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Orzęski dna odrostowych stawów rybnych Zespołu Gołysz

Ciliata of the bottom of rearing fishponds in the Gołysz Complex

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Abstract — In the years 1963—1964 investigations were carried out on the microfauna of the bottom mud of 10 artificial fishponds of the Gołysz Complex of Experimental Farms, particular attention being paid to *Ciliata*. Qualitative investigations were carried out (184 *Ciliata* species being reported) as well as quantitative, in which the variations in the numbers of the *Ciliata* population during the whole rearing season against the background of some physico-chemical factors of the bottom environment were noted. The most abundant and greatly varied microfauna was found in the ponds of the Farm Gołysz, which had been intensively manured with mineral (composite) fertilizers.

The aim of the present work was to investigate the development of the microfauna of bottom mud, particular attention being paid to the group of *Ciliata*, against the background of conditions developing in the rich environment of artificial fishponds manured with mineral fertilizers. The extensive protozoological literature contains almost no works dealing with this group of protozoans in the mentioned environment. The present investigations were based on materials collected in the years 1963—1964 from 10 experimental fishponds of three farms (Ochaby, Gołysz, Landek) controlled by the Laboratory of Water Biology of the Polish Academy of Sciences, and lying on the terrain of the Bielsko and Cieszyn districts in the Katowice province.

Characteristics of the investigated ponds

All the investigated ponds are used as rearing ponds, i.e. they are flooded every year in the spring and drained in autumn, being left without water during the winter-time.

The ponds of the farm Ochaby (Baranowice complex) receive water through a supply from the Vistula. They are poorly kept, largely overgrown with hard and soft vegetation, slimy, shallow, and characterized by a low production of fish. Heavy clay loam occurs in their bottom (P a s t e r n a k 1959). The layers of mud contain a very large amount of clayey and organic matter and almost no carbonates; they are moderately rich in phosphorus and potassium and highly acid.

The complex of ponds in the farm Gołysz receives water from the Vistula through a supply three kilometres long. The ponds are well kept and for the most part little overgrown. As was reported by P a s t e r n a k (1959), the layer of mud and the primary soils of these ponds are silt-clay deposits. The layers of mud are rich or moderately rich in organic matter, rather poor in carbonates, with a moderate content of P_2O_5 and K_2O, and they have an acid reaction.

The ponds in the farm Landek, forming part of the complex Landek-Iłownica, are supplied with water from the river Iłownica. On the whole, they are well kept. The layers of mud and the primary soils (P a s t e r n a k 1959) consist of heavy clay loam or of silt clays. The soils are richer in carbonates than those of the ponds of Gołysz. The layers of mud are poor in phosphorus and potassium, but have a high content of iron.

The names of ponds of the particular farms and detailed data concerning their fertilization in the year in which the samples were collected are presented in Table I.

The bottom zone in a body of water provides different living conditions for plant and animal communities. Of the physico-chemical factors the changes in temperature and pH of water near the bottom in the shallow and deep part of the pond were illustrated on diagrams (figs 1-4). In the ponds of the farm Ochaby the temperature of water near the bottom ranged from 12.0 to 23.5°C. The warmest water was noted in the middle of June and towards the end of July and the coldest in September. In 1963 i nthe ponds of the farm Gołysz the water temperature near the bottom during the investigated period ranged from 10.5 to 22.0°C, the highest being recorded in the middle of July and the lowest at the beginning of October. The temperature of the water at shallow and deep stations differed only slightly, generally not exceeding 0.5°C during the summer-time. Slightly greater differences were observed only in the spring and autumn. In 1964 the temperature of the water near the bottom in the ponds of the farm Gołysz during the investigated period was 11.6—25.0°C. The highest temperature in all the investigated ponds was noted towards the end of July. Towards the end of May it was also relatively high. In September the water was the coolest. As regards pH, a considerable difference was noted between the reaction of the surface water and of that near the bottom. The latter always had a lower pH. Some differences were also observed between the two stations. The reaction of water in the shallow part of the pond was

Tabela I. Szczegółowe dane dotyczące badanych stawów
Table I. Detailed data concerning the investigated ponds

Gospodarstwo Farm	Nazwa stawu / Name of pond	Powierzchnia w ha / Area in ha: Ogrobla-wana Impouned	Produk-cyjna Flooded	Głębokość stanowiska w cm / Depth of stands in cm: "A"	"B"	"C"	Rodzaj i ilość nawozów w kg/ha / Kind and amount of fertilization in kg/ha	Obsada ryb Ilość w szt./ha / Fish stock Number of indiv/ha	Inne zabiegi gospodarcze / Other treatments	Stan zarośnięcia stawu / Degree of overgrowth of the pond
Ochaby	Szynkowski 1964	7,20	4,00	80-90	-	20-30	Superfosfat / Superphosphate 18 kg P_2O_5	K_1 - 4400 karmione / feeded	wapnowanie / liming	Wypłycone, zarośnięte (50% pow.)
	Pasieczny 1964	10,80	10,00	100-130	-	40-50	Siarczan amonu / Ammonium sulphate 42 kg N; Superfosfat / Superphosphate 27 kg P_2O_5; Mocznik / Urea 23 kg N	K_1 - 2000 karmione / feeded; K_2 - 160	-	Shallow, overgrown (50% area)
Gołysz	Wyszni VII 1964	14,10	14,00	70-120	-	20-40	Siarczan amonu / Ammonium sulphate 70 kg N; Superfosfat / Superphosphate 18 kg P_2O_5	K_1 - 600 karmione / feeded; K_2 - 400	wapnowanie / liming	
	Wyszni VI 1963	6,80	6,00	100-180	80-180	30-50	nie nawożony / not fertilized	K_1 - 2000	-	Wszystkie stawy mało zarośnięte
	Wyszni II 1963	8,30	8,30	140-170	60-80	30-40	Woda amoniakalna / Ammonia water 55 kg N; Mocznik / Urea 55 kg N; Superfosfat / Superphosphate 27 kg P_2O_5	K_1 - 2000 karmione / feeded	wapnowanie / liming	All the ponds were overgrown in a small degree
	Baginiec I 1964	10,50	10,00	70-110	-	40-50	nie nawożony / not fertilized	K_1 - 2000 karmione / feeded; K_2 - 800	wapnowanie / liming	
	Baginiec III 1964	14,00	13,00	80-180	-	30-50	Siarczan amonu / Ammonium sulphate 80 kg N	K_1 - 900 karmione / feeded; K_2 - 400	wapnowanie / liming	
	Chyliński Mały 1964	3,30	3,00	90-100	-	40-60	nie nawożony / not fertilized	K_1 - 300 karmione / feeded	-	
Landek	Księżok Mały III 1963	3,90	3,00	90-120	80-100	30-40	nie nawożony / not fertilized	K_1 - 660	-	Wypłycone, bardzo zarośnięte (60% pow.)
	Księżok Środkowy 1963	6,42	4,40	110-160	70-120	20-40	Woda amoniakalna / Ammonia water 55 kg N; Mocznik / Urea 55 kg N; Superfosfat / Superphosphate 27 kg P_2O_5	K_1 - 2000 karmione / feeded	wapnowanie / liming	Shallow, overgrown in a high degree (60% area)

always acid (the lowest pH amounted to 6.2), whereas at the deep station it generally approximated the neutral reaction or was weakly alkaline. The bottom of the investigated Gołysz ponds was strongly acid (pH = 4—5) (W r ó b e l 1966), showing at the shallowest sites a greater acidity than in the middle of the pond and in its deeper part.

An important factor also is the content of organic matter in the mud. The non-uniform accumulation of organic matter in various parts of the investigated ponds was noted by W r ó b e l (1960, 1966), who reported that the lowest content of organic matter in the bottom occurred in the deepest parts of the pond and the highest one at the shallowest sites. Detailed data on the content of organic matter in ponds Wyszni II and Wyszni VI are presented after W r ó b e l (1965) in figs 5 and 6. A full physico-chemical characteristic of ponds manured with mineral fertilizers in 1963 was given by W r ó b e l (1965), whereas those manured in 1964 were investigated by L e w k o w i c z (1966).

Method of investigation

The material for investigation was collected every 2 weeks in each year during the whole rearing period. Altogether 260 samples were collected. In each of the ponds investigated in 1963 — 3 sampling stations were chosen. (A- in the deepest, not overgrown zone, B- in the middle of the pond, and C- in the shallowest and overgrown zone). In the ponds investigated in 1964 the materials were collected only from stations A and C. The sampling was carried out with S t a r m a c h ' s mud sucker of 4.83 cm^2 scooping surface area and capacity of about 75 ml of sediment mixed with the layer of water near the bottom. From each station the mud was collected twice and put in glass bottles of 150 ml content. In the course of 4 days after its collection the material was elaborated in the local laboratory of the farm Gołysz.

