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Joanna PIJANOWSKA

Department of Hydrobiology, Institute of Zoology, University of Warsaw,
Nowy Świat 67, 00–046 Warsaw, Poland*

ZOOPLANKTON COMMUNITIES IN NINE MASURIAN LAKES

ABSTRACT: Zooplankton communities (crustaceans and rotifers) in nine lakes of the Great Masurian Lakes complex (with considerably different morphometry and less different trophic state) have similar composition and dominance structure during the summer stagnation. Only the communities from mesotrophic Lake Mamry Północne and from polymictic Lake Śniardwy differ quite significantly from the rest. A singificant increase was found of the number and biomass of Cyclopoida, of the number of Rotatoria and of the species diversity of non-predatory Cladocera and of the whole Crustacea and Rotatoria communities with an increase of values of the trophic state index. It was found, also, that together with an increase of pressure of predatory crustaceans, the species diversity in populations of their potential prey, the non-predatory Cladocera and Crustacea, increases, too.

KEY WORDS: Lakes, pelagic zone, zooplankton, Crustacea, Rotatoria, number, biomass, species diversity, invertebrate predation, eutrophication.

Contents

1. INTRODUCTION

Numerous papers on zooplankton of Great Masurian Lakes (a broad review of them is given by G l i w i c z et al. – in press) describe synthetically problems, e.g., of total production and biomass of taxonomic or trophic groups, with not much thought devoted to

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*Present address: Department of Environmental Microbiology, Institute of Microbiology, University of Warsaw, Karowa 18, 00–325 Warsaw, Poland.

the comparison of composition and quantitative relations within communities. That was the reason why characterising the zooplankton communities of these lakes as far as their composition, numbers, dominance structure and species diversity are concerned seemed reasonable.

The relation of the pressure of predatory species to the numbers and species diversity in populations of their potential prey was tried to establish.

2. TERRAIN, MATERIAL AND METHODS

The zooplankton communities were studied during the summer stagnation (in the second half of July 1977) in nine lakes of the Great Masurian Lakes complex: Mamry Północne, Niegocin, Jagodne, Tałtowisko, Tałty, Ryńskie, Mikołajskie, Bełdany and Śniardwy (Table I). These lakes, connected in one waterway, are located in the watersheds of rivers Pisa in southern direction and Węgorapa in nothern direction.

Table I. Morphometry and trophic state of lakes studied

The sequence of lakes in the Table is acc. to their geographic location, North to South

Lake	Area (ha)	Depth (m)		TSI_{SD}*
		maximum	mean	
Mamry Północne	2504	43.8	11.8	35.4
Niegocin	2600	39.7	10.0	50.8 (50.0–51.5)
Jagodne	943	37.4	8.7	49.0 (48.6–49.3)
Tałtowisko	327	39.5	14.0	48.4 (46.8–50.0)
Tałty, Ryńskie	1831	50.8	13.6	60.0
Ryńskie				58.6
Mikołajskie	460	27.8	11.0	57.4
Bełdany	941	46.0	10.0	53.7
Śniardwy	14230	23.4	5.8	45.1

*Values of the trophic state index (if sampling sites differed in their TSI_{SD} the range variation is in brackets).

All of the lakes are dimictic, with an exception of Lake Śniardwy.

Trophic classification of these lakes made of the basis of numerous indices by Gliwicz et al. (in press) shows, that only Lake Mamry Północne is a mesotrophic lake, all the other are eutrophic, with relatively lower eutrophy of lakes Śniardwy and Tałtowisko. The remaining lakes show the symptoms of advanced eutrophy of their surface waters, the hypolimnia and of bottom sediments.

For the present study only one parameter characterising lake trophic state was used, i.e., Secchi disc readings were taken at the moment of zooplankton sampling, and the readings were calculated acc. to Carlson (1977) to values of trophic state index (TSI_{SD}):

$$TSI_{SD} = 10\left(6 - \frac{\ln SD}{\ln 2}\right)$$

where: *SD* is the visibility of Secchi disc in metres.

Logarithmic transformation of Secchi disc readings allows to show the real differences of trophic state of lakes in a linear scale from 0 to 100 (Table I).

