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Wpływ ścieków cukrowniczych na fitoplankton stawów*

The influence of beet sugar factory wastes on the phytoplankton of ponds

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Abstract — Beet sugar factory wastes fed to ponds stimulated the development of algae, especially of chlorococcous green algae, the effect of undiluted wastes being much stronger than that of diluted ones. After the inflow of the wastes was stopped, their consequent effect was observed. If beet sugar wastes are to play an active role in fertilizing ponds they should be applied at carefully selected concentrations.

The utilization of beet sugar factory wastes in pond management was investigated in the Laboratory of Water Biology of the Polish Academy of Sciences in Kraków in 1967 and 1968, other biological investigations (Grabacka 1973, Huk 1973, Zięba 1973) being carried out apart from the chemical ones (Lewkowicz 1973).

The plankton of these ponds was elaborated by Kyselowa (1973). This author included four ponds, of which two, Zimowy Wielki and Łąkowy, were also elaborated in a second cycle of investigations in 1971—1974.

In this period Zimowy Wielki was used as an accumulative pond where undiluted wastes were fed directly from the sugar factory from November to December 1970 and in November 1971.

Łąkowy was used as an assimilative pond fed with beet sugar factory wastes from Zimowy Wielki during 2—3 weeks in May 1971. In this pond the introduced wastes were diluted in a ratio of 1 : 5.

The pond Gorol, of the same complex, was treated as a control, no wastes being introduced there.

* Praca wykonana w problemie węzłowym 09. 1. 7.

Tabela I. Skład jakościowy glonów

Table I. Qualitative composition of algae

Glony - Algae	Staw - Pond						
	Zimowy Wielki				Łąkowy	Gorol	
	1971	1972	1973	1974	1971	1971	1973
Anabaena circinalis Rbh.			+		+		
- solitaria Kleb.				+			+
- spiroides Kleb.				+			
Anabaena sp.	+		+	+	+	+	+
Aphanizomenon flos-aquae (L.) Ralfs			+		+	+	
Aphanizomenon sp.					+	+	
Aphanocapsa sp.			+	+	+	+	+
Chroococcus sp.		+			+		
Gomphosphaeria sp.			+	+	+	+	+
Lyngbya sp.	+	+	+	+		+	
Merismopedia elegans A. Braun				+			
- minima G. Beck	+	+			+	+	
- tenuissima Lemm.			+	+			+
Merismopedia sp.	+	+	+	+	+	+	+
Microcystis aeruginosa Kütz.		+	+	+	+	+	+
Microcystis sp.	+			+	+	+	+
Oscillatoria sp.	+	+	+	+	+	+	+
Phormidium sp.			+				+
Romeria sp.			+		+		+
Spirulina sp.	+			+			
Cyanophyceae n. det.		+	+	+	+	+	+
Astasia sp.	+	+	+				+
Colacium vesiculosum Ehr.			+				+
Colacium sp.	+	+	+	+	+	+	+
Euglena acus Ehr.	+	+	+		+		
- Ehrenbergii Kleb.		+					
- intermedia (Kleb.) Schmitz		+					
- limnophila Lemm.		+	+				
- oxyuris Schmarda	+	+	+				
- proxima Dang.		+	+				+
- sphathirhyncha Skuja		+					
- spirogyra Ehr.		+	+		+		+
- splendens Dang.		+					
- tripteris (Duj.) Kleb.	+	+	+			+	+
- viridis Ehr.		+					
Euglena sp.	+	+	+	+	+	+	+
Lepocinclis fusiformis (Carter) Lemm.			+				
- Marssonii Lemm.					+		
- ovum (Ehr.) Lemm.		+	+	+	+		
- texta (Duj.) Lemm.	+	+	+	+	+		
Lepocinclis sp.	+	+	+	+	+	+	+
Peranema sp.		+					
Phacus acuminatus Stokes	+	+					
- aenigmaticus Drez.		+					
- alatus Kleb.		+					
- caudatus Hübn.		+					
- - var. minor Drez.	+						
- costatus Conr.	+						
- curvicauda Swir.	+	+					
- helicoides Pochm.	+	+	+		+		
- longicauda (Ehr.) Duj.	+	+			+		+
- - var. insecta Koczw.		+					
- - var. major Swir.		+					
- orbicularis Hübn.	+	+					
- pleuronectes (O.F.M.) Duj.	+	+	+	+	+	+	+
- pyrum (Ehr.) Stein	+	+	+		+		+
- textus Pochm.		+					
- tortus (Lemm.) Skv.	+	+	+	+	+	+	+
- triqueter (Ehr.) Duj.	+	+	+		+	+	+
- undulatus (Skv.) Pochm.		+					
- Wettstenii Drez.		+			+		
Phacus sp.	+	+	+	+	+	+	+
Strombomonas sp.	+		+		+		+
Trachelomonas abrupta (Swir.) Defl.	+			+			
- armata (Ehr.) Stein			+				
- dubia Swir. et Defl.			+				
- granulata Swir. et Defl.							+
- hexangulata (Swir.) Playf.							+
- hispida (Perty) Stein	+	+	+	+	+	+	+
- - var. coronata Lemm.	+		+		+	+	
- - var. punctata Lemm.			+				
- intermedia Dang.	+						
- lacustris Drez.	+		+				
- nigra Swir.			+				+
- oblonga Lemm.			+	+			+
- planctonica Swir.	+	+	+	+	+		
- - var. oblonga Drez.			+				
- rotunda Swir.				+			
- Woycickii Koczw.				+			
- volvocina Ehr.	+	+	+	+	+	+	+
- - var. punctata Playf.	+						
Trachelomonas sp.		+	+	+	+	+	+
Euglenophyta n. det.	+	+	+	+	+	+	+
Ceratium cornutum (Ehr.) Clap. et Lachm.	+						

Caratium hirundinella (O.F.M.) Bergh.	+		+		+		+
Peridinium sp.			+		+	+	+
Dinophyceae n. det.						+	
Cryptomonas Marssonii Skuja		+					
- erosa Ehr.	+	+	+	+	+	+	+
Cryptomonas sp.	+	+	+	+	+	+	+
Chromulina sp.			+	+			
Chrysococcus minutus (Fritsch) Nygaard							+
Chrysococcus sp.			+	+	+		+
Dinobryon bavaricum Imhof	+		+	+		+	+
- divergens Imhof			+			+	+
- sertularia Ehr.						+	
- sociale Ehr.							+
- stipitatum Stein						+	
Dinobryon sp.						+	+
Kephyrion ovum Pascher							+
- Rubri-Claustri Conrad			+	+	+	+	+
- spirale (Lackey) Conrad			+				+
Kephyrion sp.	+		+	+	+	+	+
Mallomonas producta Ivanof							+
Mallomonas sp.			+	+	+	+	+
Ochromonas sp.							+
Pseudokephyrion Schilleri Conrad				+		+	+
Synura uvella Ehr.	+		+	+	+	+	
Uroglena sp.			+				
Achnanthes lanceolata (Bréb.) Grun.			+				
Achnanthes sp.	+	+	+	+	+	+	+
Amphora ovalis Kütz.			+	+	+		+
Amphora sp.	+	+	+	+	+	+	+
Asterionella formosa Hass.	+			+	+	+	+
Asterionella sp.			+		+		
Caloneis Schumanniana (Grun.) Cl.							+
Ceratoneis arcus (Ehr.) Kütz.	+	+	+	+	+		+
Cocconeis placentula Ehr.	+	+	+	+	+	+	+
Cocconeis sp.	+	+	+			+	+
Cyclotella comta (Ehr.) Kütz.			+				+
Cyclotella sp.	+	+	+	+	+	+	+
Cymatopleura solea (Bréb.) W. Sm.			+	+			
Cymatopleura sp.					+		
Cymbella naviculiformis Auersw.							+
- ventricosa Kütz.							+
Cymbella sp.	+	+	+	+	+	+	+
Diatoma vulgare Bory	+	+			+	+	
- - var. productum Grun.	+						
Diatoma sp.			+				+
Epithemia sp.				+			
Eunotia sp.		+	+	+		+	
Fragilaria capucina Desm.			+	+			+
- constricta Ehr.							+
- construens (Ehr.) Grun.							+
- crotonensis Kitt.	+	+	+	+	+	+	
- virescens Ralfs							+
Fragilaria sp.	+	+		+	+	+	+
Gomphonema acuminatum Ahr.	+	+	+			+	
- angustatum (Kütz.) Rabh. var. productum Grun.			+				
- constrictum Ehr.		+	+	+			+
- lanceolatum Ehr.			+				
- olivaceum (Lyngb.) Kütz.			+	+			
- parvulum (Kütz.) Grun.			+	+			
- ventricosum Greg.		+	+	+			+
Gomphonema sp.	+	+	+	+	+	+	+
Hantzschia sp.				+			
Melosira granulata (Ehr.) Ralfs			+	+		+	
- - var. angustissima (O. Müll.) Hust.	+		+				+
- varians Ag.		+				+	
Melosira sp.						+	+
Navicula cryptocephala Kütz.		+		+	+	+	
- dicephala (Ehr.) W. Sm.			+				
- hungarica Grun.							+
- oblonga Kütz.				+			
- placentula (Ehr.) Grun.			+				
- radiosa Kütz.				+		+	
- viridula Kütz.			+	+			
Navicula sp.	+	+	+	+	+	+	+
Nitzschia acicularis W. Sm.	+	+	+	+	+	+	+
- amphibia Grun.							+
- dissipata (Kütz.) Grun.	+			+	+	+	+
- gracilis Hantz.			+				+
- palea (Kütz.) W. Sm.			+				+
- sigmoidea (Ehr.) W. Sm.			+		+		
- thermalis Kütz.							+
Nitzschia sp.	+	+	+	+	+	+	+
Pinnularia gibba Ehr.							+
- maior (Kütz.) Cl.							+
- mesolepta (Ehr.) W. Sm.							+
Pinnularia sp.	+	+	+	+	+	+	+
Rhoicosphaenia curvata (Kütz.) Grun.		+					
Suriella sp.			+	+			+
Synedra acus Kütz.	+	+	+	+	+	+	+
- ulna (Nitzsch.) Ehr.	+		+	+	+	+	+