A qualitative and quantitative analysis of the investigated microfauna was carried out, several microscopic preparations being examined from each sample. The quantitative analysis was carried out 1) according to the estimating method, applying the scale after G r o s p i e t s c h (1958) presented in fig. 8 and 2) by means of the quantitative — voluminal method consisting in counting exactly the number of animals in each preparation, which permitted an approximate determination of the number of *Ciliata* specimens present in 1 cu.cm of the sediment.

To characterize the physico-chemical conditions prevailing on the bottom the temperature of water near the bottom was measured simultaneously with the collection of samples, as well as the pH value of water in the sample, this being carried out according to the colorimetric method.

Results of investigations

a) Seasonal development of the population of Ciliata

When analysing the seasonal development of the microfauna of *Ciliata* one notices at once that in the particular months there occur considerable differences in its specific composition and numbers. Apart from species occuring continuously or with only small breaks during the whole season of vegetation, others appear which can be observed only at the begining, in the middle, or towards the end of the season, or else are present only sporadically. The same can be said about the numbers of the particular species. Some of them always occur in small or very small numbers, others develop in masses in the particular seasons, while a large number of species can be found only sporadically as single specimens. To determine the frequency of occurrence of the particular species the percentage in which they occur in the total number of collected samples was calculated. Subsequently, all the species found were classified into the five following groups: 1) regular species, i.e. occurring in 51—100 per cent of all collected samples, 2) very frequent, i.e. occurring in 31—50 per cent of the samples, 3) frequent, i.e. found in 11—30 per cent of the samples, 4) rare, i.e. present in 1—10 per cent of the samples, and 5) very rare encountered only once or twice. As a result of this calculation it was found that only 4 species could be assigned to the first group, i.e. *Aspidisca costata, Cinetochilum margaritaceum, Coleps hirtus,* and *Halteria grandinella.* They were regular components of the bottom fauna, occurring almost uninterruptedly during the whole season in all the investigated ponds. At the same time, all of them represent common species. The only regular species developing during some periods in masses was *Coleps hirtus.* The others occurred as a rule in small numbers (small or very small), being found numerously in a few cases only. The seasonal occurrence of some species according to the estimating scale is shown in figs 8—10.

To the second (very frequent) group the following 8 species were assigned: *Aspidisca lynceus, Cyclidium citrullus, Loxodes striatus, Oxytricha* sp., *Paramecium caudatum, Prorodon* sp., *Spirostomum minus, and Uroleptus* sp. Each of them occurred in all ponds. Only two species, *Loxodes striatus* and *Spirostomum minus,* developed in masses during the summertime (figs 9 and 10). The others occurred irregularly and in small numbers. Much more numerous was the group of frequent species, including 24 forms. Of these *Spirostomum filum* developed seasonally in masses.

The most numerous proved to be the last two groups, since to the rare species were assigned as many as 91 forms and to the very rare ones 57. The representatives of the latter group appeared sporadically as a rule and in very small numbers. There occurred an increase in the number of species as the degree of regularity of their occurrence diminished. The

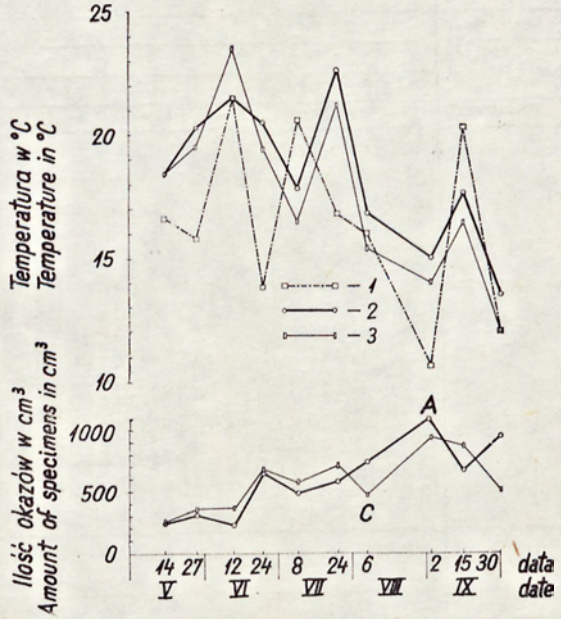
specific composition of *Ciliata, Rhizopoda* and *Rotatoria* and the site where they were found are shown in Tables II, III, IV, whereas their quantitative development in the chosen ponds and the variations of temperature are represented in figs 1—4.

One should not consider as characteristic of the given environment species occurring almost uninterruptedly during the whole season but in small numbers, since for the most part they are common species, whose presence can be expected in any sample. As characteristic species should rather be regarded those finding in the given environment sufficiently favourable conditions to develop in masses. The bottom environment in the fishponds provided such conditions for only four species, recognized as characteristic here. These were *Coleps hirtus, Loxodes striatus, Spirostomum filum,* and *Spirostomum minus.* They all appeared in the majority of ponds, during the summer- time in masses (figs 8-10).

The seasonal development of the population of *Ciliata* was in general fairly similar in all the investigated ponds, but their qualitative composition was fairly variable (only 4 regular species). Many of them appeared only seasonally, though the quantitative ratios were approximate. In the spring months the population of *Ciliata* was poor. It consisted of a few species occurring usually in small numbers, composed of forms living on algae and of forms feeding on bacteria. Such a state was maintained at about the same level till June; sometimes the number of animals decreased (e.g. ponds Wyszni II and Wyszni VII). During this period the number of *Ciliata* was similar at the particular sites, although slightly larger in the shallow ones. A sudden quantitative increase occurred in most ponds in the summer from the middle of July or August. The number of *Ciliata* grew twice or even several times larger than it had been in the spring. This resulted not only from the increase in the number of species but also from the abundant development of *Ciliata* recognized as characteristic. Of the latter only one species lives on algae (*Loxodes striatus*), the others feeding on bacteria and detritus. The quantitative difference between the shallow and the deep stations at that time was distinctly to the advantage of the shallow ones. The great numbers of *Ciliata* often coincided with the highest noted temperature of water near the bottom. The other factor favourable in this respect is that beginning from July the bottom of ponds grows richer in organic matter, owing to the increased supply of dead plankton organisms. This brings about the development of bacterial flora, which is the food of many *Ciliata.* The comparison of the number of *Ciliata* in fertilized and not fertilized ponds shows as a rule that they are more numerous in fertilized ponds, their most abundant occurrence being noted in ponds manured with composite fertilizers, where large doses of the latter were applied (Gołysz). The smallest numbers of *Ciliata* occurred in poorly fertilized and little fertile ponds of the farm Ochaby.

In the group of not fertilized ponds Baginiec I proved to be relatively

rich in *Ciliata*. However, it should be noted that this is a fertile pond and had been intensively fertilized in the previous years. Similarly Wyszni VI, being for a number of years a control pond, is also one of the fertile ponds of the farm Gołysz and the population of *Ciliata* was abundant in it as well (fig. 2). The number of *Ciliata* greatly incresed in the summer,



Ryc. 1. Populacja orzęsków na tle zmian temperatury wody w stawie Szynkowski na stanowisku głębokim (A) i płytkim (C) w roku 1964. 1 — średnia dzienna temperatura powietrza wg S z u m c o w e j (materiały nie publikowane), 2 — temperatura wody przy dnie na stanowisku A, 3 — temperatura wody przy dnie na stanowisku C.

Fig. 1. Population of *Ciliata* on the background of changes in temperature of the water in the pond Szynkowski at a deep station (A) and a shallow one (C) in 1964. 1 — mean daily temperature of air after S z u m i e c (unpublished), 2 — temperature of water at the bottom at station A, 3 — temperature of water at the bottom at station C.

especially in the ponds which had been intensively fertilized and in which, moreover, fish were fed. As was reported by W r ó b e l (1965), the primary production in fertilized ponds was three to five times greater than in the control pond, i.e. the increase in the amount of organic carbon in the bottom of these ponds was much higher. At the shallow sites microfauna developed more intensely, which can be explained by the fact that organic matter accumulates there in larger amounts. As was illustrated in figs 5 and 6, there occurred a considerable concordance between the enlargement of the population of *Ciliata* in the course of the season and the increase in organic carbon in the bottom sediments of the ponds.