The samples were collected at the central part of lakes, from the neighbourhood of the deepest place (from one or two stations). A quantitative plankton net with mesh size 50 μm and the inlet diameter 13.8 cm was used. The net was towed from the depth of 13.5 m to the surface (with an exception of Lake Śniardwy, where the net was towed twice from twice smaller depth), thus each sample contained the material from 200 l.

At single stations on lakes Niegocin, Jagodne, Tałtowisko, Mikołajskie and Bełdany additional samples were collected every 5 m from surface to the bottom with Bernatowicz 5 l sampler (4 samples at each depth). The material was fixed with 4% formaldehyde. For statistical elaboration, the data from all sampling stations were used. The data presented below are the mean values of analysed features.

3. RESULTS

The occurrence of 21 species of crustaceans, including 10 species of Cladocera, 4 species of Calanoida, 7 of Cyclopoida (Table II), and 40 species of Rotatoria (Table III) was found in the pelagial of studied lakes during the summer stagnation. The highest number of species was found in the Mikołajskie Lake, the lowest one of the sampling stations in Lake Bełdany. Between the TSI_{SD} values and the number of species there was no statistically significant relation.

The species composition of zooplankton communities of lakes studied was compared with the help of Sörensen's (1948) index, acc. to Łuczak (1963):

$$QS = 100\left(\frac{2c}{a + b}\right)$$

where: *a* and *b* are the total number of species in communities *a* and *b*, *c* is number of species in common for both communities.

All lakes and all sampling stations are similar in their species composition; the lowest calculated value of *QS* is 64% (between sampling station 2 on Lake Mamry Północne and station 2 on Lake Tałty). For all other cases these values are in between 71–92% (Fig. 1).

Among the nine species of crustaceans which occurred in all lakes (at all sampling stations), the following dominated the most often: *Daphnia cucullata*, *Mesocyclops leuckarti* and *Mesocyclops* (*Thermocyclops*) *oithonoides* (Table II). Among the ten species of rotifers which occurred in all lakes, *Pompholyx sulcata* and *Keratella cochlearis*, represented by two forms, dominated the most often (Table III).

The occurrence of four species of crustaceans (*Bythotrephes longimanus* and three species of the genus *Cyclops*) and of four species of rotifers (*Ascomorpha minima* and three species of the genus *Trichocerca*) were noted only once (Tables II, III).

Bythotrephes longimanus, found only in Lake Mamry Północne, is known as a species characteristic of lakes with slightly advanced trophic state (Bowkiewicz 1938, Pata-

Table II. Species composition, numbers and biomass of pelagic crustanceans and the per cent contribution of particular species to their total numbers in studied lakes during the summer stagnation

A – Cladocera, B – Calanoida, C – Cyclopoida; in frames – dominant species (above 10% of the total numbers); + – species with numbers below 1% of the total. Sequence of lakes as in Table I

	Species	Mamry Północne	Niegocin	Jagodne	Tałtowisko	Tałty	Ryńskie	Mikołajskie	Bełdany	Śniardwy
	Diaphanosoma brachyurum (Liévin)	+	+	+	+	1.7	+	+	+	+
	Daphnia longispina typica (O. F. Müller)	+	+							+
	D. l. hyalina pellucida (Leydig)	1.1	+	+	1.2	+	+	+	+	+
	D. l. galeata (Wagler)			+				+	2.1	1.0
	D. cristata G. O. Sars		3.0	+	4.1	+		+		
	D. cucullata G. O. Sars	[47.7]	[24.6]	[11.3]	[15.0]	[10.3]	[30.3]	7.7	[13.7]	2.6
	Ceriodaphnia quadrangula O. F. Müller	3.5	+	+	+			+		
A	*Bosmina coregoni coregoni* (Baird)	+	+	+	3.9	1.1	2.4	+	2.2	+
	B. c. crassicornis (O. F. Müller)	3.1	+	+	[27.6]	7.5	2.9	2.9	9.7	+
	B. c. thersites (Poppe)		+	+	+	1.2	+	1.9	+	
	B. c. berolinensis (Imhof)	[10.8]							+	2.6
	B. longirostris O. F. Müller)	+	+	3.0	3.1	3.3	+	4.7	+	
	Chydorus sphaericus O. F. Müller	+	[22.9]	2.8	[15.0]	2.2	6.7	1.7	1.6	+
	Bythotrephes longimanus Leydig	+								
	Leptodora kindtii (Focke)	1.3	+	+	+	+		+	+	+
	Numbers (ind. $\cdot$ l^{-1})	21.0	92.4	29.4	74.8	44.1	39.5	53.3	35.5	4.8
	Biomass (mg $\cdot$ l^{-1})	2.0	4.7	1.8	4.0	2.7	2.5	5.7	2.4	0.3