Tab. I. cont. (3)

Synedra sp.		+				+	
Tabellaria fenestrata (Lyngb.) Kütz.	+						+
- flocculosa (Roth.) Kütz.	+	+	+	+	+	+	+
Bacillariophyceae n. det.	+	+	+	+	+	+	+
Dichotomococcus sp.			+		+		+
Ophiocytium capitatum Wolle			+		+	+	+
- - var. longispinum (Moebius) Lemm.			+				+
- parvulum A. Braun							+
Ophiocytium sp.		+			+	+	+
Tribonema sp.		+	+	+			+
Chlamydomonas alatus Stein			+				
Chlamydomonas sp.	+	+	+	+	+	+	+
Eudorina elegans Ehr.			+	+	+	+	+
Gonium pectorale Müller				+			
Lobomonas sp.				+			
Pandorina morum (Müll.) Bory	+	+	+	+	+	+	+
Phacotus lenticularis (Ehr.) Stein	+			+		+	
Phacotus sp.			+			+	
Pteromonas angulosa Lemm.				+			
Pyrobotrys elongata Korsch.		+					
- squarrosa Korsch.		+					
Volvox aureus Ehr.	+		+		+	+	+
- globator Linne em. Ehr.			+				
Volvox sp.			+	+			
Ulotrix sp.				+	+		
Cladophora sp.			+	+	+	+	
Bulbochaeta sp.			+	+			+
Oedogonium sp.		+	+	+	+	+	+
Actinastrum Hantzschii Lagerh.	+	+	+	+	+	+	+
Ankistrodesmus acicularis Korschik.	+	+	+		+	+	+
- arcuatus Korschik.	+	+	+	+	+	+	+
- Braunii Brunth.		+					
- falcatus (Corda) Ralfs	+	+	+	+	+	+	+
- minutissimus Korschik.	+	+	+	+	+	+	+
- pseudomirabilis Korschik.	+	+	+	+	+	+	+
- spiralis (Turn.) Lemm.			+				+
Ankistrodesmus sp.	+	+	+	+	+	+	+
Asterococcus superbus (Cienk.) Scherff.		+		+	+	+	+
Asterococcus sp.	+		+	+		+	+
Botryococcus Braunii Kuetzing						+	
Botryococcus sp.						+	
Characium gracilipes Lamb.				+			
Characium sp.	+	+	+	+	+	+	+
Coelastrum cambricum Arch.					+		+
- microporum Naeg.	+	+	+	+	+	+	+
- proboscideum Bohl.		+	+	+	+	+	+
- reticulatum (Dang.) Senn	+	+			+		+
- sphaericum Naeg.	+						
Coelastrum sp.	+	+	+	+	+	+	+
Crucigenia apiculata (Lemm.) Schmidle	+	+	+	+	+	+	+
- fenestrata Schmidle	+			+	+		
- minima Brunnth					+		
- rectangularis (A. Braun) Gay	+	+	+	+	+	+	+
- tetrapedia (Kirchn.) W. et W.	+	+	+	+	+	+	+
- quadrata Morren	+	+	+	+	+	+	+
Crucigenia sp.	+	+	+		+	+	+
Desmatractum sp.					+		
Diacanthos belanophorus Korschik.	+		+	+			+
Dicellula sp.			+				
Dictyosphaerium Ehrenbergianum Naeg.	+		+		+	+	+
- pulchellum Wood	+	+	+	+	+	+	+
Dictyosphaerium sp.	+	+	+	+	+	+	+
Didymocystis tuberculata Korschik.							+
Elakatothrix gelatinosa Wille		+	+	+	+	+	+
Elakatothrix.sp.	+	+	+		+	+	+
Franceia tennuispina Korschik.						+	
Franceia sp.					+		
Golenkinia radiata Chod.			+		+		+
Golenkinia sp.			+				
Hofmania appendiculata Chod.			+				
Kirchneriella contorta (Smidle) Bohl.					+		
- intermedia Korschik.					+		
- obesa (West) Smidle				+	+		
- subsolitaria G. West						+	
Kirchneriella sp.	+	+	+	+	+	+	+
Lagerheimia ciliata (Lagerh.) Chod.			+				
- wratislaviensis Schroeder			+	+	+	+	+
Lagerheimia sp.			+		+	+	+
Lambertia sp.	+	+	+	+	+	+	+
Micractinium pusillum Fr.					+	+	
- quadrisetum (Lemm.) G. M. Smith	+	+			+		
Micractinium sp.	+	+	+		+		+
Nephrochlamys subsolitaria (West) Korschik.		+			+		
- Willeana (Printz) Korschik.	+		+	+	+	+	+
Nephrochlamys sp.	+	+	+	+	+	+	+
Oocystis crassa Wittr.	+						
- elliptica West	+						
- gigas Ar.				+	+	+	
- solitaria Wittr.	+				+		
Oocystis sp.	+	+	+	+	+	+	+

