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Sociological studies on the phytoplankton in Lake Garbaś (Ełk Lake District, northeastern Poland)

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Abstract — The paper deals with investigations of net phytoplankton and nannoplankton and attempts to distinguish and describe the communities of phytoplankton in the mesotrophic Lake Garbaś. The quantitative analysis of 205 algological samples showed the presence of 375 taxa of algae. From the phytosociological aspect, the species *Dinobryon divergens* was considered to have the greatest diagnostic value, hence the community described was called *Dinobryon divergens planctonicum mesotrophicum*.

Key words: lakes, phytoplankton, communities, ecology, taxonomy

1. Introduction

The process of eutrophication of lakes with all its negative results has recently been greatly accelerated by anthropogenic factors. It is a worldwide phenomenon, for years critically observed by hydrobiologists (Davis 1964, Hutchinson 1967, Vollenveider 1968, Kajak 1979, Hilbricht-Ilkowska 1986).

In order to deepen knowledge of the reasons for eutrophication, the catchment basin of Lake Garbaś in the Ełk Lake District was selected as the first Polish monitoring station of the environment of the subsystem GEMS (Global Environment Monitoring System), system GSMOS-RWPG (Globalnaya Sistiema Monitoringa Okruzhayushchey Sriedy — Council of Mutual Economic Aid) (Breymeyer 1984, 1985).

The algae of Lake Garbaś have not hitherto the subject of ecological and sociological investigation. Therefore the intention of the present work was to carry out the fullest possible characterization of the phytoplankton of this lake.

This study comprises detailed research on the net phytoplankton and nannoplankton of Lake Garbaś and constitutes an attempt to distinguish and describe the phytoplankton communities there. Thus, the study is a basic material for directing further works aimed at establishing the mechanism and range of changes in algal phytocenoses, caused by increasing anthropopressure. The data obtained might also be of practical importance in solving current fishing and sanitary problems.

2. Study area

The Ełk Lake District is a mesoregion of very varied relief, composed of a few smaller units as yet poorly known (K o n d r a c k i 1972).

Lake Garbaś is situated in the southern Ełk Lake District near the village of Liski. The water from this area drains into the River Ełk which falls into the River Biebrza. The catchment area of Lake Garbaś is altogether 400 ha, of which 150 ha are forest, 109.8 ha arable, 72 ha pastures, 46.1 ha water, 17.5 ha meadows, and 4.6 ha sedgeland.

The lake lies at an altitude of 129.8 m and has the shape of an elongated rectangle running evenly with a parallel of latitude and a slightly wavy bank line. The surface film measures 42.5 ha, while maximum length is 1300 m, maximum width 450 m, maximum depth 38 m, average depth 10.2 m, bank line of the lake basin 3400 m, capacity 4342.6 · 10^3 m^3, and pH 7.0—7.5.

The lake fills a depression in the land among morainic hills of the II phase of Baltic glaciation. The lake bottom is formed by outwashed sands.

The southern, western, and northern banks are formed by morainic hills and kame knolls from 178 to 194 metres, while the hills surrounding the eastern bank are lower, up to 149 metres in alititude. The incline of the hills surrounding the lake reaches up to 5° in the eastern part and up to 30° in the southern one. The hills to the south of the lake are cut by four valleys, two of which are periodically filled with water.

Currently, the lake has four small inflows, one of which on the eastern part of the lake is a drainage canal (fig. 1). They all collect water from the fields and meadows of the village of Liski. Lake Garbaś has one outflow on the north-eastern side carrying the water to Lake Rekąty.

The bank line of the lake is surrounded by dense cleading of the Alno-Padion Knapp 1942 em Medw.-Korn. ap Mat. et Bor. 1957 type and with a dense area of mixed forests and woods with a domination of *Pinus silvestris* L.

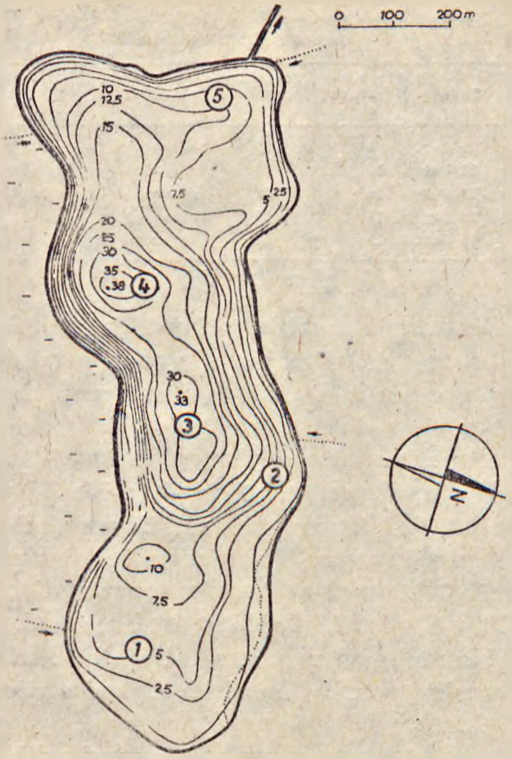

Fig. 1. Bathometric design of Lake Garbaś with sampling stations (1—5)

The littoral vegetation is well formed especially in the bays and curves of the lake. It is composed of the following alliances: *Charion fragilis* Krausch 1964, *Nitellion* Dąmbska 1966, *Potamogetonion* (W. Koch 1926), Oberd. 1957, *Nymphaeion* W. Koch 1926, *Phragmition* W. Koch 1926, and *Magnocaricion* W. Koch 1926 (Endler et al. 1988).

