate of other lakes was not studied) depended on the character of the bottom. On silty soil where the organic matter content was about 42 per cent (private communication) the number of fungi reached sometimes several thousand cells per 1 g dry weight, as for instance in Jeziorak Mały and was many times higher than in littoral sandy sediments, for instance at site 9 of the lake Jeziorak. Greater numbers of yeasts were found only by Rodina (1950) in the silty lakes Klin, Imolozhe and Ostrowno in the U.S.S.R. (up to 1.3 million cells per 1 g dry weight) and Hedrick and Soyugenc (1965) in similar conditions in the lake Michigan (up to 8.5 million cells per 1 ml of silt). In the sandy sediments of the littoral of the lake Jeziorak the amount of yeast corresponded to the value reported for similar soil conditions in other lakes of the U.S.S.R. (Rodina, 1948). The factor limiting the development of this kind of fungi on the sandy bottom of the Jeziorak lake was the low content of organic matter (1-2%). Seasonal variations in the number of yeasts in the bottom sediments of the Iława lakes may have been connected with the periods of multiplication of the invertebrates living in the benthos and the dying of plankton plant organisms which enrich the bottom sediments in easily available organic compounds as well as with the devouring of these microorganisms by benthos dwellers.

CONCLUSIONS

It results from the present investigation (Tables 2-6) that:

1. The abundance of yeasts in the waters of the Masurian Lakeland

depended on the degree of their pollution. The fungi were most numerous in the waste water lake Jeziorak Mały (up to 2310 cells/1 ml water), in the polluted zones of the lake Jeziorak (up to 565 cells/1 ml water, Table 2) and in the Kortowskie lake (up to 260 cells/1 ml water, Table 1) the smallest amounts were noted in the unpolluted Węgorzewo lakes (up to 82 cells/1 ml water).

2. In all the lakes yeasts are more numerous in generai in the surface water and in the water near bottom and less so in the metalimnion. Jeziorak Mały showed no distinct regularity in the seasonal occurrence of fungi in the water. In the Kortowskie, Jeziorak, Czarna Kuta, Dgał Mały, Piecek and Smolak lakes more of these fungi appeared in spring than in autumn.

3. About 50 per cent of the yeasts isolated from the waters of the Węgorzewo lakes produced carotenoid pigments. Fungi were more numerous in the upper water layers, this indicating perhaps a higher resistance of these organisms to UV radiation.

4. As regards qualitative composition of the yeasts isolated from the waters of the lakes Czarna Kuta and Dgał Mały, the majority were species of the genera *Rhodotorula* (*R. glutinis, R. rubra*), *Candida, Cryptococcus* and *Torulopsis*. In the water of the lake Piecek species of the genus *Rhodotorula* and *Cryptococcus* were more numerous, while in Smolak species of the genus *Sporobolomyces, Rhodotorula, Candida* and *Torulopsis* prevailed (Table 6).

5. The amount of yeasts in the bottom sediments of the Iława lakes depended on the type of the bottom and the degree of pollution. The greatest amount (up to 6200 cells/1 g dry weight) were noted in the silty sediments of Jeziorak Mały and the smallest (up to 60 cells/1 g dry weight) in the littoral sandy substrate of Jeziorak.

6. The number of yeasts in the net plankton of the Iława lakes varied from 150 to 15 000 cells/1 g fresh weight, depending on the season (Table 2).

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Występowanie grzybów drożdżoidalnych w niektórych jeziorach mazurskich

Streszczenie

W pracy przedstawiono wyniki badań przeprowadzonych w latach 1966-1971 nad rozmieszczeniem grzybów drożdżoidalnych w jeziorze Kortowskim k/Olsztyna, w jeziorach iławskich (Jeziorak Mały i Jeziorak) oraz węgorzewskich (Czarna Kuta, Dgał Mały, Piecek i Smolak) na Pojezierzu Mazurskim.

W wodzie badanych jezior Pojezierza Mazurskiego zawartość grzybów drożdżo-

idalnych zależała od stopnia zanieczyszczenia. Najwięcej grzybów drożdżoidalnych (do 2310 komórek w 1 ml wody) występowało w ściekowym Jezioraku Małym; stosunkowo dużo występowało również na stanowisku 6 jeziora Jeziorak (do 565 komórek w 1 ml wody), zanieczyszczanym ściekami bytowo-gospodarczymi miasta Iławy oraz na stanowisku 3 jeziora Kortowskiego (do 260 komórek w 1 ml wody), gdzie dopływają ścieki burzowe miasta Olsztyna.

We wszystkich jeziorach na ogół więcej grzybów drożdżoidalnych występowało w wodzie powierzchniowej i przydennej, rzadziej w innych warstwach wody. W Jezioraku Małym brak było wyraźnej regularności w sezonowym występowaniu grzybów drożdżoidalnych w wodzie, podczas gdy w jeziorach: Kortowskim, Jeziorak, Czarna Kuta, Dgał Mały, Piecek i Smolak grzyby drożdżoidalne występowały liczniej wiosną i w jesieni.

Około 50% grzybów drożdżoidalnych, wyodrębnionych z wody jezior węgorzewskich wytwarzało barwniki karotenoidowe. Barwne ich szczepy występowały liczniej w górnych warstwach wody. W składzie jakościowym grzybów drożdżoidalnych wyodrębnionych z wody jezior Czarna Kuta i Dgał Mały przeważały gatunki z rodzaju *Rhodotorula* (*R. glutinis, R. rubra*), *Candida, Cryptococcus* i *Torulopsis*; w wodzie jeziora Piecek przeważały gatunki z rodzaju *Rhodotorula* i *Cryptococcus*, w jeziorze Smolak — gatunki z rodzaju *Sporobolomyces, Rhodotorula, Candida* i *Torulopsis*.

Zawartość grzybów drożdżoidalnych w osadach dennych jezior iławskich zależała od typu dna i stopnia zanieczyszczenia. Więcej ich występowało w mulistych gruntach Jezioraka Małego (do 6200 komórek w 1 g suchej masy), zanieczyszczanych ściekami mleczarskimi i odpadkami z tartaku. Muliste osady jeziora Jeziorak zawierały natomiast do 1000 komórek tych grzybów w 1 g suchej masy; nieco bogatsze w grzyby były osady sapropelowe tego zbiornika (do 1600 komórek w 1 g suchej masy), natomiast w gruntach pieszczystych zawartość grzybów drożdżoidalnych nie przekraczała 60 komórek w 1 g suchej masy.

Zawartość grzybów drożdżoidalnych w planktonie sieciowym jezior iławskich wahała się od 150 do 15 000 komórek w 1 g świeżej masy, zależnie od pory roku.