Pediastrum biradiatum Meyen				+			
- Boryanum (Turp.) Menegh.	+	+	+	+	+	+	+
- duplex Meyen	+	+	+	+	+	+	+
- obtusum Lucks							+
- tetras (Ehr.) Ralfs	+	+	+	+	+	+	+
- - var. tetraedon (Corda) Rabenh.	+	+	+	+	+	+	+
Pediastrum sp.			+			+	+
Planctococcus sp.	+						
Rhaphidonema sp.	+	+	+		+		+
Scenedesmus acuminatus (Lagerh.) Chod.	+	+	+	+	+	+	+
- - var. biseriatus Rein.							+
- - var. elongatus G. M. Smith					+		
- - - f. tortuosus (Skuja) Uherkov.					+		
- acutus Meyen	+	+	+	+	+	+	+
- apiculatus W. et W. Chod.	+				+		
- arcuatus Lemm.				+			+
- - var. platydisca G. M. Smith			+				
- armatus (Chod.) G. M. Smith	+	+	+	+		+	+
- balatonicus Hortob.					+		
- bicaudatus (Hansg.) Chod.	+				+		
- bijugatus (Turp.) Kütz.				+	+		
- brasiliensis Bohl.	+	+	+		+	+	+
- circumfusus Hortob.	+	+				+	
- denticulatus Lagerh.	+	+	+	+	+	+	+
- dispar Bréb.	+	+			+		+
- ecornis (Ralfs.) Chod.	+	+	+	+	+	+	+
- - var. disciformis Chod.	+		+		+	+	+
- ellipsoideus Chod.				+			
- granulatus W. et W.			+			+	+
- intermedius Chod.	+	+	+			+	
- obiquus (Turp.) Kütz.		+		+			
- opoliensis P. Richt.	+				+		
- polyglobulus Hortob.							+
- protuberans Fritsch		+					
- spinosus Chod.	+	+	+	+	+	+	+
- quadricauda Chod.	+	+	+	+	+	+	+
- - var. biornatus Kiss		+					
- - var. longispina (Chod.) G. M. Smith							+
- - - f. asymetricus (Hortob.) Uherkov.	+						
Scenedesmus sp.	+	+	+	+	+	+	+
Schroederia sp.			+		+		
Selenastrum acuminatum G. S. West					+		
Selenastrum sp.					+		
Siderocelis sp.			+		+	+	
Sorastrum spinulosum Naeg.				+		+	
Sphaerocystis Schroeterii Chod.	+		+	+	+	+	+
Sphaerocystis sp.	+				+	+	
Tetraëdron caudatum (Corda) Hansg.	+	+	+	+	+	+	+
- constrictum G. M. Smith	+	+	+			+	+
- gracile (Reinsch) Hansg.					+	+	
- Incus (Teil.) G. M. Smith		+	+	+	+		+
- minimum (A. Br.) Hansg.	+	+	+	+	+	+	+
- regulare Kuetzing			+				+
- - var. incus Teiling			+				+
- trigonum (Naeg.) Hansg.	+	+	+	+	+	+	+
Tetraëdron sp.	+	+	+	+	+	+	+
Tetrastrum elegans Playfair					+		
- glabrum (Roll) Ahlstr. et Tiff.	+		+	+	+	+	+
- hastiferum (Arn.) Korschik.					+		
- heteracanthum Schill.	+				+	+	+
- punctatum (Smidle) Ahlstr. et Tiff.					+		
- staurogeniforme (Schroed.) Lemm.	+	+	+	+	+	+	+
Tetrastrum sp.					+		
Westella botryoides (W. West) Wild.	+			+			+
Westella sp.						+	
Closterium acerosum (Schrank) Ehr.		+			+		+
- aciculare Tuffen West		+			+		
- Ehrenbergii Menegh.	+		+				
- gracile Bréb.							+
- moniliferum (Bory) Ehr.	+	+	+	+		+	
Closterium sp.	+	+	+	+	+	+	+
Cosmarium Botrytis Menegh.			+	+	+		+
- Meneghinii Bréb.				+			
- obtusatum Schmidle				+			
- rectangulare Grunow				+			
- reniforme (Ralfs) Archer.				+			
- subcrenatum Hantzsch.				+	+	+	
- subprotumidum Nordst.	+		+	+	+		+
- subtumidum Nordst.	+		+	+	+		
- Turpinii Bréb.			+	+			
- undulatum Corda			+	+			
Cosmarium sp. div.	+	+	+	+	+	+	+
Desmidium sp.							+
Euastrum dubium Näg.						+	
- insulare (Wittr.) Roy				+			
- verrucosum Ehr. var. alatum Wolle						+	
Euastrum sp.						+	
Spirogyra sp.			+	+		+	+
Staurastrum alternans Bréb.		+	+	+	+		+
- tetracerum (Kütz.) Ralfs			+				
Straurastrum sp.			+	+	+	+	+
Chlorophyta n. det.	+	+	+	+	+	+	+

Tabela II. Liczebność glonów w 1 ml wody w stawie Zimowy Wielki
Table II. Number of algae in 1 ml water in the pond Zimowy Wielki

Rok Year 1971 Data Date	Cyanophyta	Euglenophyta	Cryptophyceae	Chrysophyceae	Bacillariophyceae	Chlorophyta
7.IV.	38	286		19	190	551
23.IV.	30	198			76	1 429
6.V.	104	1 397	37		300	48 870
14.V.	1	24 586			236	304 666
17.V.	104	8 237			834	118 456
21.V.	+	20	1		133	96
27.V.	16	200			339	3 582
3.VI.	9	167			26	15 300
18.VI.	55	354			1 272	32 684
1.VII.	42	76	370		151	648
15.VII.	1	28			17	1 792
29.VII.	1	34	+		85	124
12.VIII.	27	22	78	5	230	20
26.VIII.	284	38	152		570	44
9.IX.	228	16	46		989	360
23.IX.	116	3		3	5 460	367
1972						
8.IV.	136	397			356	1 878
25.IV.	90	502			340	431 926
15.V.	52	2 887			33	193 603
31.V.		19 938				2 179 535
6.VI.	37	18 170			71	464 004
15.VI.	171	1 504	277		764	3 617
22.VI.	1	65	410		69	1 140
30.VI.	4	125	3 557		363	92 895
13.VII.	788	357	84		471	193 314
27.VII.	220	275	14		141	560
10.VIII.	6	5			259	15
25.VIII.	218	6	12		536	404
7.IX.	61	16	474		542	245
28.IX.	53	11	53		968	150
12.X.	15	11	82		371	343

Rok Year 1973 Data Date	Cyanophyta	Euglenophyta	Dinophyceae	Cryptophyceae	Xanthophyceae	Chrysophyceae	Bacillariophyceae	Chlorophyta
27.IV.	131	5		854			1 521	7 068
3.V.	169	5		116			1 021	5 057
10.V.	6	1		45			158	28
17.V.	5	2		6			181	23
25.V.	4	5		2		1	105	31
30.V.	5	3		25		+	106	46
14.VI.	57	234		1 442		22	463	933
28.VI.	98	168		1 571		62	1 764	1 597
11.VII.	14	9		26			289	175
25.VII.	74	22		187	5	63	1 042	402
8.VIII.	142	106		2		24	477	613
16.VIII.	38	71		105	7	140	588	960
22.VIII.	186	295			20	123	676	2 554
30.VIII.	510	830	21	756		759	846	2 935
13.IX.	20	177	8	147		244	410	1 054
27.IX.	18	665		15		44	432	2 908
1974								
8.IV.	29	6		31			614	3 811
8.V.	2	1		134		+	200	172
3.VI.	18	1		39			126	275
2.VII.	31	9		2		+	151	177
1.VIII.	77	2		276			66	273
27.VIII.	146	58		58		19	358	474
27.IX.	62	69		1 388		161	437	536

Tabela III. Liczebność glonów w 1 ml wody w stawie Łąkowy

Table III. Number of algae in 1 ml water in the pond Łąkowy

Rok Year 1971 Data Date	Cyanophyta	Euglenophyta	Dinophyceae	Cryptophyceae	Xanthophyceae	Chrysophyceae	Bacillariophyceae	Chlorophyta
6.V.	203	2				156	6 510	29 053
14.V.	333	204		48		54	675	19 726
17.V.	1	55		95			17	2 458
21.V.	28	235			1		445	1 924
27.V.	18	3					26	301
3.VI.	64	222		171			2 500	423
18.VI.	126	43		1			58	105
1.VII.	206	29		34			185	274
15.VII.	101	54		46			169	1 007
29.VII.	176	40		58			188	558
12.VIII.	225	358	2	206			615	3 291
26.VIII.	217	204	5	1	8	7	206	1 216
9.IX.	2 103	121		524		79	663	7 949
23.IX.	198	26				5	256	2 855
14.X.	165	149		9		9	496	1 546

The above ponds belong to the Experimental Fishery Farm of the Polish Academy of Sciences at Gołysz, in the province of Bielsko while the wastes are supplied from the neighbouring sugar factory at Chybie.

In 1973 and 1974 no wastes were fed to Zimowy Wielki in order to test their consequent effect.

The present investigation was accompanied by parallel chemical (M. Lewkowicz, S. Lewkowicz 1977, Zygmuntowa 1977) and more comprehensive biological ones (Grabacka 1977, Kyselowa 1977, Srokosz 1977, Starzecka, Ronchetti 1977, Zięba 1977).

Method

The algae were collected from April to October, usually at fortnightly intervals. In the initial period of filling in the first two years, the sampling was carried out so frequently in order to investigate the effect of undiluted wastes.