B	*Eudiaptomus graciloides* (Lilljeborg)	4.0	7.5	2.8	1.8	1.7	1.9	6.5	5.1	12.6
	E. gracilis (G. O. Sars)	2.6	4.2	1.8	2.4	+	+	4.5	2.2	6.1
	Heterocope appendiculata G. O. Sars	+		+				+		
	Limnocalanus macrurus G. O. Sars	2.8			+		+			1.7
	Nauplii of Calanoida	6.6	5.9	3.7	1.7	2.5	+	5.2	9.6	19.0
	Numbers (ind. · l^{-1})	4.8	30.9	12.6	6.6	7.6	3.2	40.9	18.5	25.7
	Biomass (mg · l^{-1})	0.7	4.2	1.6	1.0	0.5	0.6	6.3	1.6	2.8
C	*Cyclops bicuspidatus* Claus					1.2				
	C. scutifer G. O. Sars			1.0						
	C. vicinus Uljanin							1.8		
	Acanthocyclops viridis (Jurine)				+			+		
	Mesocyclops leuckarti Claus	5.4	11.5	16.5	7.5	14.4	21.4	16.4	14.6	15.6
	M. (Thermocyclops) oithonoides (G. O. Sars)	5.4	6.1	20.1	11.7	15.5	15.3	12.2	6.0	10.0
	M. (T.) crassus (Fischer)	+	2.0				6.1	1.8		
	Cyclopoida ssp.*			2.7		1.4	6.1			1.8
	Nauplii of Cyclopoida	3.6	9.9	30.5	2.9	34.1	2.7	28.0	28.6	25.8
	Numbers (ind. · l^{-1})	4.5	51.7	102.3	23.7	103.0	45.5	146.1	55.0	34.7
	Biomass (mg · l^{-1})	0.1	1.2	3.4	0.8	3.5	2.3	5.0	1.7	1.0
Total numbers (ind. · l^{-1})		30.3	175.0	144.3	105.1	154.7	88.2	240.3	109.0	65.2
Total biomass (mg · l^{-1})		2.8	10.1	6.8	5.8	6.6	5.4	17.0	5.7	4.0

*I–III copepodites of Cyclopoida, not determined to species.

Table III. Species composition, numbers and biomass of planktonic rotifers and the per cent contribution of particular species to their total numbers in studied lakes during the summer stagnation

In frames – dominant species (above 10% of the total numbers); + – species with numbers below 1% of the total. Sequence of lakes as in Table I

Species	Mamry Północne	Niegocin	Jagodne	Tałtowisko	Tałty	Ryńskie	Mikołajskie	Bełdany	Śniardwy
Brachionus angularis Pallas	+	+	+	+	+	+	+	+	+
Keratella cochlearis f. typica Gosse	**12.8**	3.1	**28.3**	**22.6**	**18.7**	**15.1**	**18.8**	**41.1**	**14.4**
K. c. f. tecta Gosse	+	1.0	7.7	**16.3**	**27.8**	**11.8**	**21.0**	**13.6**	+
K. quadrata (Müller)		8.7	5.3	1.2	4.8	3.4	4.4	1.7	+
Kellicotia longispina (Kellicot)	2.3	1.3	1.6	1.4	1.4	3.7	2.4	3.1	1.1
Anuaeropsis fissa (Gosse)	+							+	+
Euchlanis dilatata Ehrenberg	+				+		+	+	+
Trichotria pocillum (Müller)	+							+	+
Lecane flexilis (Gosse)	+	+	+	+	+		+	+	+
Trichocerca tigris (Müller)								+	
T. similis (Wierzejski)			+	+	4.9	5.6		+	
T. porcellus (Gosse)	+	+	+	+		+	1.2	+	1.7
T. rousseleti (Voigt)					+				
T. cylindrica (Imhof)				+					
T. capucina (Wierzejski et Zacharias)	5.2	+	+	1.0	2.0	1.6	4.8	3.3	5.5
T. stylata (Gosse)			+				+		
T. elongata (Gosse)			+			+			
T. pusilla (Jennings)			+	+	+	1.3	1.9		
Gastropus stylifer Imhof	+			+	+	+	+	+	+
Chromogaster ovalis (Bergendal)	+	+		+	+	+	1.1	1.5	6.4
Ascomorpha ecaudis Perty		+	1.1	1.7	1.0	+	2.0	+	4.0
A. saltans Bartsch		+	+	+	+	+		+	+
A. minima Hofsten	+								
Asplanchna priodonta Gosse	3.7	+	+	+	+	+	+	+	