The investigations were carried out at five stations comprising as far as possible all the microhabitat types within the lake (fig. 1).

The temperature of the air and of the surface layers of water and the colour and transparency of the water (visibility of Secchi disc) during the investigations carried out at Station 4 are presented on Table I.

3. Material and method

The investigations were carried out in the periods most representative for spring, summer, and autumn. The material was taken on 25 April, 21 May, 19 July. 19 September, and 18 October 1988 at the same time from five stations.

Table I. Some typical ecological factors in Lake Garbaś in 1988 at Station 4

Date	Air temperature °C	Water temperature °C	Colour of water	Transparency of water cm
25 Apr.	6	5	greenish	820
21 May	19	18	greenish	760
19 July	26	22	greenish	660
19 Sept.	15	15	olive-green	640
18 Oct.	14	12	olive	520

The samples were taken with a Ruttner sampler in the water column at every 2 m, the first sample being taken at a depth of 10—20 cm below the surface, and the last most frequently at 1 m above the bottom or very close to it.

For qualitative analysis of the phytoplankton 10 dm^3 of water was collected from every level, poured through a No 25 plankton net, and then condensed to 0.1 dm^3. From the same levels and at the same time 0.5 dm^3 of unstrained water was taken for investigations of the nannoplankton and 2 dm^3 of water for quantitative analysis of the phytoplankton (Chudyba 1979, Chudyba et al. 1987).

At one time 41 samples were taken. Altogether, in the whole period of research 205 samples from different levels and stations were collected and examined (fig. 1).

The net plankton in the area was conserved with an ethyl alcohol mixture with formalin in the ratio 3:1 with an addition of thymol, and the nannoplankton with concentrated Lugol's solution. The samples for quantitative analysis were placed in calibrated cylinders and elaborated by Starmach's method (Starmach 1963, Chudyba et al. 1987). The species composition and the quantitative relations of diatoms were evaluated on the basis of solid preparations fixed in pleurax (Siemińska 1964).

The sociological analysis of the collected material was carried out on the basis of Starmach's criteria (Sosnowska 1974, Chudyba 1979). In evaluating the numbers of algae a 6-degree scale was used:

\+ — species occuring very seldom. The organism occurs singly, not in each preparation. Altogether there are 1—6 specimens in 3 preparations.

1 — species occurs singly. Altogether there are about 10 specimens on the standard surface equal 20 mm^2.

2 — species occurring in small numbers. Altogether about 50 specimens on the standard surface.

3 — species of medium numbers. 1—3 specimens in almost every field of vision. Altogether about 100—150 specimens on the standard surface.

4 — species occurring in large numbers. 4—5 specimens in almost every field of vision. Altogether about 250 specimens on the standard surface.

5 — species occuring in very large numbers. It predominates absolutely, as more than 5 specimens occur in every field of vision. Altogether more than 250 specimens on the standard surface.

Constancy was determined by a 5-degree scale: V — species occurring in 81—100% of photographs, IV — 61—80%, III — 41—60%, II — 21—40%, I — 1—20%.

As a result of the microscopic analysis a species list of algae from this lake was drawn up with the numbers and constancy of particular taxa. This list represents algae from a euphotic habitat, in which the phytoplankton reached the fullest picture as to quality and quantity and was characterized by natural vitality. The samples of this layer constituted the main basis for further considerations of phytosociological or ecological nature.

The term phytoplankton was used to determine all the algae floating in the water, thus organisms constantly or transiently and fortuitously living in the water mass. All the plankton organisms were treated as single individuals regardsless of the form in which they occurred (filaments, colonies, etc.).

The characteristics of the plankton development were based on the dominant species, that is those having the highest degree of numbers and the greatest degree of conastancy. The dominants distinguished allowed comparison of lakes in relation to the similarity of conditions deciding their number and species composition.

4. Results

As a result of analysis of algological samples, altogether 375 taxonomic algal units were found. The participation of representatives of particular systematic groups is given in Table II. Chlorophyta constituted the most numerous group with regard to the number of species — 37.0% of all determined taxa (Tables II, III). Among them the dominants

Table II. Floristic spectrum of algae in the epilymnetic layer of Lake Garbaś in 1968

Systematic groups	Number of taxa					
	25 Apr.	21 May	19 July	19 Sept.	18 Oct.	total
Cyanophyta	14	43	40	37	29	48
Euglenophyta	16	16	15	12	8	26
Pyrrophyta	17	15	12	14	9	19
Chrysophyceae	15	31	30	18	7	37
Bacillariophyceae	96	60	30	63	75	96
Xanthophyceae	4	4	2	2	1	5
Chlorophyta	39	70	95	103	57	139
Cherales	2			3	1	5
Total	203	239	232	253	187	375

Table III. List of algal taxa collected from Lake Garbad with reference to their mean numbers (Arabic numerals) and constancy (Roman numerals)