In ponds with sugar wastes the samples were collected at three stations (inflow, centre of the pond, outflow) differing in depth and in the

Tabela IV. Liczebność glonów w 1 ml wody w stawie Gorel

Table IV. Number of algae in 1 ml water in the pond Gorel

Rok Year 1971 Data Date	Cyanophyta	Euglenophyta	Dinophyceae	Cryptophyceae	Chrysophyceae	Bacillariophyceae	Xanthophyceae	Chlorophyta
14.V.	31			2 001		236	•	477
17.V.	6	5		934		102		226
21.V.	1	3		1		696		108
27.V.	3	2		3		20	1	20
3.VI.	7	8		12		25		49
18.VI.	32	26		1	1	938		1 276
1.VII.	6	4		27		45		52
15.VII.	22	497		208	1	173		1 539
29.VII.	138	21	3	1 095	6	104		687
12.VIII.	270	268		397	4 927	411	265	18 611
26.VIII.	23	161				476		5 337
9.IX.	184	21		1 111	6	802		13 810
23.IX.	12	1		27	1 512	51		429
14.X.	22	38		8	468	230		514

Rok Year 1972 Data Date	Cyanophyta	Euglenophyta	Dinophyceae	Cryptophyceae	Chrysophyceae	Xanthophyceae	Bacillariophyceae	Chlorophyta
6.VI.	211	61		465	241	5	1 459	2 426
15.VI.	17	81		753	711	54	376	4 067
1973								
27.IV.	34	13		39			397	992
3.V.	39						955	2 037
10.V.	49	36	1	372	4		186	4 601
17.V.	1	1	1	8	1		7	15
25.V.	10	5		70	19	3	80	157
30.V.	4	4		25			37	42
14.VI.	37	10		55			25	38
28.VI.	260	18		527		+	241	418
11.VII.	346	116		3 760			333	1 380
25.VII.	43	3	19	636	48	3	256	445
8.VIII.	37	11		275	78	18	176	2 106
16.VIII.	29	35	23	375	43	+	126	1 575
22.VIII.	282	8		357	156	127	578	14 282
30.VIII.	1 763	194		837	174		917	10 017
13.IX.	1 835	115		223	303	67	562	5 374
27.IX.	337	188		40	159	20	218	2 814

Tabela V. Liczebność ważniejszych składników fitoplanktonu w 1 ml wody stawu Zimowy Wielki

Table V. Number of more important phytoplankton components in 1 ml water from the pond Zimowy Wielki

Rok Year 1971 Data Date	Euglena sp. div.	Trachelomonas sp. div.	Cyclotella comta	Nitzschia sp. div.	Ankistrodesmus sp. div.	Coelastrum microporum	Dictyosphaerium pulchellum	Rhaphidonema sp.	Scenedesmus sp. div.
7.IV.	+	20		40			190		270
23.IV.	110			60	20	60	1 190		91
5.V.	660	40	+		430		39 680		6 910
14.V.	10	4 790		230	16 360		264 500		23 810
17.V.	8 110	100		730	4 140		99 190	1 760	12 420
21.V.		10		110	4		4	4	20
27.V.		150	20	210	100	1 620			1 260
3.VI.	140	20	10	10		14 810			190
18.VI.			690	30	60	520			190
1.VII.	10		+	70	30	280		1	170
15.VII.	5		2	3	2	1 750			20
29.VII.	5	+	5	30	10	5			60
12.VIII.	2	5	80	5	5				10
26.VIII.			140	30		8			30
9.IX.		10	120	200	160		10		70
23.IX.			2 430	710	720	2			10

Rok Year 1972 Data Date	Euglena sp. div.	Phacus sp. div.	Cryptomonas sp. div.	Ankistrodesmus sp. div.	Coelastrum sp. div.	Dictyosphaerium pulchellum	Scenedesmus sp. div.
8.IV.	260	110		30		2	620
25.IV.	500			360		419 640	300
15.V.	2 180	660		720		190 880	1 940
31.V.	15 510	3 380		52 460		1 433 940	318 110
6.VI.	17 510	180		6 130		443 720	13 800
15.VI.	1 110	90	280	80	1		1 660
22.VI.	30	+	410	20	10		1
30.VI.	2	60	3 560	500	14 970		1 120
13.VII.	40	310	80	680	143 460		390
27.VII.	70	120		3	370		4
10.VIII.		3		+			3
25.VIII.		10	10				60
7.IX.			470	4	40		1
28.IX.			50	20	100		20
12.X.	10		80	50	10		230

Rok Year 1973 Data Date	Trachelomonas sp. div.	Cryptomonas sp. div.	Cyclotella comta	Nitzschia sp. div.	Chlamydomonas sp. div.	Volvox aureus	Ankistrodesmus sp. div.	Crucigenia sp. div.	Dictyosphaerium pulchellum	Scenedesmus sp. div.
27.IV.		850		1 000	1 430		2 170		3 000	360
3.V.	5	120	8	980	+		1 040		3 930	60
10.V.	1	40		130	2		10	+		10
17.V.		6	+	110			5			10
25.V.		3	3	50	1		2	+	+	20
30.V.		30	2	30	6		1	+	9	20
14.VI.		1 440	50	230	90	20	40		110	450
28.VI.	60	1 570	290	900	30	920	1			230
11.VII.		30	10	110	20	20	+		3	40
25.VII.	10	190	180	610	70	50	10	20	+	160
8.VIII.	100	2	300	50	40	5	20	40	130	150
16.VIII.	130	110	190	190	10	10	1	60	180	270
22.VIII.	250		460	70	80	+	80	120	610	430
30.VIII.	680	760	240	110	850	10	40	290	730	470
13.IX.		150	70	10	160		20	300	180	240
27.IX.		20	70	50	+	+	180	1 470	500	390

Rok Year 1974 Data Date	Cryptomonas sp. div.	Cocconeis placentula	Cyclotella comta	Nitzschia sp. div.	Ankistrodesmus sp. div.	Dictyosphaerium pulchellum	Scenedesmus sp. div.
8.IV.	30		160	160	2 030	1 540	210
8.V.	130		2	100	30	2	70
3.VI.	40			60	50		110
2.VII.	2	10	+	100	20	4	20
1.VIII.	280	40		6	4	5	40
27.VIII.	60	120	100	5	40	3	210
27.IX.	1 210	60	50	20	30	4	190

Tabela VI. Liczebność ważniejszych składników fitoplanktonu w 1 ml wody stawu Łąkowy

Table VI. Number of more important phytoplankton components in 1 ml water from pond Łąkowy

Rok Year 1971 Data Date	Nitzschia sp. div.	Actinastrum Hantzschii	Ankistrodesmus sp. div.	Dictyosphaerium pulchellum	Kirchneriella sp. div.	Scenedesmus sp. div.	Tetraëdron sp. div.
6.V.	3 880	7 760	6 990	10 380	1 210	890	440
14.V.	310	1 760	3 570	1 800	3 250	1 920	2 900
17.V.	10	50	150		70	90	150
21.V.			30	50		1 370	300
27.V.	10	30	50	1	10	30	30
3.VI.	1	1		2	10	110	80
18.VI.	10		3	2	1	30	30
1.VII.	90		10		10	60	150
15.VII.	20	2	30	10	10	440	360
29.VII.	60		30	20	20	220	60
12.VIII.	100	80	170	580	960	830	200
26.VIII.	60	4	90	310	50	210	140
9.IX.	180	30	410	1 810	620	1 210	500
23.IX.	30	20	730	420	40	670	70
14.X.	30		150	40	40	250	480

degree and character of macrophyte overgrowth (Łąkowy 1971, Zimowy Wielki 1972—1974). In other ponds and years only one or two stations were taken into consideration (Zimowy Wielki, 1971 outflow, Gorol 1971 and 1972 outflow, 1973 outflow and the centre of the pond).

Samples were collected of water strained through a plankton net of No 25 bolting cloth and of unfiltered water, these kinds of sample from each station being separately elaborated. The qualitative composition of the phytoplankton is shown in Table I; the quantitative data were calculated per 1 ml water and are shown in Tables II—VII, while zonation in the occurrence of algae will be the subject of a separate work.