A. girodi de Guerne			+				+		
Synchaeta tremula (Müller)	7.3								+
S. kitina Rousselet	1.2	+	+	+	+	2.4	9.3	5.9	+
S. grandis Zacharias		+			+	+	+		
S. stylata Wierzejski		1.0	+	1.6	1.5		+	2.8	+
S. pectinata Ehrenberg	**12.9**	3.3	5.4	6.0	2.7	3.2	1.5	5.9	+
S. oblonga Ehernberg	6.3	+	1.4	5.3	+	+	1.6	1.1	+
Bipalpus hudsoni (Imhof)	1.0	+	+				+		+
Ploesoma sp. Herrick	+	+							
Polyarthra dolichoptera Idelson	3.0	5.1	8.9	1.9	+	+	**10.2**	1.2	1.7
P. major Burckhardt		+	+	+	+				
P. remata Skorikov	+		+				+	+	
Pompholyx sulcata Hudson	**20.2**	**50.9**	**22.7**	**33.2**	**36.9**	**46.7**	**14.7**	**12.7**	**22.5**
Filinia longiseta (Ehrenberg)	5.0	+	1.6	+		+	+		
Conochilus hippocrepis (Schrenk)	+	+	+	+			+		**16.7**
C. unicornis Rousselet	**18.1**	+	**11.2**	4.2	+	1.2	2.2	2.0	**21.2**
Collotheca mutabilis (Hudson)		+	+	+	+	+	+		+
Total numbers (ind $\cdot$ l^{-1})	179.2	767.5	646.8	711.8	836.2	616.5	387.9	284.1	446.1
Total biomass (mg $\cdot$ l^{-1})	0.34	0.29	0.28	0.26	0.29	0.15	0.20	0.01	0.22

l a s 1954). Species of the genus *Cyclops* are related in summer with near-bottom water layers, only seldom becoming a component of plankton in this period (R y l o v 1963).

The number of crustaceans in studied lakes during the summer stagnation was 30–240 ind. · l^{-1}, of rotifers 179–838 ind. · l^{-1}, and of the whole communities 210–991 ind. · l^{-1}.

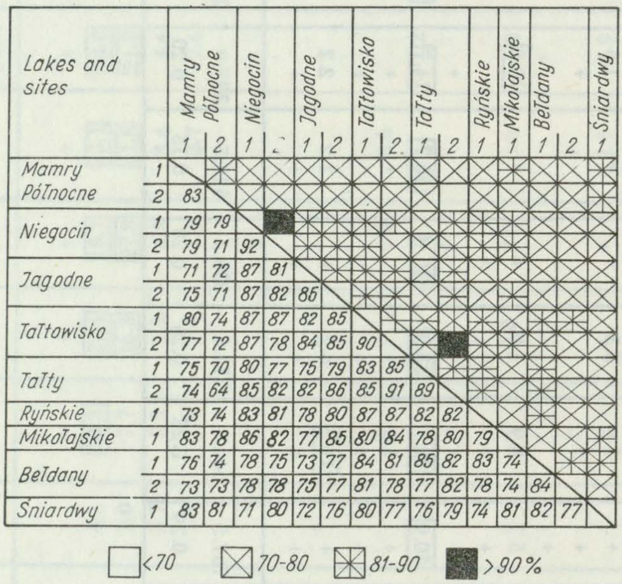

Fig. 1. Species similarity of plankton communities of lakes studied (Sörensen's index)
Sequence of lakes as in Table I