Taxa / Date	25 Apr. 1988	21 May 1988	19 July 1988	19 Sept 1988	18 Oct. 1988
1	2	3	4	5	6
Cyanophyta					
Achroonema articulatum Skuja			+.II	+.I	
- simplex Skuja			+.I		
Anabaena circinalis Rabh.		1.II	2.V	1.IV	1.II
- flos-aquae Naeg.		+.II	2.V	1.IV	1.II
- flos-aquae Naeg. f. lemmermannii Con		+.II	1.IV	+.II	
- solitaria Kleb.	+.I	1.IV	3.V	2.V	1.IV
- solitaria Kleb. f. planctonica Kom.	+.II	2.III	5.V	1.II	
- spiroides Kleb.	+.I	1.III	3.V	5.V	5.V
- spiroides Kleb. f. crassa Elenk.		1.II	2.IV	1.V	1.III
Aphanothece clathrata West	+.I	+.II	1.IV	2.V	+.II
- saxicola Naeg.	+.I	+.III	1.IV	1.IV	+.III
- stagnina Petera.		+.II	1.IV	3.V	1.III
Dactylococcopsis planctonica Tell.		+.II	1.IV		
Dermocarpa solitaria Coll.		+.I	2.V		
Gloeocapsa limnetica Hollerb.		+.I	1.IV	2.IV	+.II
- elabr Hollerb.			+.IV	3.V	1.IV
- minuta Hollerb.		+.II	1.IV	2.V	+.II
Gomphosphaeria aponina Kütz.		+.II	1.III	+.I	+.II
- fusks Skuja		+.I	1.IV	3.V	1.IV
- lacustris Chod.		+.I	+.II	+.IV	+.II
- nasgeliana Lemm.		+.II	1.IV	+.I	
Lyngbya endophytica Elenk.		+.I	+.II	1.IV	+.II
- intermedia Gard.		+.I	+.IV		
- limnetica Lemm.		+.II	+.III	1.IV	+.II
- ochracsae Thur.		+.III	+.IV	1.V	
Merismopedia elegans Lemm.			+.II		
Merismopedia elegans Braun		+.I	+.II	+.I	+.II
- tenuissima Lemm.		+.I	+.II	+.IV	1.IV
Microcystis aeruginosa Kütz.	+.I	+.V	2.V	3.V	3.V
- aeruginosa Kütz. f. flos-aquae Elenk.		+.III	1.IV	2.V	1.V
- grevillei Elenk.		+.I	1.IV	2.V	+.III
- marginata Kütz.		+.I	1.IV	1.V	+.II
- viridis Lemm.	+.I	+.III	1.V	2.V	+.II
Nodularia spumigena Mert.			+.II		
Oscillatoria agardhii Gom.	+.I	1.II	1.III	+.II	1.V
- amphibia Ag.	+.I	1.IV	+.II		
- chalybaea Gom.	+.II	+.IV	+.V	1.IV	+.III
- geminata Gom.		+.I	+.I		
- irrigua Gom.	+.I	1.IV	+.IV	+.III	+.II
- lacustris Geitler	+.I	1.IV	+.IV	+.II	+.I
- ornata Gom.		+.I	+.II	1.IV	+.II
- redeckei V.G.	+.II	1.IV	+.I	1.IV	+.III
- splendida Grev.		+.I	+.IV		
- woronichii Anis.	+.I	+.IV	1.IV		
Pelonema pseudovacuolatum Laut.		+.I	+.II		
Spirulina major Kütz.		+.I	1.III	+.II	
- tenuissima Kütz.		+.II	+.II	+.IV	
Synechococcus aeruginosus Naeg.		+.I	1.V	+.II	
Euglenophyta					
Astasia inflata Duj.	+.I	+.II			
- pygmaea Skuja			+.I	+.II	
Colacium sideropus Skuja			+.I	+.II	
- simplex Huber-Past.			+.I	+.III	
- vesiculosum Ehr.		+.II	+.I	+.I	
Euglena acus Ehr.				+.II	
- gracilis Klebs		+.I	+.II	+.IV	
- pisciformis Klebs		+.I	+.II		
- stellata Maine.		+.II	+.III		
Lepocynclis lobate Conr.	+.I	+.II			+.I
- ovum Lemm.	+.II	+.II	+.II	+.I	
- ovum Lemm.var. globula Lemm.	+.I	+.II	+.II		
Phacus acuminatus Stokes			+.I	+.II	+.I
- caudatus HÜbn.	+.I	+.II		+.II	+.I
- caudatus HÜbn. var. minor Dre2.	+.II				