Tabela II. Wykaz znalezionych orzęsków
Table II. List of Ciliata

\+ obecność okazu w próbie
\+ presence of the specimens in a sample

Gatunki / Species \ Nazwa stawu / Name of pond	Szynkowski	Pasieczny	Wyszni VII	Wyszni VI	Wyszni II	Baginiec I	Baginiec III	Chyliński Mały II	Księżok Mały III	Księżok Środkowy
Askenasia volvox Clap. et L.			+	+	+				+	+
Aspidisca costata Dujardin	+	+	+	+	+	+	+	+	+	+
- herbicola Kahl		+	+		+				+	+
- lynceus Ehrb	+	+	+	+	+	+	+	+	+	+
- sulcata Kahl			+		+	+			+	
- turrita Ehrb					+				+	
Aspidisca sp.	+	+	+	+	+	+	+	+	+	+
Atopodinium fibulatum Kahl										+
Campanella umbellaria Linné					+					
Caenomorpha lauterborni Kahl		+			+				+	
- levanderi Kahl		+							+	
- medusula Perty	+	+		+	+	+	+		+	+
- universalis Levander	+	+		+	+	+				+
Chilodonella cucullulus O.F.M.		+	+	+		+	+			+
- uncinata Ehrb	+	+	+	+	+	+	+	+	+	+
Chilodonella sp.	+	+	+	+	+	+	+	+		+
Cinetochilum margaritaceum Perty	+	+	+	+	+	+	+	+	+	+
Codonella cratera Leidy	+	+	+	+	+	+	+	+		+
Coleps amphacanthus Ehrb.	+	+	+	+	+	+	+	+	+	+
- hirtus Nitzsch	+	+	+	+	+	+	+	+	+	+
- - var lacustris Fauré-Fr			+						+	
- - var minor Kahl				+						+
- uncinatus Clap et L				+						
Coleps sp.	+		+			+	+	+	+	
Colpoda sp.										+
Cyclidium citrullus Cohn	+	+	+	+	+	+	+	+	+	+
- heptatrichum Schewiakoff								+		
libellus Kahl	+	+	+	+	+	+	+			+
obliguum Kahl				+						
- oblongum Kahl			+					+		
- singulare Kahl						+				
Cyclidium sp.							+	+		
Cyclogramma protectissima Penard					+					
- trichocystis Stokes									+	
Dactylochlamys pisciformis Lauter.	+		+			+	+			
Didinium sp.						+	+	+		
Dileptus anser O.F.M.				+						
- monilatus Stokes				+					+	
Dileptus sp.				+						

Gatunki / Species \ Nazwa stawu / Name of pond	Szynkowski	Pasieczny	Wyszni VII	Wyszni VI	Wyszni II	Baginiec I	Baginiec III	Chyliński Mały II	Księżok Mały III	Księżok Środkowy
Discomorphella pectinata Levander			+							+
Epalxella exquia Penard			+							
- striata Kahl									+	
Epalxella sp.	+		+	+					+	
Euplotes patella fo. latus Kahl	+		+		+				+	
- - fo. typicus Kahl	+			+	+				+	
Frontonia acuminata Ehrb.	+		+	+	+				+	
- leucas Ehrb.	+			+	+	+	+		+	
- vernalis Ehrb.	+		+		+				+	
Glaucoma scintillans (Ehrb.) Schew.					+	+			+	
Glaucoma sp.					+	+			+	
Halteria grandinella O.F.M.	+		+	+	+		+		+	
- - var. cirrifera Kahl	+								+	
Hemiophrys filum Gruber					+					
- meleagris Ehrb.							+			
- procera Penard					+			+	+	
Hemiophrys sp.						+				
Holophrya simplex Schewiakoff	+						+			
Holophrya sp.									+	
Keronopsis monilata Kahl									+	
Lacrymaria caudata Kahl						+				
- elegans Engelmann	+							+		
- olor O.F.M.								+		
- pupula O.F.M.	+			+	+			+		
Legendrea bellerophon Penard							+			
- loyezae Fauré										
Lembadion lucens Maskell										
- magnum Stokes	+									
Litonotus fasciola Ehrb.-Wrześniowski										
Litonotus sp.	+									
Leptopharynx euglenivora Kahl	+									
Loxocephalus halophilus Kahl										
Loxocephalus sp.	+									
Loxodes magnus Stokes	+									
- rostrum O.F.M.										
- striatus Engelmann	+									
- vorax Stokes										
Loxophyllum helus Stokes	+									
- meleagris Dujardin										

Loxophyllum rostratum Cohn						+		+		
Loxophyllum sp.	+	+		+	+	+	+	+	+	
Ludio parvulus Penard		+			+			+	+	
Metacystis sp.						+				
Mesodinium acarus Stein	+		+	+	+	+	+	+		
- pulex Calkins				+	+	+		+	+	
Mesodinium sp.		+		+			+			
Metopus acuminatus Stokes	+	+								
- acutus Kahl								+		
- bacillatus Levander	+	+						+		
- caducus Kahl									+	
- campanula Kahl		+		+			+			
- concortus Quennerstedt			+		+					
- contractus Penard	+	+	+		+	+	+	+		
darvini Kahl									+	
- es O.F.M.	+	+	+	+		+	+	+	+	+
- - var. rectus Kahl					+				+	+
- var. pinquis Kahl	+									
- extensus Kahl	+	+	+				+			
- fuscus Kahl				+						
- galeatus Kahl		+								
- intercredens Kahl		+				+	+			+
- laminarius fo minor Kahl	+	+		+	+	+	+		+	+
- minimus Kahl	+						+			
- mirabilis Kahl	+	+							+	
- mobilis Penard				+						
- nasutus Da Cunha	+		+			+	+	+		+
- ovalis Kahl					+					+
- propagatus Kahl	+						+			
- pulcher Kahl				+						+
- pullus Kahl						+				
- ridiculus Kahl	+	+		+			+			
- spinosus Kahl		+			+		+	+	+	+
- spiralis Smith	+	+		+			+		+	+
- striatus Mc Murrich		+								+
- undulans Stokes	+	+	+		+	+	+	+	+	
- violaceus Kahl	+						+			
Metopus sp.	+	+	+	+	+	+	+	+	+	+
Microthorax spiniger Penard										+
Microthorax sp.			+			+	+			
Mylestoma anatinum Penard		+								+
- bipartitum (Gourr. et R.) Kahl								+		
- discoideum Penard	+									+
- uncinatum Penard										+
Mylestoma sp.	+	+	+		+	+	+	+	+	
Nassula aurea Ehrb										+
- elegans Ehrb										+
Nassula sp.				+	+					
Oxytricha sp.	+	+	+	+	+	+	+	+	+	+
Paramecium caudatum Ehrb.	+	+	+	+	+	+	+	+	+	+
Paruroleptus lacteus Kahl	+	+	+	+	+	+	+	+	+	+
- musculus var. simplex Kahl		+				+			+	
Perispira ovum Stein		+			+		+	+		+
- strephosoma Stokes			+		+	+				

Plagiopyla nasuta Stein										+
- fo. wetzeli Kahl									+	+
- ovata Kahl	+	+			+	+	+	+	+	+
Pleuronema coronatum Kent		+							+	+
- crassum Dujardin				+					+	+
Prorodon ovum Ehrb.-Kahl		+		+	+		+			+
- platyodon Blochmann	+	+								
- teres Ehrb.	+	+		+	+		+	+	+	+
Prorodon sp.	+	+	+	+	+	+	+	+	+	+
Saprodinium dentatum Lauterborn	+	+		+	+			+	+	+
Saprodinium sp.		+								
Spathidium antennatum Kahl								+		
- porculus Penard	+		+			+	+	+	+	+
- spathula O.F.M.				+						
- vermiforme Penard	+							+		
Spathidium sp.	+		+	+	+		+	+	+	+
Spirostomum ambiguum Müller-Ehrb.	+			+				+	+	
- filum (Ehrb.) Penard	+	+	+	+	+	+	+	+	+	+
- intermedium Kahl	+	+		+	+	+	+	+	+	
- minus Roux	+	+	+	+	+	+	+	+	+	+
- teres Clap. et L.	+	+		+	+	+	+	+	+	+
Stentor coeruleus Ehrb.	+	+		+	+	+	+	+	+	+
- mülleri Bory St. Vincent				+			+			
- polymorphus Müller	+	+	+	+	+	+	+	+	+	+
- roeseli Ehrb.					+		+			
Stentor sp.			+		+	+	+	+	+	+
Stichotricha aculeata Wrześniowski				+	+	+	+	+		
- fo. sapropelica Kahl							+	+		
Stichotricha sp.	+	+		+				+		+
Strobilidium gyrans Stokes	+	+		+	+		+	+	+	
Strombidium viride Stein			+							
Stylonychia mytilus Ehrb.				+	+	+	+		+	+
Tintinopsis sp.							+			
Trachelophyllum pusillum Perty-Clap. et L.			+		+					
- vestitum Stokes				+						
Trachelophyllum sp.	+	+	+	+	+	+	+	+	+	+
Tropidoatractus acuminatus Lev.		+			+		+			+
Urocentrum turbo O.F.M.	+	+	+	+	+	+	+	+	+	+
Uroleptus dispar Stokes	+	+	+	+	+	+	+	+	+	+
- limnetis Stokes							+			
- piscis (Müller) Stein		+	+			+				
- rattulus Stein								+	+	
Uroleptus sp.	+	+	+	+	+	+	+	+	+	+
Uronema marinum Dujardin									+	
Urostyla grandis Ehrb.						+				
Urostyla sp.	+	+	+	+	+	+	+	+	+	+
Urotricha agilis Stokes			+	+	+	+	+	+	+	
- farcta Clap et L.		+	+	+	+	+	+		+	+
Vorticella convallaria L.								+		
- natans Fauré-Fr.				+						
- similis Stokes								+		+
Vorticella sp.	+	+	+	+	+	+	+	+	+	