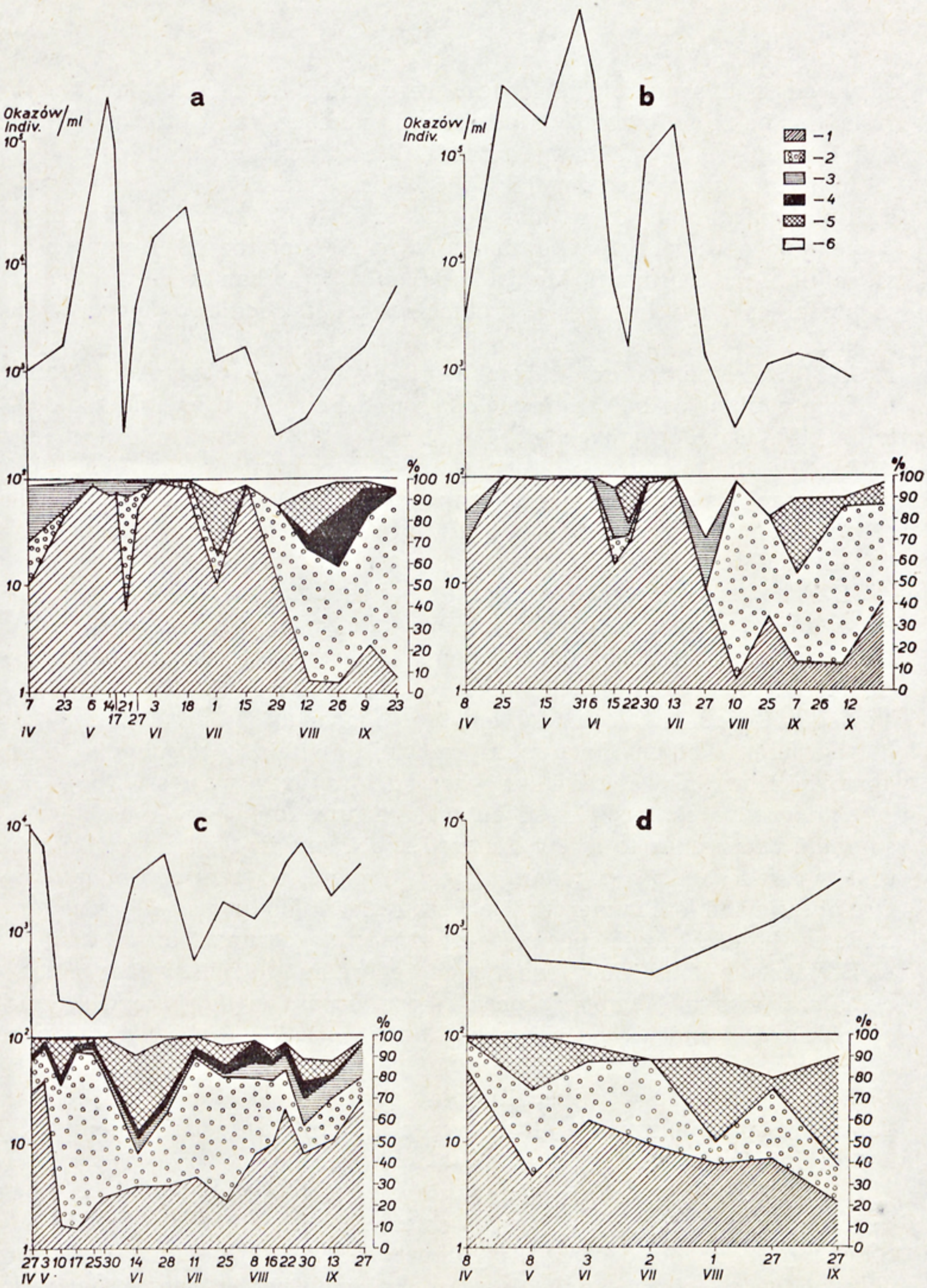
Results

In 1971 in Zimowy Wielki the most abundant growth of algae was observed in May, their mass development being noted on 14th followed by a decrease in number. In the next year very large numbers of algae

Tabela VII. Liczebność ważniejszych składników fitoplanktonu w 1 ml wody stawu Gorol

Table VII. Number of more important phytoplankton components in 1 ml water from the pond Gorol

Rok Year 1971 / Data Date	Cryptomonas sp. div.	Dinobryon divergens	Dinobryon sp. div.	Synura uvella	Ankistrodesmus sp. div.	Crucigenia sp. div.	Coelastrum sp. div.	Dictyosphaerium pulchellum	Kirchneriella sp. div.	Scenedesmus sp. div.	Tetraëdron sp. div.	Oocystis sp. div.	Merismopedia sp. div.	Nitzschia sp. div.	Chlamydomonas sp. div.
14.V.	2 000				2	30		30	10	350	1				
17.V.	930				20	10		+	20	150					
21.V.	+				40					1					
27.V.	3				+	+		+	+	10	+				
3.VI.	10				2	+		30	2	20	2				
18.VI.	1		+		50	2			50	660					
1.VII.	30				3	2	1		20	10	1				
15.VII.	210				250	250	250			290	120				
29.VII.	1 100			10	30	100	40	80	50	110	40				
12.VIII.	400		4 930		4 290	2 120	790	960	4 500	4 100	790				
26.VIII.					80	840	400	250	160	3 100	320				
9.IX.	1 110			2	160	11 080		330	640	960	10				
23.IX.	30			1 510	10	210			30	110	20				
14.X.	10		140	330	20	140		10		280	10				
1972															
6.VI.	470	240				130	1 270	40		340	170	40			
15.VI.	750	710				1 240	10	700		270	700	650			
1973															
27.IV.	40				130		10	210	10	260	10			250	330
3.V.					260	20		930	10	510	60			370	20
10.V.	370				140		10	4 080	60	180	10	40	10	70	10
17.V.	10				3	+	2	2	1	4	1		+	3	
25.V.	70				20	5	10	3	20	60	10	2	+	30	
30.V.	30				3	5				20	3		3	10	5
14.VI.	60				4	3	1		+	20	3	1	10	10	1
28.VI.	530				30	30		30		170	+	20	170	100	100
11.VII.	3 760				60			780	1	370				80	60
25.VII.	640				20	100		50	5	220		30		5	
8.VIII.	280				90	270	560	380	+	280	120	30	3	30	100
16.VIII.	370				1	330	350	90	20	360	70	180	20	1	
22.VIII.	360				80	1 750	6 450	1 660	480	1 490	870	680	280	150	360
30.VIII.	840				80	2 890	3 220	710	200	2 260	240	600	1 860	60	+
13.IX.	220				70	2 140	1 320	230	150	960	200	20	1 790		20
27.IX.	40				80	1 350	30	300	280	620	50	40	310	50	



Ryc. 1. Sezonowa zmienność liczebności fitoplanktonu oraz procentowy udział poszczególnych grup systematycznych w stawie Zimowy Wielki w latach: a — 1971, b — 1972, c — 1973, d — 1974, 1 — *Chlorophyta*, 2 — *Bacillariophyceae*, 3 — *Euglenophyta*, 4 — *Cyanophyceae*, 5 — *Cryptophyceae*, 6 — inne

Fig. 1. Seasonal changes in the numbers of phytoplankton and the percentage share of particular systematic groups in the pond Zimowy Wielki in: a — 1971, b — 1972, c — 1973, d — 1974, 1 — *Chlorophyta*, 2 — *Bacillariophyceae*, 3 — *Euglenophyta*, 4 — *Cyanophyceae*, 5 — *Cryptophyceae*, 6 — other

appeared in this pond. The largest were noted from 25th May to 6th June, this being followed by a decrease in number, except for 30th June and 13th July. The maximum numbers were found on 31st May.

In periods of greatest development *Chlorophyta* were dominant, especially those from the order *Chlorococcales* (Table I). They showed a large percentage occurrence, amounting to over 90% of the total number of algae (fig. 1a). Later on, in August and September, when the development of algae was less intense, a greater share of *Bacillariophyceae* was noted.

In 1973 a much poorer development of algae was observed, *Chlorophyta* prevailed as before, especially on the first two sampling dates, followed by *Bacillariophyceae*.

In 1974 the numbers of algae were equally small in this pond, the largest numbers being found in April, August, and September. In general, green algae and diatoms developed more abundantly than others.