cont. tab. III

1	2	3	4	5	6
Phacus curvicauda Swir.	+.IV				+.I
- parvulus Klebs	+.III	+.I	+.I	+.II	+.II
- polytrophos Pocha.		+.II	+.II		
- suecicus Lemm.	+.II				
Trachelomonas hispida Stein	+.II				
- planctonica Lemm.	+.III				
- planctonica Lemm. var. oblonga Drez.	+.III	+.I			
- rhelnhardtii Swir.	+.III	+.I			+.I
- stokesiana Palm.	+.III	+.II	+.I		
- verrucosa Stokes	+.I	+.II	+.I	+.I	+.III
- volvocina Ehr.	+.V	+.V	+.V	1.IV	2.IV
Pyrrophyta					
Ceratium cornutum Clap.	+.I		+.III		
- hirundinella Schr.	1.V	2.V	5.V	3.V	1.V
Cryptomonas caudata Schill.	+.III	1.IV	+.II	+.IV	
- erosa Ehr.	1.IV	4.V	2.V	1.V	+.III
- gracilis Skuja		+.II	1.IV	1.V	
- maresoni Skuja	+.I	+.IV	1.V	5.V	4.V
- ovata Ehr.	+.I	2.IV	1.V	3.V	+.III
- phaseolus Skuja		+.IV			
Chroomonas acuta Nordst.	+.II				
Glenodinium gymnodinium Penard	1.III	1.IV	+.III	+.I	
- coronatum Geitl.	+.II	+.IV			
- oculatum Penerd	+.I			+.II	+.II
Gymnodinium aurytopum Skuja	1.III	+.II	+.I		
- paradoxum Schill	+.II			+.II	+.II
Peridinium bipes Stein	2.V	1.III	+.I	+.II	+.I
- cinctum Ehr.	1.III	+.II		+.I	
- willei Huitf.-Kaas.	3.V	1.III	+.I	+.II	+.II
- volzii Lemm.	+.III	+.II		+.II	
Rhodomonas minuta Skuja	+.II	+.IV	1.V	2.V	+.III
Chrysophyceae					
Calycomonas cylindrica Lund.			+.I	+.II	
Characiopsis sp.			+.I	+.IV	
Chromulina nebulosa Cienk.	+.II	1.IV			
- ovalis Klebs	+.II	+.IV	1.IV	+.II	
- pygmaea Nyg.	+.II	+.IV			
- truncata Conr.		+.IV	+.II	+.III	
- vagans Pasch.	+.II	+.IV	1.IV	+.V	
Chrysococcus biporus Skuja	+.II	+.II			+.II
- ealor Lackey	+.I	+.II			
- minutus Nyg.	+.I	+.II			
- rufescens Klebs	+.IV	1.V	+.II		+.II
Dinobryon bavaricum Imhof.	1.III	1.V	+.IV		
- divergens Imhof.	4.V	5.V	5.V	4.V	+.III
- sertularia Ehr.		+.IV	+.II	+.I	+.II
- sociale Ehr.	2.IV	3.V	1.V		
- sociale Ehr. var. stipitatum Lemm.		+.V	+.IV		
Kephyrion planctonicum Hill.		+.II	+.IV	+.II	
- spirale Conr.		+.I	+.I	+.I	
Mallomonas acaroides Perty		+.IV	1.V	+.III	
- coronata Bol.		+.I	+.IV		
- dentata Conr.		+.I	+.II		
- elegans Lemm.		+.III	+.IV	+.II	+.I
Ochromonas lenta Skuja		+.II	+.II		
- oblique Skuja	+.I				
- ornata Skuja	+.II	+.III	+.II		
- sessilis Skuja	+.I	+.II			
Ophiocytium arbuscula Rabh.			+.II	+.I	
- parvulum Braun			+.I		
Pseudokephyrion conicum Schmid		+.II	+.I	+.I	
- schilleri Conr.		+.III	+.II	+.IV	
Salpingoeca frequentissima Lemm.		+.I	1.IV	1.V	+.II
Stokesiella gracilis Pasch.			+.I		
Synerypta volvox Ehr.	+.I	+.II	+.IV	+.II	
Synura uvella Ehr.		1.IV	+.II	+.II	+.I
Uroglena articulata Korsch.		+.I	+.IV		
- botrys Conr.		+.II	+.I		
- volvox Ehr.		+.III	+.IV	+.V	
Bacillariophyceae					
Achnanthes affinis Grun.	+.II			+.I	+.II
- clevei Grun.	+.I				
- exigua Grun.	+.IV			+.I	+.II
- kolbei Hust.	+.I				
- lanceolata Grun.	+.V	+.II		+.II	+.III