Tabela III. Wykaz znalezionych korzenionóżek
Table III. List of Rhizopoda

\+ obecność okazu w próbie
\+ presence of the specimens in a sample

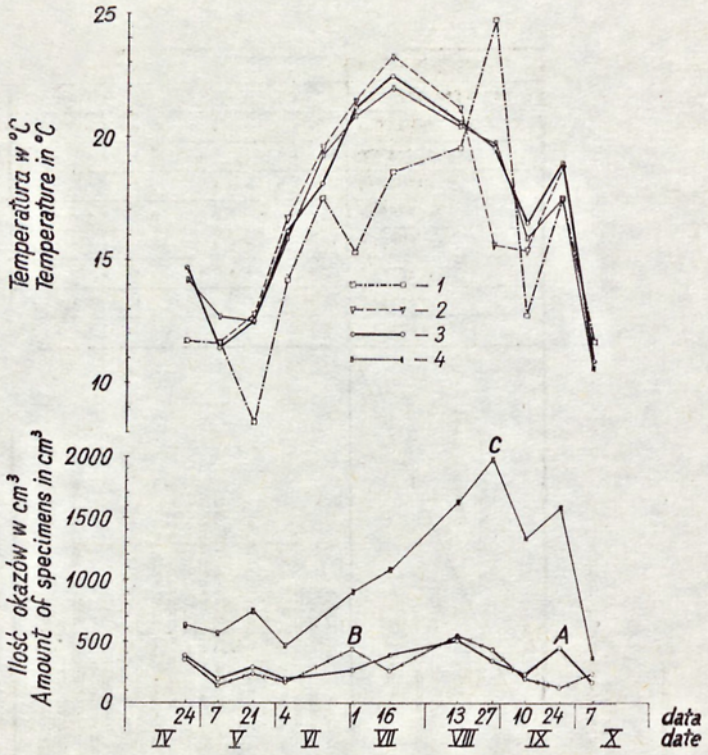
Gatunki / Species \ Nazwa stawu / Name of pond	Szynkowski	Pasieczny	Wyszni VII	Wyszni VI	Wyszni II	Baginiec I	Baginiec III	Chyliński Mały II	Księżok Mały III	Księżok Środkowy
Actinosphaerium sp.	+	+	+		+	+			+	
Amoeba discoides Schäffer						+			+	
- limax Duj.	+	+	+	+	+	+	+	+	+	
- proteus Pallas			+							
Amoeba sp.	+	+		+	+	+	+	+	+	+
Arcella discoides Ehrb.							+	+		
- hemisphaerica Perty	+			+					+	
- vulgaris Ehrb.	+	+	+		+	+				
Arcella sp.	+	+	+	+	+	+	+	+	+	+
Centropyxis aculeata (Ehrb.) Stein	+	+	+	+	+	+	+	+	+	+
Centropyxis sp.				+	+	+		+	+	+
Difflugia acuminata Ehrb.	+	+	+	+	+	+	+	+	+	+
- corona Wallich			+							
- elegans Pen.				+				+	+	
- globulosa Pen.		+	+	+	+	+	+	+	+	+
- oblonga Ehrb.				+	+				+	+
- - var. curvicaulis Pen.			+	+	+	+			+	+
- pyriformis Perty	+	+	+	+	+	+	+	+	+	+
- urceolata Carter				+		+				
Difflugia sp.	+	+	+	+	+	+	+	+	+	+
Euglypha sp.	+		+			+				
Lecquersia sp.					+					

Tabela IV. Wykaz znalezionych wrotków
Table IV. List of Rotatoria

\+ obecność okazu w próbie
\+ presence of the specimens in a sample

Gatunki / Species \ Nazwa stawu / Name of pond	Szymkowski	Pasieczny	Wyszni VII	Wyszni VI	Wyszni II	Baginiec I	Baginiec III	Chyliński Mały II	Księżok Mały III	Księżok Środkowy
Asplanchna sp.									+	
Brachionus angularis Gosse	+						+			
- calyciflorus Pallas						+				
- quadridentatus Hermann	+	+	+			+	+			
- urceolaris O.F.M.							+			
Brachionus sp.	+	+	+	+	+	+	+		+	+
Cephalodella forficula Ehrb.						+	+	+		
- gibba Ehrb.	+		+	+	+	+	+	+	+	+
Cephalodella sp.	+	+	+			+	+	+		
Collotheca trilobata Collins				+						
Colurella uncinata O.F.M.	+	+	+	+	+	+	+	+	+	+
Colurella sp.	+	+		+	+			+	+	
Conochilus hippocrepis Schrank	+									
Dicranophorus forcipatus O.F.M.		+		+				+		
Dicranophorus sp.				+			+			+
Dissotrocha aculeata Ehrb.				+						
Encentrum plicatum Eyferth		+								
Eudactylota eudactylota Gosse			+				+			
Keratella cochlearis Gosse	+	+				+	+		+	
- quadrata O.F.M.						+	+			+

Gatunki / Species \ Nazwa stawu / Name of pond	Szymkowski	Pasieczny	Wyszni VII	Wyszni VI	Wyszni II	Baginiec I	Baginiec III	Chyliński Mały II	Księżok Mały III	Księżok Środkowy
Lecane luna O.F.M.	+	+								
- lunaris Ehrb.	+	+	+							
Lepadella ovalis O.F.M.	+							+		
- patella O.F.M.		+	+	+				+	+	
- triptera Ehrb.									+	
Lophocharis salpina Ehrb			+	+	+	+	+			+
Macrotrachela sp.			+	+	+			+	+	
Monnomata longiseta O.F.M.				+	+	+	+			
Platyas quadricornis Ehrb.		+	+							
- patulus O.F.M.	+									
Polyarthra vulgaris Carlin	+									
Rotaria elongata Weber										
- neptunia Ehrb.		+	+	+	+	+	+	+	+	+
- rotatoria Pallas								+		
- tardigrada Ehrb.	+		+	+	+	+	+	+	+	+
Rotaria sp.	+	+	+	+	+	+	+	+	+	+
Trichocerca bicristata Gosse		+								
Trichocerca sp.	+	+	+	+	+	+	+	+	+	+
Trichotria tetractis Ehrb.				+		+				



Ryc. 2. Populacja orzęsków na tle zmian temperatury wody w stawie Wyszni VI na stanowisku głębokim (A) i płytkim (C) w roku 1963. 1 — średnia dzienna temperatura powietrza wg Szumcowej (materiały nie publikowane), 2 — średnia dzienna temperatura wody przy dnie wg Szumcowej (jak wyżej), 3 — temperatura wody przy dnie na stanowisku A, 4 — temperatura wody przy dnie na stanowisku C.

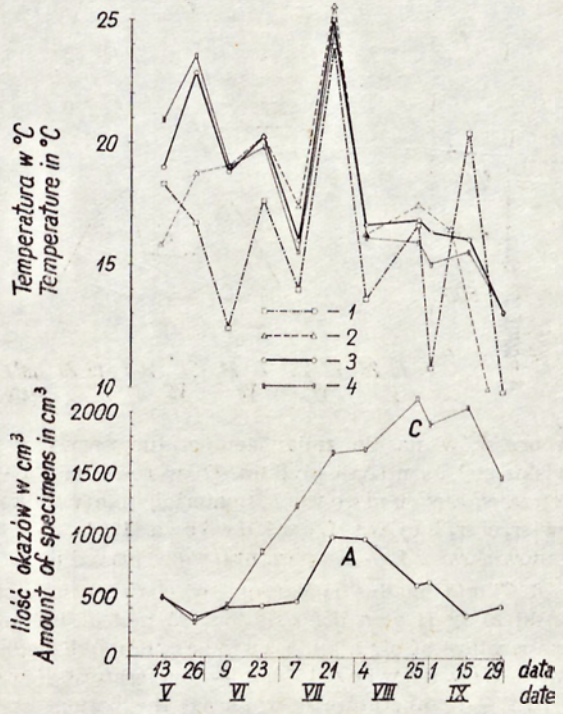
Fig. 2. Population of *Ciliata* on the background of the changes in temperature of the water in the pond Wyszni VI at a deep station (A) and a shallow one (C) in 1963. 1 — mean daily temperature of air after Szumiec (unpublished), 2 — mean daily temperature of water at the bottom after Szumiec (as above), 3 — temperature of water at the bottom at station A, 4 — temperature of water at the bottom at station C.