The biomass was calculated on the basis of the number and mean weight of individuals of crustaceans acc. to N a u w e r c k (1963), and of rotifers acc. to J. Ejsmont-Karabin (unpublished data). The biomass of crustaceans was 2.8–17.0 mg · l^{-1}, of rotifers 0.01–0.34 mg · l^{-1}, and of the whole communities 3.1–17.2 mg · l^{-1}. The highest numbers of communities was found for Lake Tałty, the highest biomass – in Mikołajskie Lake. The lowest numbers and biomass of communities was found in Lake Mamry Północne (Tables II, III).

A significant dependence was found between the TSI_{SD} values and the numbers (N) and biomass (B) of Cyclopoida (r_N = 0.70 and r_B = 0.69, r_N, $r_B > r_{0.005}$) and of rotifers (r_N = 0.046 and r_B = –0.46, r_N, $r_B > r_{0.1}$). Similar relations were not found for the TSI_{SD} values and the numbers and biomass of Cladocera, Calanoida, communities of non--predatory Cladocera and Crustacea, the whole communities of crustaceans and particular species of planktonic filtrators.

The rotifers contributed the most to the numbers of the whole communities at all sampling stations (above 60% of the total numbers). Their contribution to the biomass of communities was, however, very small (always below 12%) (Fig. 2). Contribution of Cladocera to the total numbers varies from 0.9% in Lake Śniardwy to 10% in Lake Mamry Północne, and to the total biomass from 7.1% in Lake Śniardwy to 65.8% in Lake Tałtowisko.

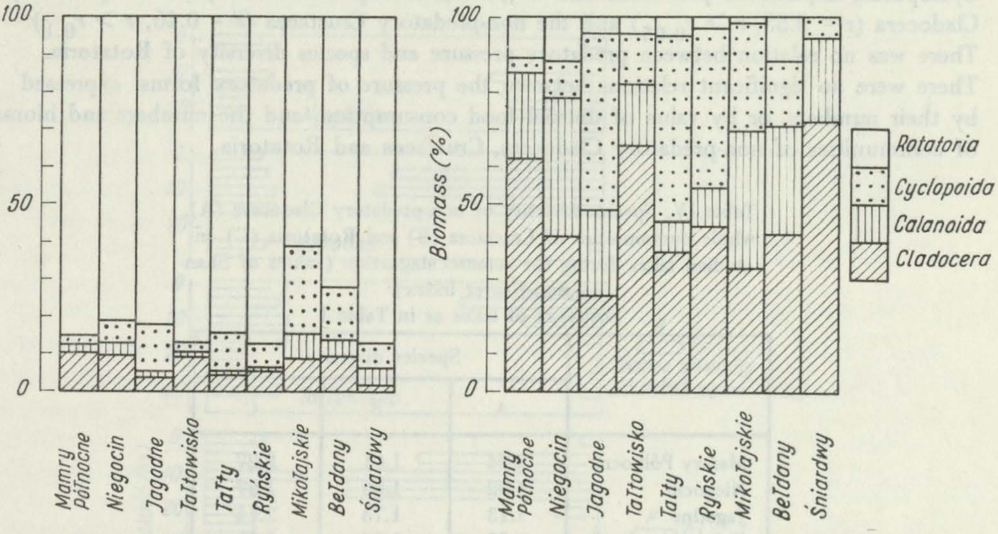

Fig. 2. The per cent contribution of Cladocera, Calanoida, Cyclopoida and Rotatoria to the total numbers and biomass of zooplankton communities in studied lakes during the summer stagnation
Sequence of lakes as in Table I

Contribution of Calanoida to the total numbers on all sampling stations does not exceed 6.5%, and to the biomass it varies from 7.1% in Lake Tałty to 65.2% in Lake Śniardwy. Contribution of Cyclopoida to the numbers of communties varies from 2.1% in Lake Mamry Północne to 23.3% in the Mikołajskie Lake, and to the biomass from 3.8% in Lake Mamry Północne to 47.7% in Jagodne Lake (Fig. 2).