cont. tab. III

1	2	3	4	5	6
Amphora ovalis Kütz.	+.II			+.II	+.II
Asterionella formosa Hass.	2.V	+.IV	+.II	+.II	+.III
Caloneis silicula Cl.	+.II			+.II	+.III
Cocconeis pediculus Ehr.	+.IV	+.II	+.II		
- placentula Ehr.	+.II	+.II	+.I		+.II
- placentula Ehr. var. euglypta Cl.	+.IV	+.V	+.II	+.II	+.III
Cyclotella comta Kütz.	1.IV	+.II	+.I	+.I	+.II
- kützingiana Thw.	+.II	+.I	+.I	+.I	+.III
Cymbella affinis Kütz.	1.V	+.IV	+.II	1.IV	1.V
- cistula Grun.	+.II			+.I	+.II
- lanceolata V.H.	+.V	+.II	+.I	1.IV	1.V
- prostrata Cl.	+.I				
- reinhardtii Grun.	+.II	+.I		+.I	+.II
- sinuata Greg.	+.II	+.III	+.II		
- turgida Cl.	+.II			+.I	+.II
- ventricosa Kütz.	1.V	+.IV	+.II	1.V	1.V
Epithemia turgida Kütz.	+.II				
- zebra Kütz.	+.II			+.I	+.II
Eunotia arcus Ehr.	+.I				
Fragilaria brevistriata Grun.	1.IV	+.II		+.II	+.III
- capucina Desm.	2.V	1.V	1.IV	2.V	3.V
- capucina Desm. var. mesolepta Rabh.	1.III	+.II		+.II	+.III
- construens Grun.	1.IV	+.III	+.II	3.V	2.IV
- construens Grun. var. binodis Grun.	+.III	+.II	+.I	+.II	+.III
- construens Grun. var. capitata Herib.	+.III	+.II		+.I	+.II
- construens Grun. var. exigua Schulz.	+.II	+.I		+.IV	+.V
- crotonensis Kitt.	2.V	1.IV	+.II	1.IV	1.V
- intermedia Grun.	+.III	+.II		+.II	+.IV
- pinnata Ehr.	1.V	1.V	+.II	1.IV	+.V
- pinnata Ehr. var. lancettula Hust.	+.IV	+.II		+.I	+.II
Gomphonema acuminatum Ahr.	+.V	+.I		+.II	+.III
- angustatum Rabh.	1.IV	+.I		+.I	+.II
- capitatum Ehr.	+.I			+.I	+.II
- constrictum Ehr.	+.III	+.I			
- gracile Ehr.	1.IV	+.I			+.I
- lanceolatum Ehr.	+.II	+.I		+.I	+.II
- olivaceum Kütz.	1.V	+.IV	+.II	1.IV	1.V
- parvulum Grun.	+.II			+.I	+.II
Gyrosigma acuminatum Rabh.	+.IV			+.II	+.V
Melosira granulata Ralfs.	+.IV			+.II	+.V
- granulata Ralfs.var.angustissima Hust.	+.II				+.II
- islandica O. Müll.	+.I			+.I	+.II
- varians Ag.	1.V	+.II	+.I	1.V	+.V
Navicula anglica Ralfs.	+.II			+.I	+.III
- bacillum Ehr.	+.I				
- cincta Kütz.	+.II	+.I			
- cryptocephala Kütz.	1.V	+.II	+.II	1.IV	+.V
- cryptocephala Kütz.var.intermedia Grun	+.II	+.I		+.I	+.III
- cryptocephala Kütz.var.venata Grun.	+.I				+.II
- cuspidata Kütz.	+.III	+.I		+.I	+.II
- exigua O. Müll.	+.IV	+.I			
- gracilis Ehr.	+.II	+.I	+.I		
- hungarica Grun.	+.II				+.II
- hungarica Grun.var.intermedia Skab.	+.I				
- lanceolata Kütz.	+.IV	+.II		+.I	+.II
- minima Grun.	+.V			+.I	+.III
- oblonga Kütz.	+.II			+.I	+.II
- pupula Kütz.	1.V	+.II	+.II	1.IV	+.V
- pupula Kütz.var.capitata Hust.	+.III	+.I			+.I
- pupula Kütz.var.elliptica Hust.	+.II				
- pupula Kütz.var. rostrata Hust.	+.IV	+.II		+.I	+.II
- simplex Krasske	+.I				
- tuscula Grun.	+.III	+.I		+.I	+.II
Meidium iridis Cl.	+.I				+.II
Nitzschia amphibia Grun.	+.II	+.I			+.I
- kützingiana Hilse	1.IV	+.II		+.I	+.II
- linearis W.Sm.	1.III	+.IV	+.I	+.II	+.III
- recta Hantz.	+.IV	+.I			
- sigmoidea W.Sm.	1.V	+.IV	+.II	+.II	+.III
Opephora martyi Herib.	+.IV				+.II
Rhoicosphaenia curvata Grun.	+.IV	+.II			+.I
Rhopalodia gibba O.Müll.	+.I				+.II
Stephanodiscus astraea Grun.	1.V	+.II	+.I	+.II	+.IV
- hantzschii Grun.	+.III			+.I	+.II
Surirella biseriata Breb.	+.II			+.I	+.II
- ovata Kütz.	+.I				+.I
- turgida W.Sm.	+.II			+.I	+.III
Synedra acus Kütz.	+.V	1.V	1.IV	+.II	+.III
- acus Kütz.var.angustissima Grun.	1.IV	+.III			
- acus Kütz.var.radians Hust.	+.II	+.II			+.II