A great number of *Ciliata* subsisted during July and August till the middle of September. Towards the end of this month, when the temperature of the water was falling, their number decreased, although the amount of organic matter in the bottom continued to be large.

b) Vertical distribution on *Ciliata* microfauna in the mud

The authors who investigated to what depth microfauna can develop in the bottom mud established that *Ciliata* do not move below 5 cm, the majority of them occupying the upper centimetre of the sediment (Cole 1955, Moore 1939). Although the way in which the samples were collected did not permit direct observations on the vertical distribution of

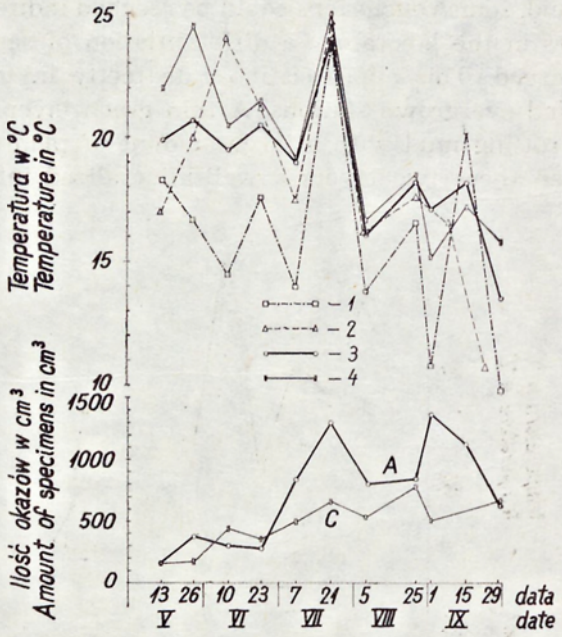
Ciliata in the mud, some conclusions could be reached indirectly. In samples left for analyses in the laboratory a differentiation of several layers was repeatedly observed. This appeared most distinctly in the rich samples from shallow and overgrown stations. A thin green layer collected at the top and black rotting mud with a large amount of plant remains on the bottom. Between these two layers a well-mineralized intermediate layer



Ryc. 3. Populacja orzęsków na tle zmian temperatury wody w stawie Baginiec I na stanowisku głębokim (A) i płytkim (C) w roku 1964. 1 — średnia dzienna temperatura powietrza wg Szumcowej (materiały nie publikowane), 2 — temperatura wody powierzchniowej wg Lewkowicza 1966, 3 — temperatura wody przy dnie na stanowisku A, 4 — temperatura wody przy dnie na stanowisku C.

Fig. 3. Population of *Ciliata* on the background of changes in temperature of the water in the pond Baginiec I at a deep station (A) and a shallow one (C) in 1964. 1 — mean daily temperature of air after Szumiec (unpublished), 2 — temperature of water surface after Lewkowicz 1966, 3 — temperature of water at the bottom at station A, 4 — temperature of water at the bottom at station C.

of red-brown colour was visible. In each layer different *Ciliata* species lived. In the surface layer were grouped above all species feeding on algae and detritus. At the very bottom of the sample sapropelic species prevailed. In the intermediate layer the two groups were intermixed. The dominant species (*Coleps hirtus, Loxodes striatus, Spirostomum minus*), which appeared seasonally in masses, also lived in the top layer of the sediment.



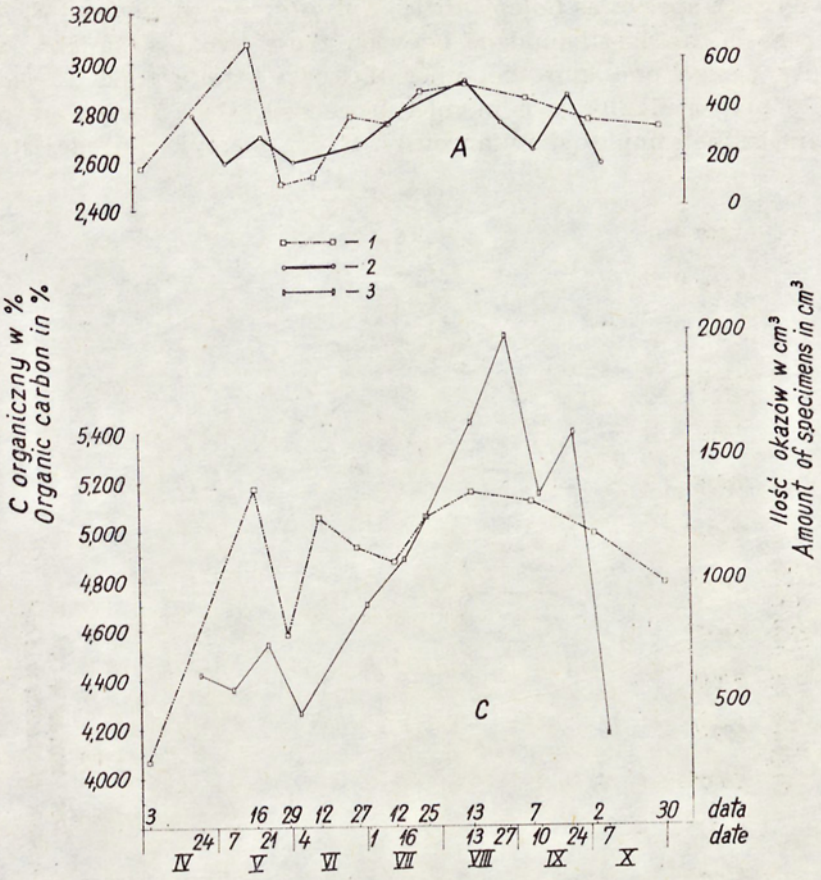
Ryc. 4. Populacja orzęsków na tle zmian temperatury wody w stawie Chyliński Mały II na stanowisku głębokim (A) i płytkim (C) w roku 1964. 1 — średnia dzienna temperatura powietrza wg Szumcowej (materiały nie publikowane), 2 — temperatura wody powierzchniowej wg Lewkowicza 1966, 3 — temperatura wody przy dnie na stanowisku A, 4 — temperatura wody przy dnie na stanowisku C.

Fig. 4. Population of *Ciliata* on the background of changes in temperature of water in the pond Chyliński Mały II at a deep station (A) and a shallow one (C) in 1964. 1 — mean daily temperature of air after Szumiec (unpublished), 2 — temperature of water surface after Lewkowicz 1966, 3 — temperature of water at the bottom at station A, 4 — temperature of water at the bottom at station C.

Discussion and conclusions

Protozoans living in the mud of fresh-water reservoirs form microbiocenoses. Picken (1937) and after him Fauré-Fremiet (1950, 1951) discriminated two essential types of *Ciliata* associations: blue--green and fungoid. In the first type the basic source of food are algae and in the other bacteria.

In the microbenthos of the investigated fishponds various associations developed with a predominance of one or the other type. At the beginning of the rearing season (April, May) green algae coatings were often observed, covering the bottom of ponds in irregular accumulations. Creeping *Ciliata* lived in these coatings, feeding on algae and diatoms. These associations were rather poor as regards both their species and numbers. No marked quantitative predominance of a particular species was observed at that time. During the summer and autumn season there appeared more *Ciliata*

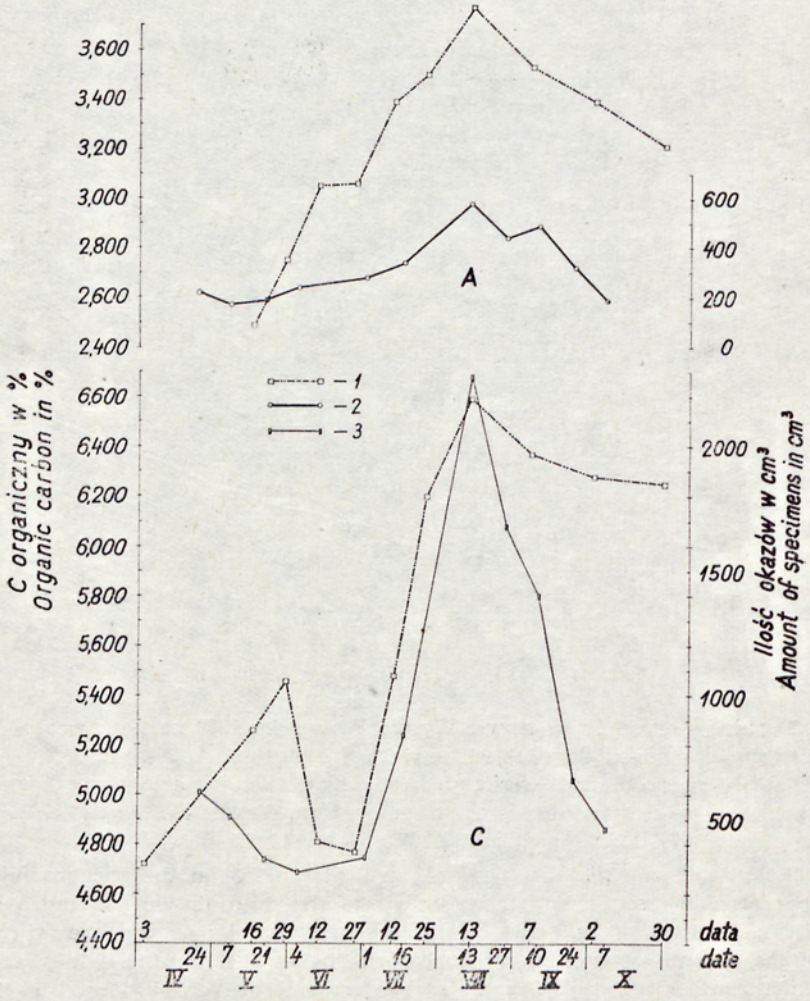


Ryc. 5. Populacja orzęsków w stawie Wyszni VI w roku 1963 na tle zawartości węgla organicznego w osadach dennych stanowiska głębokiego (A) i płytkiego (C). Oznaczenie dat zbioru prób: nad kreską podano daty analiz zawartości węgla organicznego, pod kreską daty zbioru prób mikrobentosu. Zawartość węgla organicznego podano wg W r ó b l a 1965.