Species diversity in communities of non-predatory Cladocera, of Crustacea and Rotatoria was calculated acc. to formula of Shannon-Weaver (1948, acc. to Margalef 1958):

$$H = -\sum_{i}^{1} \frac{n_i}{N} \ln \frac{n_i}{N}$$

where: n_i is number of species i, N is total number of all species.

The highest values of Shannon-Weaver index for communities of non-predatory cladocerans, of crustaceans and rotifers were found in the Mikołajskie Lake; the lowest diversity of non-predatory Cladocera and of whole communities of Crustacea was for both stations on Lake Mamry Północne, and of Rotatoria – for Lake Niegocin (Table IV). A significant relation between values of TSI_{SD} and species diversity of non-predatory Cladocera was found ($r = 0.57$, $r > r_{0.05}$) and Crustacea ($r = 0.71$, $r > r_{0.005}$).

There was established a significant relation between the predatory pressure[1] of crustaceans and rotifers (*Leptodora kindtii*, *Bythotrephes longimanus*, late copepodites and adult

[1] Value of the diurnal food consumption was used as a measure of predatory pressure, assuming similarly as Gliwicz, Hillbricht-Ilkowska and Węgleńska (1978), that in 20°C it equals for *Leptodora kindtii* 40% of its body weight (the same was assumed for *Bythotrephes longimanus*), for *Mesocycles leuckarti* and *M. (Thermocyclops) oithonoides* as 50% of their body weight, with half of

Cyclopoida, *Asplanchna priodonta* and *A. girodi*), and species diversity of non-predatory Cladocera ($r = 0.55$, $r > r_{0.05}$) and the non-predatory Crustacea ($r = 0.46$, $r > r_{0.1}$). There was no relation between predatory pressure and species diversity of Rotatoria. There were no significant relations between the pressure of predatory forms, expressed by their numbers, or by value of diurnal food consumption, and the numbers and biomass of communities of non-predatory Cladocera, Crustacea and Rotatoria.

Table IV. Species diversity of non-predatory Cladocera (A), whole communities of Crustacea (B) and Rotatoria (C) in studied lakes during the summer stagnation (values of Shannon-Weaver index)
Sequence of lakes as in Table I

Lake	Species diversity		
	A	B	C
Mamry Północne	0.94	1.61	2.27
Niegocin	1.02	1.86	1.67
Jagodne	1.13	1.73	2.14
Tałtowisko	1.38	1.95	2.03
Tałty	1.43	2.00	1.83
Ryńskie	0.99	1.67	1.88
Mikołajskie	1.67	2.17	2.38
Bełdany	1.04	1.77	2.05
Śniardwy	1.36	1.87	2.14

In pelagial of six lakes (Niegocin, Jagodne, Tałtowisko, Tałty, Mikołajskie and Bełdany) on small depths the predatory pressure is accompanied by large species diversity in communities of non-predatory crustaceans; on larger depths, decreasing predatory pressure is accompanied by decreasing species diversity of non-predatory crustanceans (Fig. 3).

4. DISCUSSION

The analysed lakes of the Great Masurian Lakes complex vary in morphometry, hydrological relations, area of their drainage basins and way of their management. Certain differences in the degree of their eutrophication are noticed, confirmed by, among the others, differences in water transparency, summer thermal and oxygen stratification, chemistry of bottom sediments, primary production, biomass, intensity and lasting of phytoplankton blooms (G l i w i c z et al. – in press). These differences among the lakes are only slightly reflected in the composition and dominance structure of zooplankton communities – the same species occur and dominate in the majority of lakes analysed. The communities in mesotrophic Lake Mamry Północne and in polymictic Lake Śniardwy are the only ones different in this aspect from others.

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this being the plant food (this value was also assumed for the remaining species of Cyclopoida), and for *Asplanchna priodonta* as 100% of its body weight, with half of this being plant food (this value was also assumed for *Asplanchna girodi*). The food consumption changes in temperatures 8–22°C acc. to the Krogh's curve.