cont. tab. III

1	2	3	4	5	6
Synedra capitata Ehr.	1.IV	+.II			
- parasitica Hust.	1.IV	+.II	+.I	+.II	+.III
- pumpens Kütz.	+.II	+.I			
- tabulata Kütz.	+.IV	+.II	+.I		+.II
- ulna Ehr	3.V	2.V	1.V	+.II	+.III
- ulna Ehr. var.amphirhynchus Grun.	+.IV	+.III	+.II	+.I	
- ulna Ehr. var.oxyrhynchus V.H.	+.III	+.II	+.I	+.I	
- vaucheriae Kütz.	1.IV	+.II	+.I	+.I	+.II
Tabellaria fenestrata Kütz.	+.II			+.I	+.III
- flocculosa Kütz.	+.I			+.I	+.II
-flocculosa Kütz.var.asterionelloides V H	+.IV	+.II		+.II	+.III
Xanthophyceae					
Dichotomococcus curvatus Korsch.		+.I			
Goniochloris mutica Fott	+.I				
Tribonema ambiguum Skuja	+.I	+.IV	+.II	+.I	
- minus Hazen	+.IV	+.V	+.II	+.III	+.II
- vulgare Pasch.	+.I	+.II		+.II	
Chlorophyta					
Ankistrodesmus acicularis Korsch.		+.I	+.II	+.III	+.II
- arcuatus Korsch.			+.II	+.I	
- densus Korsch.		+.I	+.II	+.II	
- falcatus Ralfs.		+.II	1.V	1.IV	+.III
- falcatus Ralfs.var.acicularis West			+.IV	+.II	
- falcatus var. spiralis West			+.II	+.III	
- falcatus var. stipatitus Lemm.		+.I	+.IV	+.II	
Aphanochaete globiferum Printz.		+.I	+.IV	+.I	
Arthrodesmus sp.			+.I		
- incus Hass.			+.I	+.I	
- ralfsii West			+.II	+.I	
Asterococcus superbus Scherff.	+.I	+.II	+.II	1.IV	+.II
Botryococcus braunii Kütz.	+.I	+.II	+.I	+.IV	+.II
Characium limneticum Lemm			+.I	+.II	
- obtusum A.Br.			+.I		
Chlamydomonas reinhardii Dang.		+.I			
Chlorella vulgaris Berg.		+.II	+.I	1.V	+.II
Cladophora fracta Kütz.		+.I	+.I	1.IV	+.III
- glomerata Kütz.		+.II	+.II	1.III	+.II
Closterium acerosum Ehr.			+.I	+.I	+.I
- aciculare West				+.II	
- acutum Ralfs	+.I				+.I
- acutum Ralfs.var.variabile Krieg.				+.I	
- calosporum Wittr.		+.II			
- dianae Ehr.				+.I	
- gracile Bréb.				+.II	
- gracile Bréb.var.elongatum West				+.I	
- kützingii Bréb.			+.II	+.I	
- leiblenii Kütz.			+.I	+.I	
- lineatum Ehr.			+.I		
- moniliferum Ralfs.			+.I	+.II	+.III
- navicula Lut.				+.I	
- parvulum Naeg.				+.II	
- praelongum Bréb.			+.I		
- pronum Bréb.			+.II	+.I	
- turgidum Ehr.			+.I	+.I	
- venus Kg.	+.II			+.I	+.II
- cambricum Archer.		+.II	+.III	1.IV	+.III
- cambricum Archer.var.intermedium Boh.		+.I	+.I	+.II	+.II
- microporum Naeg.		+.I	+.II	1.IV	+.II
- reticulatum Senn.		+.II	+.II	+.III	
Cosmarium aciculare West	+.I				+.II
- bioculatum Ralfs.	+.I			+.I	+.I
- botrytis Menegh.	+.II			+.I	+.III
- brebissonii Menegh.				+.I	
- circulare Rein.			+.I		
- conspersum Ralfs.				+.I	
- depressum Lund.				+.I	
- depressum Lund.var.planctonicum Rev.			+.I		
- difficile Luth.			+.II		
- formosulum Hoff.		+.I			
- humile Nordst.	+.II	+.IV	1.V	+.II	+.III
- margaritatum Roy.	+.I				+.II
-margaritiferum Men.		+.II			
- phaseolus Bréb.				+.II	
- protractum De Bary				+.I	
- pseudopyramidatum Lund.			+.I		
- punctulatum Bréb.			+.II		
- reniforme Arch.	+.I	+.I	+.II	+.II	+.III
- subtumidum Nordst.			+.I		
- undulatum Corda				+.I	
Crucigenia irregularis Wille		+.I		1.IV	+.V

cont. tab.III

1	2		4	5	6
Crucigenia quadrata Morr.		+.I	+.II	1.V	+.III
Desmidium aptogonum Brèb.		+.I		+.II	
- swartzii Ag.		+.I	+.I	1.V	+.III
Dictyosphaenium ehrenbergianum Naeg.		+.II	+.IV	1.V	
- pulchellum Wood.		+.II	+.III	2.V	
Elakatothrix gelatinosa Wille		+.I	+.II	1.IV	
- lacustris Korsch.		+.II	+.IV	+.V	
Euastrum crassum Kütz.			+.I		
- elegans Kütz.				+.I	+.II
- verrucosum Ehr.			+.I		
Eudorina elegans Ehr.		+.II	+.IV	1.V	
Franceia droescheri Smith	+.I	+.II	+.I		
- ovalis Lemm.	+.III	+.IV	+.I		
Gloeocystis gigas Lag.			+.II	1.IV	+.II
- planctonica Lemm.		+.I	+.IV	1.V	+.III
Golenkinia radiata Wille	1.IV	1.V		+.I	+.I
Gonium pectorale Müll.			+.II	1.IV	
- sociale Warm.			+.I	+.V	
Hyalotheca dissiliens Bréb.		+.I			
- mucosa Ehr.			+.I		
Koliella planctonica Hindak		+.I	+.II		
Mesotaenium sp.		+.II			
Micrasterias crux-melitensis Hass.				+.I	+.II
Microspora amoena Rabh.			+.IV	1.V	
Mougeotia sp.		+.II	+.IV	1.V	+.III
Nephrocytium limneticum Smith			+.I	+.II	
Oocystis borgei Snov.		+.I	+.III	1.IV	
- crassa Wittr.	+.I	+.II	+.III	1.V	+.III
- elliptica West	+.I	+.II	+.I	+.IV	+.II
- gigas Arch.		+.I	+.II	1.V	+.III
- lacustris Chod.			+.I	1.IV	+.II
Oocystis naegelli Chod.			+.I	+.II	
- solitaria Wittr.	+.I	+.II	+.II	1.IV	+.III
Pandorina morum Bory		+.II	1.V	1.V	
Pediastrum boryanum Menegh.	+.IV	+.V	+.II	1.V	+.V
- boryanum Menegh.var.cornutum Sulek	+.II	+.II		+.II	
- boryanum Menegh.var.granulatum A.Br.	+.I	+.II	+.I	1.IV	+.II
- duplex Meyen.	+.I	+.III	+.I	+.IV	+.III
- tetras Ralfs.	+.II	+.V	+.II	+.II	+.III
- Pleurotaenium sp.				+.I	
Pseudosphaerocystis lacustris Novak	+.II	5.V	+.II		
Quadrigula closterioides Printz.	+.I	+.II	+.I	1.V	+.II
Scenedesmus acuminatus Chod.	+.II	+.II	+.IV	1.V	+.III
- acutiformis Sch.	+.I	+.I	+.I	+.II	+.III
- arcuatus Lemm.	+.II	+.II	1.IV	+.V	+.II
- bicaudatus Chod.	+.I	+.II	1.IV	+.III	+.II
- longicauda Chod.	+.I	+.I	+.I	+.I	
- quadricaudata Bréb.	+.V	1.V	1.V	2.V	1.V
Schroederia setigera Lemm.		+.I	+.II		
Sphaerocystis schroeteri Chod.		2.V	+.IV	+.IV	
Spirogyra sp.		+.I	+.II	1.V	+.II
Staurastrum arctiscon Lund.			+.I		
- avicula Bréb.			+.I		
- chaetoceras Smith.	+.I	+.I		+.II	+.I
- cingulum Smith.		+.I			
- cuspidatum Ralfs.	+.I				+.I
- eurycerum Skuja				+.I	
- gracile Ralfs.			+.IV	+.V	+.III
- gracile Ralfs.var.planctonicum Lim.			+.I		
- lunatum Ralfs.				+.I	
- margaritaceum Menegh.		+.I			
- paradoxum Meyen.	+.I	+.I	+.II	+.I	+.III
- punctulatum Bréb.	+.I		+.I		+.II
- sebaldii Reinch.			+.II		
- smithii Teil.				+.I	+.II
- totracerum Ralfs.		+.I	+.I	+.I	+.I
- tetracerum Ralfs.var.validum West			+.I	+.I	
- vestitum Ralfs.			+.I		
Stigeoclonium amoenum Kütz.	+.I	+.III		+.I	
- fasciculare Kütz.	+.I	+.I		+.I	
- tenue Kütz.	+.II	+.I		+.I	
Xanthidium sp.				+.I	
Tetraedron caudatum Hansg.			+.I	+.II	+.III
- incus Smith	+.I	+.I		+.I	+.I
- minimum Hansg.	+.I	+.I	+.I	1.IV	+.V
- regulare Kütz.	+.I	+.II	+.I	1.V	+.II
Zygnema sp.			+.II	2.V	+.IV
Charales					
Chara fragilis Desv.	+.I				
- rudis A.Br.	+.I				
- tomentosa L.				+.I	+.I
Nitella flexilis Ag.				+.I	
Nitellopsis obtusa Grov.				+.I	