Fig. 5. Population of *Ciliata* in pond Wyszni VI in 1963 on the background of the organic carbon content in bottom sediments of the deep station (A) and a shallow one (C). Indications of the date of collection of materials: on the line is given the date of the analysis of organic carbon content, below the line the date of collection of microbenthos material. Organic carbon content is given by W r ó b e l 1965.

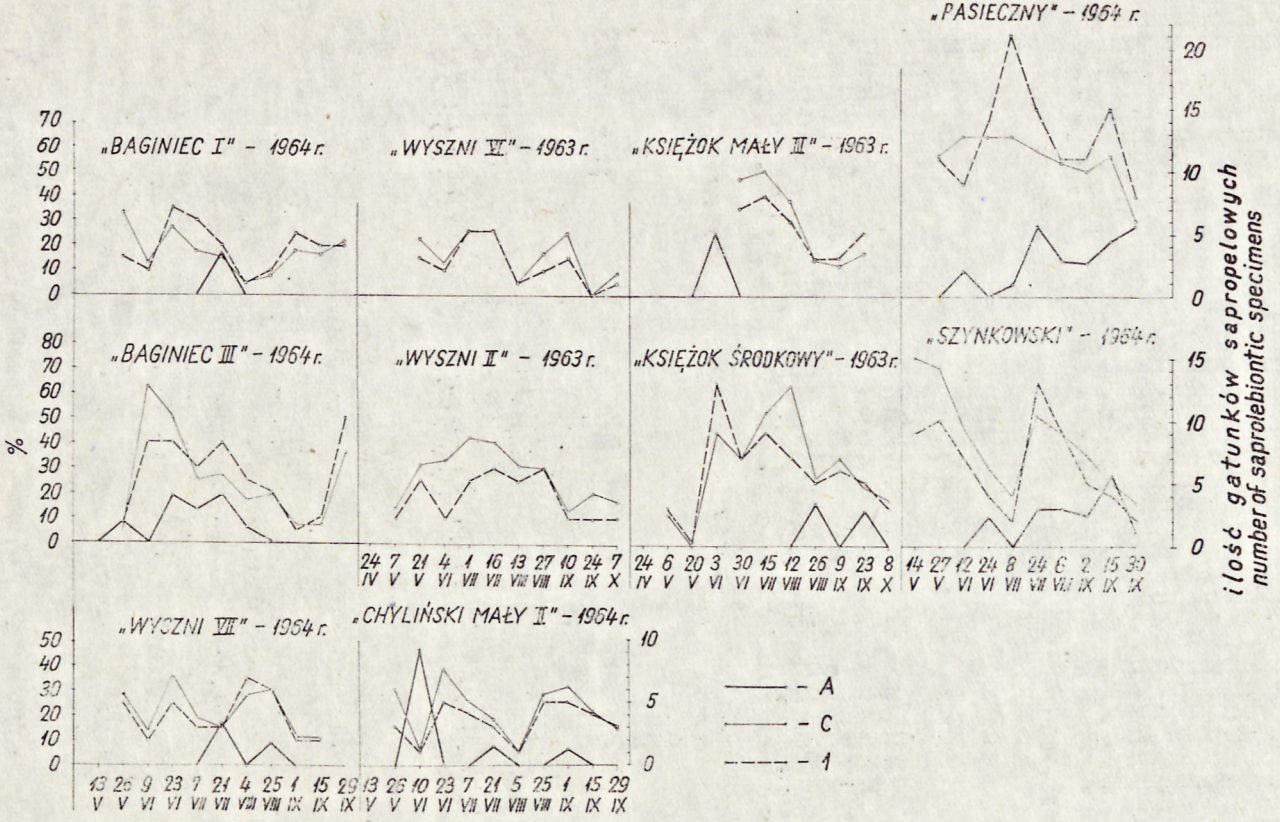
feeding on bacteria. The surface of the bottom during this period was mostly covered by an association of blue-green type, in which the prevailing forms were above all *Ciliata* feeding on algae, particularly *Loxodes striatus* and *L. magnus*, and frequently also *Frontonia acuminata* and *F. leucas*. The mentioned species were very frequent in the summer and autumn. Obviously, some *Ciliata* feeding on bacteria also occurred. An association of bacterial character developed beneath, in which forms feeding on bacteria and detritus predominated. They developed here in masses,

especially such species as *Coleps hirtus*, *Spirostomum minus*, and *S. filum*. There was no marked boundary between these two associations, which gradually passed one into the other. *Loxodes striatus* and *L. magnus* probably play a similar role in microbiocenosis, since they were never dominant in the samples simultaneously. If, for example, *Loxodes striatus*



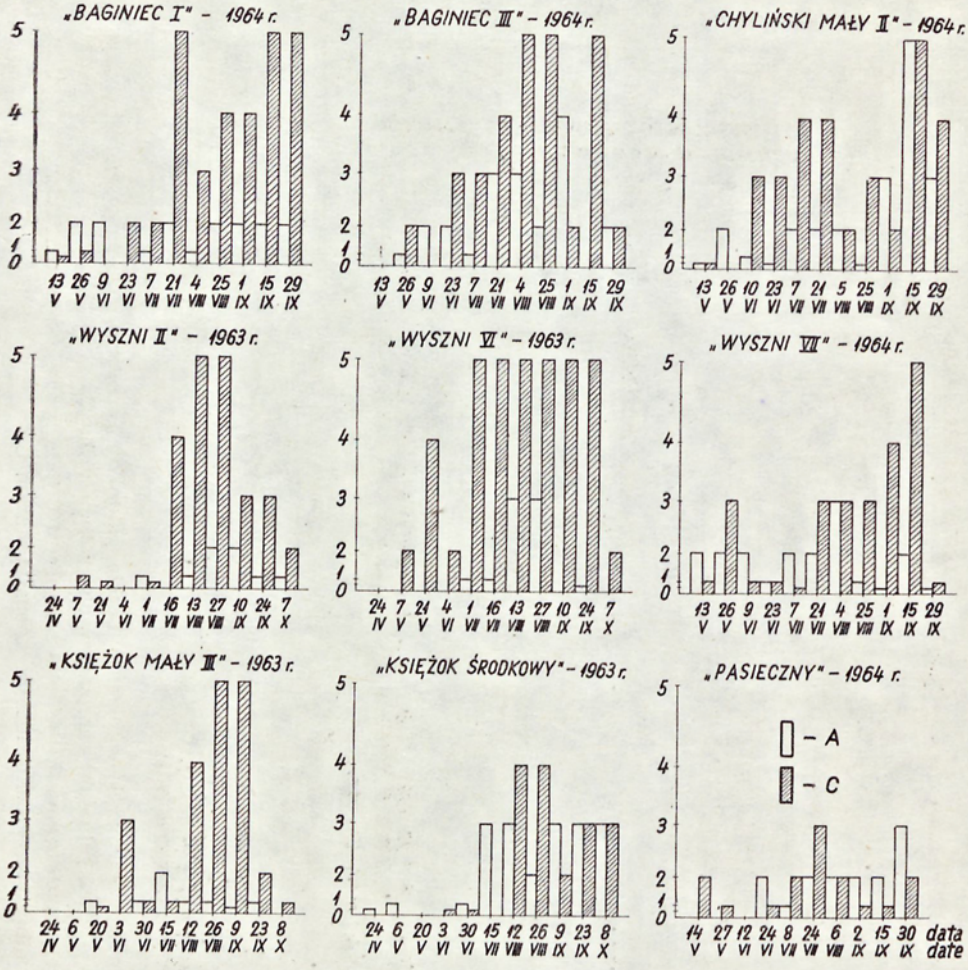
Ryc. 6. Populacja orzęsków w stawie Wyszni II w roku 1963 na tle zawartości węgla organicznego w osadach dennych stanowiska głębokiego (A) i płytkiego (C). Oznaczenie dat zbioru prób: nad kreską podano daty analiz zawartości węgla organicznego, pod kreską daty zbioru prób mikrobentosu. Zawartość węgla organicznego podano według W r ó b l a 1965.