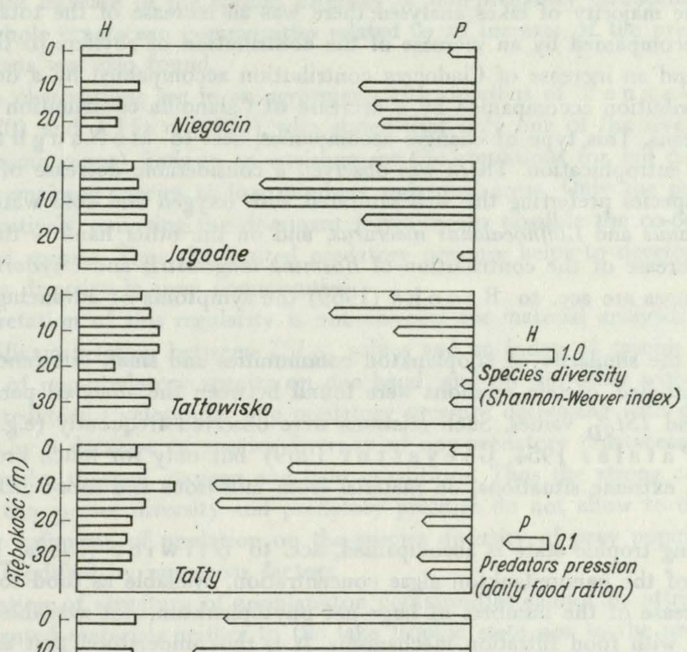

Fig. 3. Species diversity of communities of non-predatory crustaceans *H* and pressure of predatory crustaceans *P* at different depths of studied lakes during the summer stagnation

It is worth noticing, that the zooplankton communities show such similarity during the summer stagnation, when lakes are the most differentiated in their thermal and oxygen stratification, and other communities, e.g., phytoplankton, macrophytes and bottom fauna become visibly differentiated (G l i w i c z et al. – in press). Zooplankton communities become differentiated, though, in quite distinct way, during the winter stagnation and spring and fall circulations, when the lakes become similar to each other as far as thermics and oxygen saturation of waters are concerned (P i j a n o w s k a 1978). It seems that pelagic zooplankton communities are less sensible indicator of trophic state (at least for analysed narrow spectrum of lake trophic state) than, e.g., phytoplankton. The phytoplankton in the same lakes reacts to changes of trophic state, acc. to S p o d n i e w s k a (1978), with quick changes of production, biomass and dominance structure. This is obvious, as phytoplantkon, the community of producers, reacts first to changes of the nutrient pool.

It should be added that a comparison of these data with analogous ones from summer stagnation periods from previous years (G l i w i c z et al. – in press) shows that during last years in the majority of lakes analysed there was an increase of the total numbers of zooplankton accompanied by an increase of the contribution of rotifers to the whole communities, and an increase of Cladocera contribution accompanied by a decrease of Calanoida contribution accompanied by a decrease of Calanoida contribution to communities of crustaceans. This type of changes accompanies, acc. to M c N a u g h t (1975), the advancing lake eutrophication. There was observed a considerable decrease of frequency of crustacean species preferring the well saturated with oxygen and cold waters – *Bythotrephes longimanus* and *Limnocalanus macrurus*, and on the other hand – there was a noticeable increase of the contribution of *Bosmina longirostris* and *Chydorus sphaericus*. The above changes are acc. to B r o o k s (1969) the symptoms of advancing eutrophication.

Apart from the similarity of zooplankton communities and small differences in trophic state of lakes studied, certain relations were found between the analysed parameters of communities and TSI_{SD} values. Such relations were observed frequently (e.g., B o w k i e w i c z 1938, P a t a l a s 1954, G i e y s z t o r 1969) but only for much broader trophic spectrum, with extreme situations, on material from numerous and more differentiated lakes.

The advancing trophic state is accompanied, acc. to G l i w i c z (1969a, 1969b, 1977), by a decrease of the nannoplankton algae concentration, available as food for filtrators, and by an increase of the numbers of large net phytoplankton, not available for filtrators and interfering with food filtration mechanisms. It is thus understood that an increase of the numbers and biomass of planktonic filtrators (some species of Cladocera and Calanoida) did not occur with an increase of TSI_{SD} values. With an increase of these values, though, there was noticeable increases of the numbers and biomass of Cyclopoida, which supplement their animal food by significant quantities of plant material, being able to utilize large net algae, too.