were representatives of the genera: *Ankistrodesmus*, *Closterium*, *Cosmarium*, *Oocystis*, *Pediastrum*, *Scenedesmus*, and *Staurastrum*. In those lakes of the Masurian Lake District that are relatively clean a wealth and variety of green algae are to be encountered. Only one species from Chlorophyta — *Pseudosphaerocystis lacustris* — was dominant at the time of the investigations, the other taxa appearing fairly often but not in large numbers.

Bacillariophyceae took the second place, reaching 25.6% of all the determined taxa. Among these such genera as *Cymbella*, *Fragilaria*, *Gomphonema*, *Navicula*, and *Synedra* should be noted for their frequency of occurrence and considerable numbers. Among diatoms *Synedra acus* dominated in April.

Cyanophyta held the third place with 48 taxonomic units (12.8%). The genera *Anabaena*, *Microcystis*, and *Oscillatoria* were numerously represented. As to numbers, blue-green algae occurred fairly numerously in the phytoplankton, particularly in summer and autumn. *Anabaena solitaria* f. *planctonica*, *A. spiroides*, and *Microcystis aeruginosa* were dominants.

The representatives of Chrysophyceae (9.8%) with several taxa belonging mainly to the genera *Chromulina*, *Chrysococcus*, *Dinobryon*, *Mallomonas*, and *Ochromonas* must be considered constant components of the phytoplankton of the investigated lake. *Dinobryon divergens* played a particular role in the quantitative composition of the phytoplankton (Table IV).

The group Euglenophyta, with 7.0% of the determined taxa, were represented by many species belonging mainly to the genera *Phacus* and *Trachelomonas*.

In the group Pyrrophyta (5.0%) *Ceratium hirundinella*, *Cryptomonas erosa* and *C. marssonii* clearly dominated in some periods (Table IV). Many species were also found from the genera *Cryptomonas and Peridinium*.

The share of Xanthophyceae was small (1.3%) and Charales only occasional and insignificant.

The low numbers within the particular species in discussed taxonomic groups (Table III) was a characteristic feature of Lake

Table IV. Dominant species of the phytoplankton of Lake Garbaś in 1988

Species	25 Apr.	21 May	19 July	19 Sept.	10 Oct.
Anabaena soliteria f.planctonica			•		
Anabaena spiroides				•	•
Ceratium hirundinella			•		
Cryptomonas erosa		•			
Cryptomonas marssoni				•	•
Dinobryon divergens	•	•	•	•	
Microcystis aeruginosa				•	•
Pseudosphaerocystis lacustris		•			
Synedra acus	•				

Garbaś. Only the dominants (Table IV) developed abundantly and were to a high degree decisive in the quantitative composition of the phytoplankton.

The numerical relations of the algae of higher systematic unites in particular periods of the investigations are presented in Tables II and III. They show that Cyanophyta dominated from the end of spring to autumn, Euglenophyta in spring and summer, Pyrrophyta in spring and autumn, Chrysophyceae in summer, Bacillariophyceae in spring and autumn, Xanthophyceae in spring, and Chlorophyta in summer and autumn.

Taxa showing a great degree of constancy and great numbers in particular seasons are given in Table IV.

Among all the determined taxons, only 17% occurred during the whole period of the investigations, the others appearing sporadically, mainly in spring and autumn. Species occurring in the analysis only once constituted 16.5%.

The vertical distribution of phytoplankton was characterized by a distinct layer gradation, algae found at depths from 1—8 m having the highest quality and numbers.