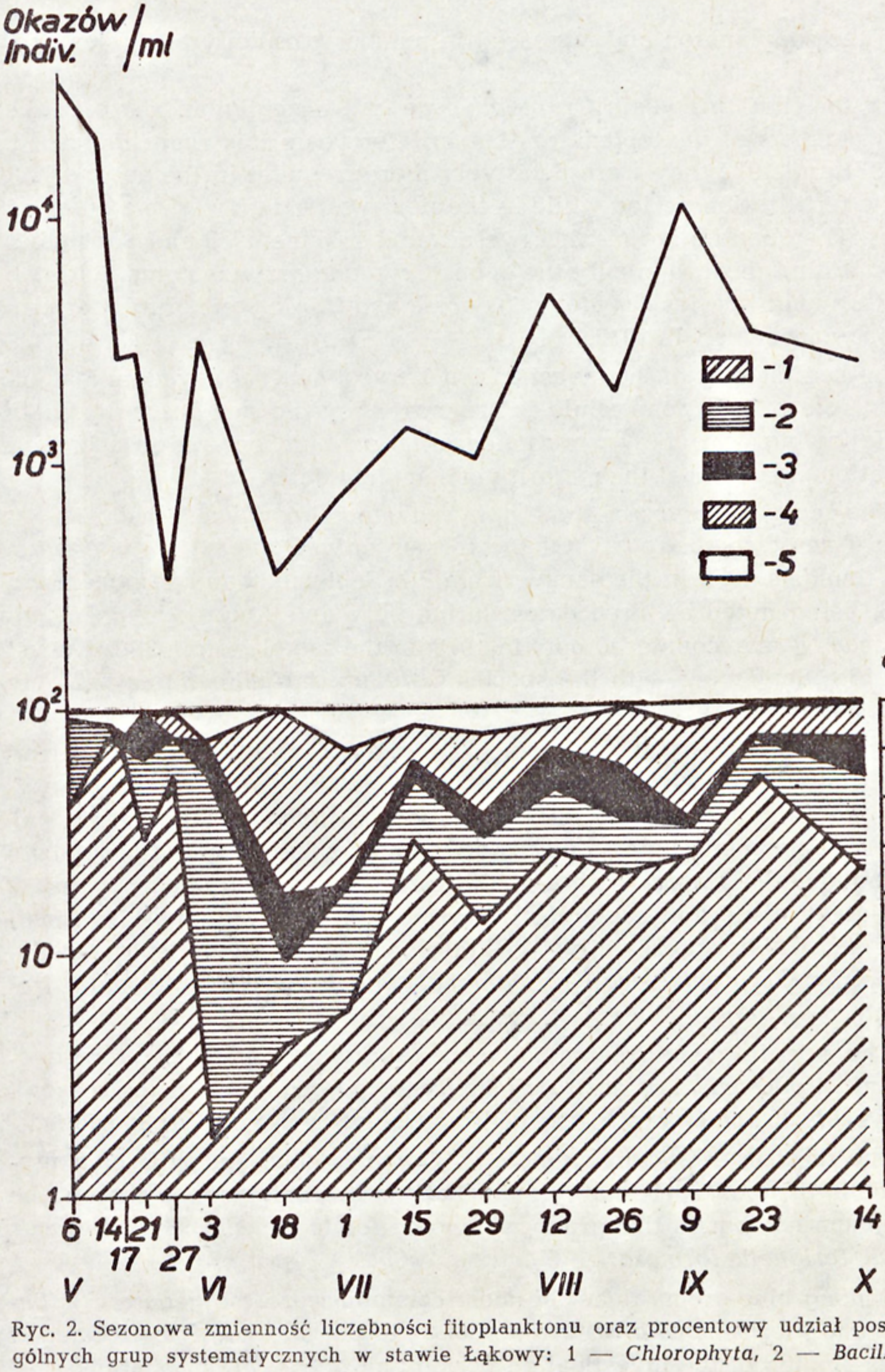
Among green algae *Chlorococcales* usually dominated (Tables V—VII). The genus *Scenedesmus*, with the most common species *S. acuminatus* and *S. acutus*, showed continuity of occurrence while as a rule *Dictyosphaerium pulchellum* and genus *Ankistrodesmus* dominated periodically. Among diatoms the most frequent were: *Cyclotella, Nitzschia, Navicula, Cocconeis placentula*, and *Gomphonema*. The greatest qualitative variability of phytoplankton, especially within *Chlorophyta*, was observed from July, at the later dates of filling with wastes.

Cyanophyta always played an insignificant role, being noted from sporadic occurrence to a few hundred specimens in 1 ml water. In the first two years only two genera appeared: more frequent and numerous *Oscillatoria* and less numerous *Merismopedia*, noted on a smaller number of dates. In 1971 single specimens of *Anabaena* occurred on two dates. Besides the above-mentioned, such genera as *Aphanizomenon, Phormidium, Lyngbya, Gomphosphaeria, Aphanocapsa*, and *Microcystis* appeared in 1973 and 1974. *Merismopedia* and, in 1972, *Anabaena* occurred in the largest numbers.

Blue-green algae were usually more numerous at later dates, in August and September, and in all the years of the investigation constituted an insignificant percentage of algae as a whole.

In the first two years euglenins developed more abundantly at the beginning of the vegetation season, chiefly in May and June, but in the following years this occurred in August and September. Taking into account the data from the whole season, a small percentage of the total number of algae was calculated for this group in all the years of the investigation. Among the observed euglenins more frequently encountered were *Euglena, Trachelomonas* (chiefly *T. hispida* and *T. volvocina*), *Lepocinclis*, and *Phacus*.

Epizoophytic algae of the genus *Colacium* had a distinct connection



Ryc. 2. Sezonowa zmienność liczebności fitoplanktonu oraz procentowy udział poszczególnych grup systematycznych w stawie Łąkowy: 1 — *Chlorophyta*, 2 — *Bacillariophyceae*, 3 — *Euglenophyta*, 4 — *Cyanophyceae*, 5 — inne

Fig. 2. Seasonal changes in the numbers of phytoplankton and the percentage share of particular systematic groups in the pond Łąkowy: 1 — *Chlorophyta*, 2 — *Bacillariophyceae*, 3 — *Euglenophyta*, 4 — *Cyanophyceae*, 5 — other groups

with the zooplankton and increased in number parallelly to its development.

In the first two years *Cryptophyceae* had a negligible share in the total numbers of phytoplankton, but in later years this share increased. In 1971 and 1972 they were decisively more frequent in the second half of the fertilization period while in the next years they were noted at all dates. The quantitative maxima were found in June 1973 and September 1974. Within this group only the genus *Cryptomonas* was noted, with the most common species *Cryptomonas erosa* and *C. Marsonii*, the latter prevailing particularly in 1972.

In the first year of the investigation *Chrysophyceae* played an insignificant role in this pond while in the next they did not occur at all. In the following years they were noted in larger numbers and in a greater variation of species at the majority of sampling dates.

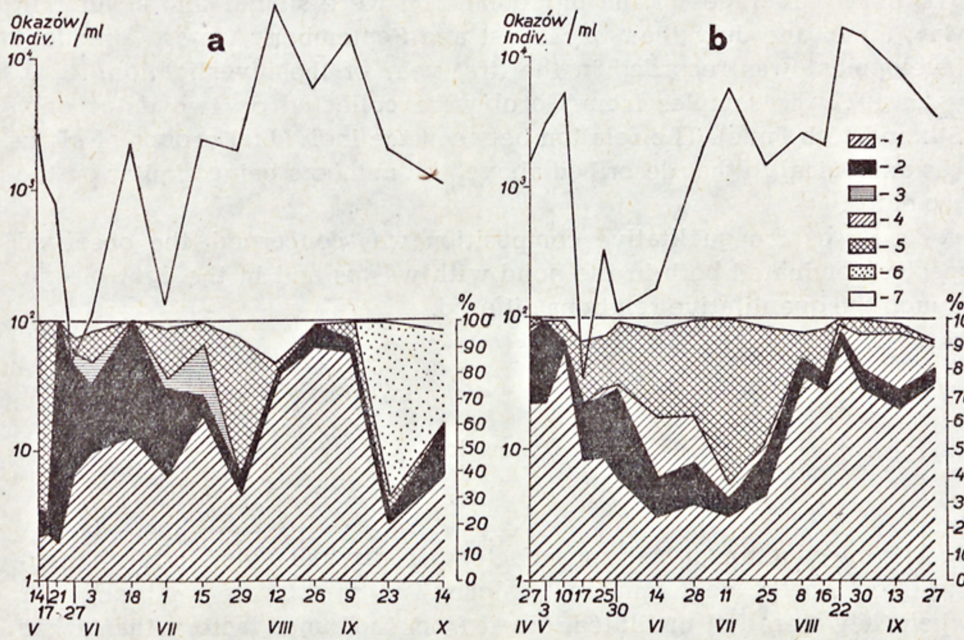
The representatives of *Xanthophyceae* and *Dinophyceae* were sporadically noted in this pond. Of the former only *Ophiocytium capitatum* was found in 1972 in the sample from 7th September and *Tribonema* in 1973, being noted at three dates during July and August. Single *Dinophyceae* were encountered only in 1973, in the samples from 30th August and 13th September with the species *Ceratium hirundinella* as the only representative.