Fig. 6. Population of *Ciliata* in the pond Wyszni II in 1963 on the background of the organic carbon content in bottom sediments of the deep station (A) and a shallow one (C). Indications of the date of collection of materials: on the line is given the date of the analysis of organic carbon content, below the line the date of collection of microbenthos material. Organic carbon content is given by W r ó b e l 1965.



Ryc. 7. Procentowy udział form sapropelowych w ogólnej liczbie gatunków orzęsków w poszczególnych stawach. 1 — ilość gatunków sapropelowych na stanowisku C.

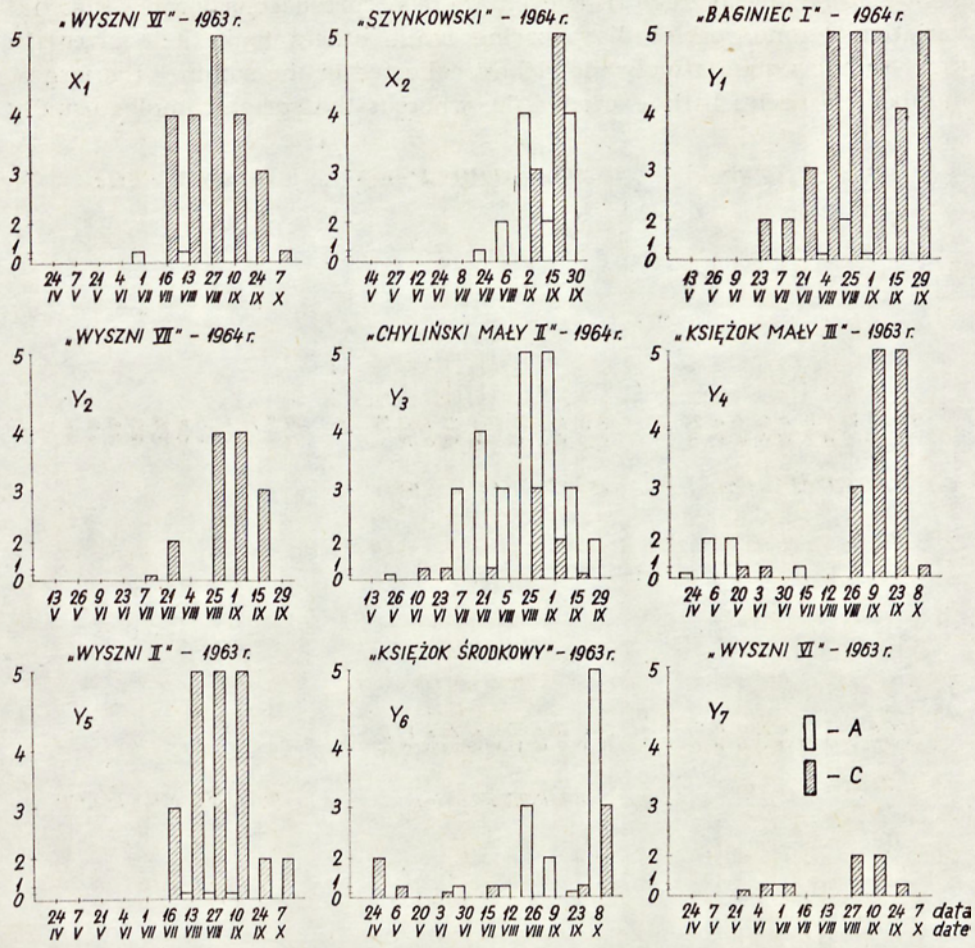
Fig. 7. Percentage share of saprolebiontic forms in the total number of *Ciliata* specimens in particular ponds. 1 — number of saprolebiontic specimens at station C.



Ryc. 8. Sezonowe występowanie gatunku *Coleps hirtus* w poszczególnych stawach na stanowisku głębokim (A) oraz płytkim (C) według skali szacunkowej. Użyto 6-stopniowej skali wg Grospietscha 1958 (0 = raz znaleziony, 1 = bardzo nieliczny, tj. 1—2 okazy pod szkiełkiem nakrywkowym, 2 = nieliczny, odpowiednio 3—10 okazów, 3 = liczny, tj. 11—20 okazów, 4 = bardzo liczny, tj. 21—30 okazów oraz 5 = masowo, czyli ponad 30 okazów pod szkiełkiem nakrywkowym).

Fig. 8. Seasonal appearance of the species *Coleps hirtus* in particular ponds at the deep station (A) and the shallow one (C) according to the estimation scale. The 6-grade scale given by Grospietsch 1958 was used (0 = found only once, 1 = not very numerous or 1—2 individuals under the cover glass, 2 = not numerous, 3—10 indiv., 3 = numerous or 11—20 indiv., 4 = very numerous or 21—30 indiv., and 5 = mass or over 30 indiv., under the cover glass).

developed very abundantly, *L. magnus* was much less numerous or lacking altogether, and conversely. A similar dependence was observed between the species *Spirostomum minus* and *S. filum* (figs 9 and 10). In the summertime *Coleps hirtus* was often the dominant species in the microbiocenosis.



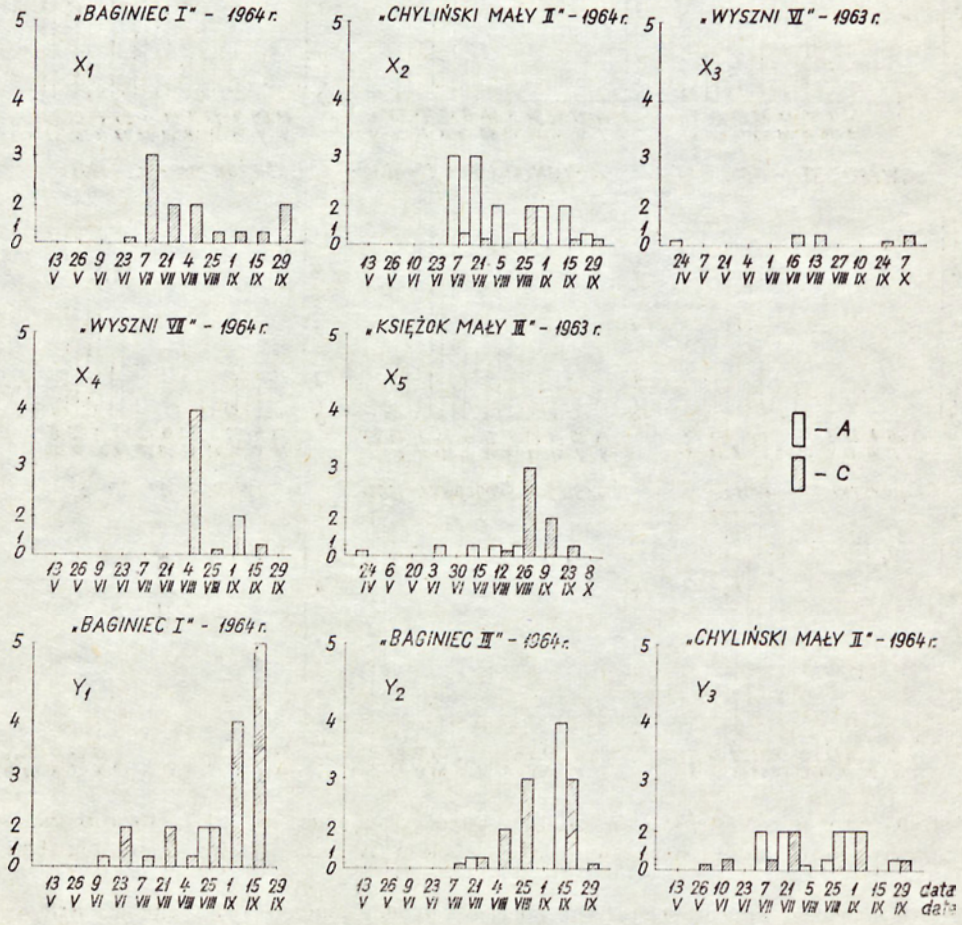
Ryc. 9. Sezonowe występowanie gatunku *Loxodes magnus* (x_{1-2}) i *L. striatus* (y_{1-7}) w poszczególnych stawach na stanowisku głębokim (A) oraz płytkim (C) według skali szacunkowej.

Fig. 9. Seasonal appearance of the species *Loxodes magnus* (x_{1-2}) and *L. striatus* (y_{1-7}) in particular ponds at the deep station (A) and the shallow one (C) according to the estimation scale.