The differentiation of planktonic algae was clearly seen in the settling of the water column at Stations 3 and 4. The vertical distribution of the algae here showed the existence of a fairly clear trophogenic layer down to 7—8. Below this layer no great occurrence of algae was observed their qualitative composition was poorer, and most of the organisms showed reduced vitality.

5. Discussion

At each of the five investigated stations the seasonal dynamics of phytoplankton organisms ran an analogous course, although particular stations in the littoral and pelagial zones of the lake represented different types of microhabitat. The shows that the differences in abiotic factors in the whole lake were too small to have any distinct influence on the composition or seasonal occurrence of planktonic algae. The lake constituted one complex of similar ecological conditions, making possible the phenomenon of the so-called paradox of phytoplankton (Gilarov 1984). In such a situation one cannot expect to find at different places in the lake completely different algal phytocenosis, although their composition in a given zone or moment is not identical, but very similar. The data obtained permits the statement that the investigated lake constitutes a specific whole with an ecological and taxonomic constitution of algae particular to it.

In the aphotic habitat no other algal taxa were found than those

determined before in the epilimnetic layer. The species of algae found in Lake Garbaś are mostly widely spread forms characteristic for eutrophic and mesotrophic lakes of our zone (Turoboyski 1970, Sosnowska 1974, Chudyba 1979, Chudyba et al. 1987). As to its quality, the phytoplankton of Lake Garbaś had a chlorophycean--cyanophycean-bacillariphycean character (Table II).

On the basis of the above data, which find a floristic and ecological similarity of the environment, it was accepted that the plankton algae of Lake Garbaś constitute one type of phytoplankton community, one phytocenosis with a similar species composition and similar structure.

Dinobryon divergens was recognized as the species of greatest diagnostic value in phytosociological interpretation, hence the discussed community has been called *Dinobryon divergens planctonicum mesotrophicum*. In Symoens systematics (1951) this community should be counted among the alliances of plankton communities of oligo- and mesotrophic waters: *Bacillariophycion planctonicum oligo-* et *mesotrophicum*. It is a supplementary outline to Symoens' systematic scheme with a description of a detailed association, hitherto lacking. The agglomerations of algae of aphotic habitat constituted an impoverished variant of the same community.

The mass occurrence of algae, that is the so-called water-bloom, was not observed at the time of the investigations. The dominants were above all decisive in the phytoplankton mass in Lake Garbaś (Table IV).

The compound phytoplankton coefficient of Nygaard (1949) and Thunmark (1945) is 3.2, which allows the supposition that Lake Garbaś belongs to mesotrophic lakes with marked eutrophy. The species composition, number of particular taxa, and also the seasonal dynamics of the development of planktonic algae confirm this statement (Table III).

The final opinions as to the usefulness of applying phytoplankton coefficients (Półtoracka 1969) in evaluation of the trophic structure of lakes arouse much controversy (Round 1984, Oleksowicz 1987). The author is inclined to the view of the authors of such works (Rawson 1956, Brook 1965, Półtoracka 1969) that state that the phytoplankton coefficients give only approximate values and cannot always be used, while if they are used then with reservations concerning especially the manner of taking the algological samples (Chudyba 1979). These requirements were fulfilled in the present work.

6. Polish summary

Socjologiczne badania fitoplanktonu w jeziorze Garbaś (Pojezierze Ełckie, północno-wschodnia Polska)

W celu pogłębienia znajomości przyczyn procesu eutrofizacji wybrano teren zlewni jeziora Garbaś na Pojezierzu Ełckim jako pierwszej polskiej stacji monitoringu środowiska podsystemu GEMS (system GSMOS — RWPG). Opracowanie niniejsze stanowi jeden z elementów charakterystyki limnologicznej jeziora Garbaś.

Badania prowadzono na pięciu stanowiskach, obejmujących możliwie wszystkie typy mikrosiedliskowe w obrębie jeziora (ryc. 1). Praca obejmuje szczegółowe badania fitoplanktonu sieciowego i nannoplanktonu, oraz stanowi próbę wyróżnienia i opisania zbiorowisk planktonu roślinnego w tym jeziorze. Temperaturę powietrza i wody warstw powierzchniowych oraz barwę i przezroczystość wody (widoczność krążka Secchi'ego) w trakcie prowadzonych badań na stanowisku 4 przedstawia tabela I.

Na podstawie analizy jakościowej 205 prób algologicznych pobranych w jeziorze Garbaś w okresie kwietnia, maja, lipca, września i października 1988 r. stwierdzono obecność 375 taksonów glonów (tabela II, III). Fitoplankton jeziora miał charakter zielenicowo-okrzemkowo-sinicowy. Za gatunek o największym walorze diagnostycznym, w rozumieniu fitosocjologicznym, uznano *Dinobryon divergens* (tabela IV), w związku z czym omawiane zbiorowisko nazwano *Dinobryon divergens planctonicum mesotrophicum*. Ugrupowania glonów siedliska afotycznego stanowiły zubożały wariant tego samego zbiorowiska.

Rozmieszczenie pionowe fitoplanktonu charakteryzowało się wyraźną gradacją warstwową, przy czym zarówno jakościowo jak i pod względem liczebności najliczniej występowały glony na głębokościach od 1 do 8 metrów.

Masowych pojawów glonów, czyli tzw. zakwitów, w okresie badań nie stwierdzono. O masie fitoplanktonu w jeziorze Garbaś decydowały przede wszystkim dominanty (tabela IV).

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