In Łąkowy the greatest amounts of algae occurred in the first half of May (fig. 2), after which a distinct decrease in their number was observed. *Chlorophyta* dominated, attaining another, though smaller maximum, on 9th September. Diatoms occurred in much smaller, uniform numbers throughout the season, with a quantitative domination at its beginning. Blue-green algae and euglenins occurred continually though in small numbers, while representatives of other groups were found sporadically, except for *Cryptophyceae (Cryptomonas)* which were slightly more frequent.

The most frequent green algae were *Chlorococcales* mainly the genera *Ankistrodesmus, Actinastrum* (chiefly at the beginning of the season), *Dictyosphaerium, Oocystis, Tetraëdron, Coelastrum,* and *Kirchneriella.*

The diatoms *Navicula, Cyclotella, Gomphonema,* and *Nitzschia* prevailed in this pond, while at one time, at the beginning of the season, the maximum number in this group was noted for the species *Synedra acus* and *Asterionella formosa.*

Among blue-green algae the most common were the genera *Oscillatoria* and *Merismopedia,* with a tendency to prevalence of the former at the beginning of the investigation period and of the latter at later dates. The genus *Oscillatoria* was frequently the only representative of this group, while *Anabaena* and *Aphanizomenon flos aquae* occurred in greater numbers only periodically in midsummer.



Ryc. 3. Sezonowa zmienność liczebności fitoplanktonu oraz procentowy udział poszczególnych grup systematycznych w stawie Gorol w latach: a — 1971, b — 1973, 1 — *Chlorophyta*, 2 — *Bacillariophyceae*, 3 — *Euglenophyta*, 4 — *Cyanophyceae*, 5 — *Cryptophyceae*, 6 — *Chrysophyceae*, 7 — inne

Fig. 3. Seasonal changes in the numbers of phytoplankton and the percentage share of particular systematic groups in the pond Gorol in: a — 1971, b — 1973, 1 — *Chlorophyta*, 2 — *Bacillariophyceae*, 3 — *Euglenophyta*, 4 — *Cyanophyceae*, 5 — *Cryptophyceae*, 6 — *Chrysophyceae*, 7 — other groups

In Gorol the most abundant occurrence of algae in 1971 and 1973 was noted in August and in the first half of September (fig. 3), *Chlorophyta* being the only representatives. They were a constant component of the plankton, but were rather more important in a later period.

Cryptophyceae were always present but much less numerous. The greatest number of their representatives was found in 1971 on 14th and 17th May, and on 29th July, and in 1973 on 11th July.

Diatoms also were a constant component of the plankton. Although their numbers were similar throughout the season, they constituted a much greater percentage in relation to other algae in the first half of the fertilization period than in later months.

Chrysophyceae developed somewhat later, reaching a maximum in August and September, though their number was smaller.

Blue-green algae and euglenins were found in all samples, their development being rather poor, while the representatives of *Dinophyceae* and *Xanthophyceae* were noted only sporadically.

Monthly averages of the phytoplankton were similar and smaller in May, June, and July than in August and September. A more abundant development was recorded in the first year of the investigation.

In 1972 the samples from Gorol were collected on two dates only (6th and 15th June). The relation between the individual groups of algae was analogical to that described above, the numbers being similar on the two dates.

As far as the qualitative composition was concerned, the observed species dominated both in the pond with wastes and in the control one, though the quantitative relations differed.

Discussion

The introduction of beet sugar factory wastes had a distinctly stimulating effect on the development of algae. This effect was much stronger when they were fed undiluted, direct from the sugar factory than when their concentration was lower. With undiluted wastes an initial mass development of algae was noted, a rapid decrease in numbers and poor development being observed in the second half on the season (figs 1 and 2). This system was more pronounced after 6 years of treatment with wastes (1977) than after 5 years.

In May, with maximum numbers of algae, a change from anaerobic to aerobic conditions was noted. A rapid reduction of phytoplankton followed and zooplankton began to appear.

The final products of mineralization are a basis for the development of eutrophic plants, these in turn being food for animals.

Besides the exhaustion of nutritive substances, the chief reason for the disappearrance of phytoplankton was the development of the zooplankton. As reported by M. Lewkowicz and S. Lewkowicz (1975), during 24 hrs the water of the discussed waste pond could be repeatedly filtered by the occurring rotifers and cladocerans.

Vollenweider (1968) gives the values of concentration of nitrogen and phosphorous compounds above which a mass development of algae is observed. Large quantities of nitrogen and phosphorus introduced to a pond with beet sugar wastes favour a mass development of phytoplankton, especially of *Chlorophyta* of the order *Chlorococcales*. According to Guseva (1952), quoted according to Kadłubowska (1975), the greatest demand for nitrogen compounds has been noted in *Chlorophyta*, a smaller one in *Cyanophyta*, and the smallest in *Bacillariophyceae*.

K y s e l o w a (1973) found *Volvocales* (chiefly *Chlamydomonas*) and *Euglenophyceae* to occur in the first stage of succession, while in the present investigation *Chlorococcales* were found almost alone in the initial period. As S t a r m a c h (1969) reports, chlorococcous algae are relative autotrophs, thus — like *Volvocales* and *Euglenophyceae* — they can use the organic matter dissolved in water. S i v k o et al. (1967) and I l č e n k o et al. (1969) also reports chlorococcous algae from ponds with beet sugar factory wastes.

In the years after cessation of feeding of undiluted wastes the development of algae was much less dynamic (figs 1c, d and 3b). However, the consequent effect of the wastes was manifested by an increase in the numbers of algae and by early maxima, right at the beginning of the season. This was also true of the pond with diluted wastes, while in the control one a gradual increase in the number of algae and late maxima (in August and September) were observed.

M. L e w k o w i c z and S. L e w k o w i c z (1975) give the greatest values of COD and BOD, oxidability, and total nitrogen for the pond with undiluted wastes in the initial period of the investigation. These values were also much greater in 1972 than in 1971. In the following years in all three ponds much smaller values were determined for these parameters. The chlorophyll content given by the above mentioned authors is connected with the occurrence of phytoplankton, the degree of its vitality and decay, and particularly, with its maximum and minimum numbers.

Z y g m u n t o w a (1977) elaborated the content of protein dissolved in the water in the pond with undiluted wastes and in the control one in 1972. She found much larger amounts of protein in the first pond, the maximum values occurring at dates which followed the phytoplankton maxima.

The succession of phytoplankton also obviously depended on the concentration of wastes. The stronger it was, the more distinctly *Chlorophyta* of the order *Chlorococcales* almost exclusively dominated the environment, being later followed by *Bacillariophyceae*.

According to P a t r i c k (1962), certain species of blue-green, brown, and green algae and of diatoms may be useful in evaluation of the chemical and physical properties of water and of the degree of its pollution. Numerous species were classified as tolerant of wastes.

K a d ł u b o w s k a (1970) discussed the dependences between the occurrence of diatoms and the purity of water. According to this author, the number of diatom species decreased under the influence of wastes, rapidly increased after they were decomposed, and was definitely dependent on the oxygen content in the water.