It may be assumed that the association in which species of the genera *Coleps-Loxodes-Spirostomum* predominate is typical of the summer microfauna of the bottom of intensively fertilized fishponds. It is they which give character to the protozoan microbiocenoses of fertile fishponds, being thereby their type forms. Associations of such character subsist till the autumn, but near the very end of the season they decrease in numbers.

Protozoan microbiocenoses of the bottom of fishponds are greatly differentiated specifically. During the season one could find in the particular ponds a relatively large number of *Ciliata* species, amounting

to 80—90 on the average. However, there occurred considerable seasonal variations, some species disappearing while others took their place. In those samples qualitatively the richest collected in the summer the largest number of species little exceeded 30, whereas the spring samples usually



Ryc. 10. Sezonowe występowanie gatunku *Spirostomum filum* (x_{1-5}) i *S. minus* (y_{1-3}) w poszczególnych stawach na stanowisku głębokim (A) oraz płytkim (C) według skali szacunkowej.

Fig. 10. Seasonal appearance of the species *Spirostomum filum* (x_{1-5}) and *S. minus* (y_{1-3}) in particular ponds at the deep station (A) and the shallow one (C) according to the estimation scale.

contained a few or at the most some ten *Ciliata* species. It should be recalled here that to the regular species of the microfauna only four were assigned.

When comparing the above results with others of this kind of investigation it appears that even under very similar environmental

conditions the fauna of *Ciliata* often greatly differs. Under analogous conditions (bottom of fishponds) one observes a considerable similarity in the specific composition, e.g. 67 per cent species were found which were common with those described from fishponds by Bick (1958) and 59 per cent with the species reported by Czapik (1959), also from fishponds, but only 46 per cent were common with the species found by Morawcowa (1955) in natural ponds.

As is well known, microassociations are based on nutritional dependences, the presence of an appropriate source of food being the most important ecological factor determining the possibilities of development of particular protozoan species. The physiological adaptation of *Ciliata* to a certain kind of food led, presumably, to an ecological adaptation to the conditions in which this food develops. Lackey (1938) wrote that in nature probably food is the only factor limiting the quantitative development of *Ciliata*. Fauré-Fremiet (1950) observed that since *Ciliata* are very resistant to physico-chemical changes, only the amount of available food determines their quantitative development. In relation to the kind of food itself the majority of species show a considerable selectivity. The most common in the investigated microfauna of the bottom of fishponds were *Ciliata* capable of feeding on mixed food. Species feeding exclusively on one kind of food, e.g. algae or bacteria, were not numerous. The majority represented microphages and phytophagous forms, whereas predatory ones were scarce. The role of *Ciliata* in the nutritive chain of microbiocenoses is undoubtedly very important, consisting in the fact that they are a natural selective factor for bacteria, contributing to keep them in a state of proper vital activity. Owing to this, the decomposing bacterial action is a continuous process. According to Rodina (1958), the bacterial flora of the bottom is 10 to 100 times richer than that of water, while fertilization has a favourable effect on the abundance of microorganisms and on the intensification of their activity. As was mentioned earlier, the summer flora contains for the most part species feeding on bacteria and detritus. This would lead to the conclusion that fertilization has an intermediate effect on protozoans, influencing the increase in the number of bacteria.

Sapropelic *Ciliata* are a specialized group among forms feeding on bacteria. In fishponds this group found during the summer favourable conditions of development at shallow sites, where under a thick layer of plants a black rotting mud was usually forming. This environment is characterized by a very low oxygen content. As was reported by Wróbel (1965), during the warmest months of the season there occurred in the ponds considerable variations in the oxygen content: in the layers of water near the bottom the O_2 content often fell below 1 mg/l. The percentage share of sapropelic forms in the total number of *Ciliata* species in the particular ponds is shown in fig. 7. *Ciliata* can to some extent reflect the

processes taking place in the mud of the pond, the occurrence of sapropelic *Ciliata* indicating the appearance of putrefactive process there.

Physico-chemical factors undoubtedly have a certain effect on the development of *Ciliata*, although their action is of minor importance. As was earlier reported, the greatest quantitative development occurred in the summer at a high temperature, the quantitative maxima being induced as a rule by thermophilous species of the genus *Coleps*, *Loxodes*, and *Spirostomum*. In the autumn their number usually decreased, although the content of organic matter in the bottom continued to be high. On the other hand, the bacterial action at a temperature of some ten degrees should still be maintained at a high level. In some cases, when the temperature of water fell below 10°C, the amount of bacteria in the bottom mud could have decreased. According to Wang (1928), the influence of water temperature on *Ciliata* consists in an action precipitating the metabolism of the protozoan's cell. The increase in the rate of metabolism brings about a more rapid rate of reproduction.

The reaction of water in the mud of fishponds was maintained in principle within the limits appropriate for the majority of *Ciliata*, i.e. near 7.0 or a little below this value. A weakly acid reaction was noted at shallow sites (lowest value 6.2). It may be presumed that in the deeper parts of the mud a correspondingly higher acidity prevailed. The most favourable conditions for the development of *Ciliata* occurred in the thin superficial layer of mud. The rotting mud lying beneath contained a characteristic sapropelic fauna. In the opinion of many authors (Noland (1925), Wang (1928), Lackey (1938), Stout (1956), Weeb (1958) the reaction of the water has no direct effect on *Ciliata*. However, some of them consider that the pH might sometimes be a limiting factor. E.g. Graaf (1957) maintains that pH = 6.0 is the boundary line for a number of species which cannot occur below this value.

In summing up it can be stated that the quantitative results obtained are in agreement with Wróbel's (1965) considerations asserting that intensively fertilized fishponds reach the highest degree of eutrophization during the summer season in July or August. The process of fertilization enriches the bottom environment, this being reflected in the stronger development of bottom protozoans.

I wish to express my sincere gratitude to Professor Karol Starmach for supervising the present work and for his valuable advice in the course of its realization.

STRESZCZENIE

Na podstawie materiałów zebranych w latach 1963—64 z 10 stawów rybnych (odrostowe) Zespołu Gospodarstw Doświadczalnych Gołysz badano mikrofaunę pierwotniaków mułu dennego, ze szczególnym uwzględnieniem orzęsków. Większość sta-

nowiły stawy intensywnie nawożone mineralnie (kompleksowo). Materiał zbierano wsysaczem mułu Starmacha w dwutygodniowych odstępach czasu przez cały sezon hodowlany z 3 stanowisk, tj.: środka stawu, z części płytkiej i zarośniętej oraz z głębszej i niezarosłej partii. Przeprowadzono analizę ilościową i jakościową mikrofauny. Podano 184 formy orzęsków, 22 korzenionóżek oraz 39 wrotków. Stwierdzono bardzo urozmaicony skład jakościowy orzęsków. Liczba gatunków znalezionych w poszczególnych stawach wahała się od 67—92. Obliczono stopień stałości ich występowania, stwierdzając, że do gatunków stałych (tj. występujących w 51—100% prób) należą zaledwie 4 formy (*Aspidisca costata, Cinetochilum margaritaceum Coleps hirtus* oraz *Halteria grandinella*). Wystąpił wzrost liczby gatunków w miarę zmniejszania się stopnia stałości ich występowania. Najmniej było gatunków rzadkich, tj. występujących w 10% prób (91) oraz bardzo rzadkich (57) występujących tylko sporadycznie. Tylko gatunki stałe znajdowano prawie nieprzerwanie przez cały okres we wszystkich stawach. Za gatunki charakterystyczne dla badanego środowiska uznano te, które były w nim dość częste a okresami pojawiały się masowo. Do takich należały: *Coleps hirtus, Loxodes striatus, Spirostomum filum* i *Spirostomum minus.*

Zmiany ilościowe w populacji orzęsków były w większości stawów dość podobne. Wiosną populacje były ubogie tak gatunkowo, jak i ilościowo. W lecie, począwszy od połowy lipca lub sierpnia, występował gwałtowny wzrost ilościowy w wyniku tak wzrostu ogólnej liczby gatunków, jak i masowego rozwoju orzęsków uznanych za charakterystyczne. Typowy dla letniej mikrofauny dna stawów intensywnie nawożonych był zespół, w którym dominowały rodzaje *Coleps-Loxodes-Spirostomum.* Duża ilość orzęsków w lecie zbiegała się z ociepleniem wody przydennej oraz gromadzeniem się na dnie znacznych ilości materii organicznej. Duże ilości orzęsków utrzymywały się zwykle do września. W obrębie stawów zaznaczyły się duże różnice pomiędzy poszczególnymi stanowiskami. W partiach płytkich i zarośniętych mikrofauna była znacznie bogatsza ilościowo. Porównanie stosunków ilościowych w grupie stawów nie nawożonych i nawożonych wypada na korzyść tych ostatnich, a zwłaszcza intensywnie nawożonych kompleksowo. W obrębie trzech badanych gospodarstw najbogatsze stawy były w gospodarstwie Gołysz.

W okresie letnim znajdowano też w mule orzęski sapropelowe.

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