It was also observed that *Euglenophyta* and *Volvocales* had a tendency to appear earlier though in small numbers, with a small share of other systematic groups. The former are regarded as very tolerant of organic pollution, while the latter are noted in both pure and slightly polluted waters and in environments with more serious organic pollution (Palmer 1969, Fjerdingstad 1964).

The poor development of some common blue-green algae (e.g. *Anabaena, Aphanizomenon,* and *Microcystis)* which frequently bloom on other fry and nursery ponds at Gołysz, was particularly striking. The stronger were the wastes, the later they appeared, while the genus *Oscillatoria* proved most resistant to the wastes and was most frequently noted. This genus is usually reported from strongly polluted environments, often together with *Sphaerotilus, Zoogloea ramigera,* and other polysaprobic organisms (Cabejszek 1951). According to Patrick (1962) this genus is very tolerant of wastes. Opaliński (1972) also found an abundant growth of *Oscillatoriales* in waters fertilized with great amounts of organic and mineral compounds. As Spodniewska (1971) found, the blue-green algae tolerate better than the others the deficit of mineral forms of nitrogen and, owing to this property, they dominate the environment after these compounds have been exhausted by algae with higher nutritive demands. On the decay of the latter considerable amounts of ammonia appear, this creating particularly favourable conditions for the development of *Microcystis aeruginosa* and *Aphanizomenon flos aquae.*

Cryptophyceae, chiefly *Cryptomonas erosa,* occurred in small numbers in the periods when wastes were introduced and were not noted before the second half of the season. After the inflow of wastes stopped, they were a constant component of the phytoplankton, as in the control pond. Liebmann (1951) and Kaufmann (1958) noted them in polluted waters while Huber-Pestalozzi (1961) considers them to be eutrophic, noted both in oligo- and polytrophic waters. According to Kyselowa (1973), these algae adapt rather in periods of more advanced destruction, thus of greater or even complete mineralization of the environment.

In all ponds small numbers of *Chrysophyceae* were noted but they played a particularly insignificant role in the ponds treated with wastes. In Zimowy Wielki they were not noted at all in 1972. Kyselowa (1973) also found that under such conditions they appeared rarely and in small numbers.

Kyselowa (1977) elaborated the algae from the surface of bottom sediment (calculated per 1 g of dry matter) in Zimowy Wielki in 1974. She found the most abundant growth of algae in the mud at the first sampling date, when their maximum number was also noted in the water. Both in the mud and water a gradual decrease in numbers was observed, but contrary to the water, in the mud diatoms were much more numerous than green algae. Many species were noted as common for the two environments.

It is worthy of note that algae which usually live a sedentary life constituted a considerable admixture of the plankton. This is frequently observed in carp ponds owing to the water being mixed to the bottom by the wind and to the disturbance of the surface layer of bottom sediment by fish searching for food.

In the control pond a different system was found. Above all, representatives of various systematic groups were noted. *Cyanophyta* and *Chrysophyta*, especially of the genus *Dinobryon* were frequently observed. *Bacillariophyceae*, occurring constantly, were more numerous at the beginning of the season, while *Chlorophyta* attained dominance in its second half, maxima being noted in midsummer.

It should be stressed that the species *Pteromonas angulosa Lemm.* was repeatedly observed in Zimowy Wielki although its numbers were small. Though this species is noted in various environments it also shows allegiance to polluted waters. It was found for the first time at Gołysz, not having been noted in ponds of this region before.

In the ponds with wastes the dominant *Dictyosphaerium pulchellum* usually occurred in single cells or in tetrads. In almost all the variously treated ponds investigated by the author over many years this species developed frequently and abundantly in the form of typical colonies. It seems that this was the effect of wastes, since the species was also noted in the form of single cells (similar to *Chlorella*) in the water of the River Dunajec (below the inflow of wastes from the Nitro-Plant in Tarnów), used in laboratory tests for the elimination of nitro-compounds from wasters (Dr. H. B u c k a, personal communication).

Similarly, other species, and chiefly *Scenedesmus*, showed a tendency to occur as single cells, in waters treated with sugar factory wastes.

In August 1972 the surface of the pond Zimowy Wielki was covered with a thick layer of duckweed over a large area. It was striking that in the samples from this period, at the deepest point near the outflow where the water surface was clear (without duckweed or vascular plants), *Chlorococcales* constituted 63%, *Cyanophyta* 19%, and *Bacillariophyceae* 14% of the total algae, while in more shallow points, in the centre of the pond and at the inflow, with the water surface covered by duckweed, diatoms occurred almost alone (96% in the centre of the pond, and 99% at the inflow). In contrast to green algae, which in the periods of mass growth of duckweed developed most abundantly in the clear part of the pond and least numerously in the most covered one, euglenins showed a tendency to appear in the largest numbers at the inflow, smaller numbers in the centre of the pond, and smallest at the outflow.

In connection with the development of phytoplankton in ponds with beet sugar factory wastes, its mass appearance in the initial period and a rapid decrease afterwards should be stressed here. In 1972 the maximum amounted to as many as 2 million specimens in 1 ml water. According to Starmach (1955), water bodies of the oligotrophic type contain about 1000 phytoplankton cells in 1 ml water, eutrophic water bodies about 10 000, and very fertile enriched ponds about 100 000—1 000 000 cells. One should also take into account the fact that in the discussed ponds the numbers of occurring forms were computed, i.e. both cells and colonies or filaments, hence the obtained results are reduced as compared with the data given by the above-mentioned author.

As has been shown, the effect of diluted wastes was much poorer, therefore the observed changes in succession and numbers were not so rapid.

The prolonged inflow to the pond of undiluted sugar factory wastes favoured a periodical excessive growth of algae and changed the natural order of other trophic levels. A later excessive development of zooplankton, which, inter alia, resulted in a decrease in the numbers of algae and bacteria, the accumulation of the products of metabolism, and the worsening of oxygen conditions (M. Lewkowicz, S. Lewkowicz 1977), deteriorated the pond environment in the subsequent years. In order to prevent conditions unfavourable for proper fish culture it is advisable to select the concentrations of beet sugar factory wastes introduced into fish ponds as an active factor of fertilization.

STRESZCZENIE

Praca dotyczy zmian w jakościowym i ilościowym składzie planktonu roślinnego, przy zastosowaniu ścieków z cukrowni o różnym stężeniu, do nawożenia stawów karpiowych. Opiera się na materiale zbieranym z trzech stawów, w latach 1971 do 1974.

Stosowanie ścieków z cukrowni wpływało stymulująco na rozwój glonów, i to tym silniej, im silniejsze było ich stężenie.

Również sukcesja fitoplanktonu była wyraźnie zależna od stężenia ścieków. Im było ono silniejsze, tym obficiel opanowywały badane środowisko stawowe, najpierw prawie wyłącznie *Chlorophyta* z rzędu *Chlorococcales*, później *Bacillariophyceae*. Dominantami pierwszych były głównie gatunki z rodzajów *Scenedesmus*, *Ankistrodesmus*, *Dictyosphaerium*, *Oocystis*, *Tetraedron*, *Coelastrum* i *Kirchneriella*, drugich *Cyclotella*, *Nitzschia*, *Navicula*, *Cocconeis* i *Gomphonema*.

Przy doprowadzaniu ścieków nie rozcieńczonych obserwowano masowy pojaw glonów w pierwszym okresie, z gwałtownymi spadkami ich liczby oraz słabym rozwojem w drugiej połowie sezonu.

W latach, po zaprzestaniu doprowadzania ścieków, rozwój fitoplanktonu był znacznie mniej dynamiczny. Notowano jednak działanie następcze ścieków, wyrażające się w zwyżce liczebności glonów oraz wczesnych maksimach, zaraz na początku sezonu.

Natomiast staw kontrolny charakteryzował wzrost liczebności glonów z czasem oraz późne maksima, bo w sierpniu i we wrześniu.

Plankton zwierzęcy rozwijał się później niż roślinny. Jego nadmierny rozwój, wpływający m. in. na obniżenie ilości glonów i bakterii, nagromadzenie produktów rozkładu materii i ujemne zmiany warunków tlenowych, pogarszały w ciągu kolejnych lat środowisko stawowe.

Podsumowując całość wyników można uznać ścieki cukrownicze za efektywny element nawożeniowy stawów rybnych, jednak pod warunkiem odpowiedniego doboru ich stężenia.

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