An increase of the rotifer numbers was also observed simultaneously with an increase of the TSI_{SD} values. The bacterioplankton and detritus, rising their concentration with advancing trophic state, are the food of numerous rotifers (G l i w i c z 1969a, 1969b). An increase of the rotifer numbers in analysed lakes with more advanced trophic state is accompanied by a decrease of their biomass. The above results from the decrease of the numbers and of the contribution of the large forms of rotifers, mainly of the genus *Asplanchna*, with simultaneous increase of significance of small forms with small biomass in lakes with higher TSI_{SD} values.

Although the material studied shows certain relations between the TSI_{SD} values and the analysed parameters of communities, already known from larger and more differentiated material, no significant changes were found of the number of species and number of dominants in relation to changes of lake trophic state. The number of species, and the number of dominants within the community should decrease with an advancing lake trophic state (B o w k i e w i c z 1938, P a t a l a s 1954, 1966), probably due to the elimination of species sensitive to extreme trophic situations (algal blooms, oxygen depletions). A significant increase of the species diversity was found, though, of non-predatory Cladocera, of the whole communities of Crustacea, and of Rotatoria, with an increase of TSI_{SD} values. The low species diversity is characteristic, in accordance with opinions of C o n n e l l and O r i a s (1964) and O d u m (1975), of ecosystems with strong physico-chemical limiting factors; the high one – for systems receiving a lot of energy and nutrients.

A significant increase of the species diversity of non-predatory cladoceran populations and of the whole crustacean communities related to an increase of the pressure of predatory crustaceans was also found.

The above observations are in an agreement with opinions of Pennak (1957), Zaret (1970) and Allan (1974), who stated that only one of the several related species (of the same genus) finds in an environment the conditions for full development, limiting the remaining species to low numbers and small areas. Only the presence of predators selectively removing the dominant forms makes possible the co-occurrence of closely related species. Thus the limited predatory pressure helps to develop an increase of the species diversity in prey communities.

An interpretation of this regularity is not univocal for material analysed, as there was found a significant relation between TSI_{SD} values and an index of species diversity in communities of non-predatory species on one hand, and on the other with numbers and biomass of predatory Cyclopoida. The predatory pressure decreasing with depth of a lake, accompanied by a decrease of species diversity of non-predatory crustaceans can be, in turn, modified by thermal, oxygen and light conditions. Thus the strong correlation indices between the species diversity and predatory pressure do not allow to determine quite positively the influence of predation on the species diversity of prey populations, as both of them are modified by numerous factors.

The formation of structure of zooplankton communities cannot be attributed, on the basis of presented material, neither to the lake trophic state nor to the predatory pressure (especially as pressure of predatory *Chaoborus* larvae and of planktonivorous fish were not considered), as effects of both can mutually cancel, reinforce or be modified by numerous factors not considered in this paper.

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5. SUMMARY

On the basis of analysis of species composition, numbers, biomass, dominance structure and species diversity of zooplankton communities (crustaceans and rotifers) of nine lakes of the Great Masurian Lakes complex during the summer stagnation (Table I) the following were found:

1. The plankton communities show considerable similarity of species composition (Fig. 1) and dominance structure (Tables II, III). Only the communities in mesotrophic Lake Mamry Północne and in polymictic Lake Śniardwy differ significantly from the others.

2. Rotifers are the most numerous component of the communities (always above 60% of the total numbers). Their contribution to the total zooplankton biomass does not exceed 12% (Fig. 2).

3. The numbers and biomass of Cyclopoida and numbers of Rotatoria increase with an increase of TSI_{SD} values. Such dependence was not found neither for Cladocera, nor for the whole communities of Crustacea, nor for particular species of planktonic filtrators.

4. The rising values of TSI_{SD} are accompanied by an increase of species diversity of non-predatory Cladocera communities, whole Crustacea communities and of Rotatoria (Table IV).

5. With an increase of the pressure of predatory crustaceans, the species diversity in populations of their potential pray – the non-predatory species of cladocerans and crustaceans, also increases (Fig. 3).

6. POLISH SUMMARY

Na podstawie analizy składu gatunkowego, liczebności, biomasy, struktury dominacyjnej i zróżnicowania gatunkowego w zespołach zooplanktonu (skorupiaków i wrotków) w okresie stagnacji letniej w dziewięciu zbiornikach kompleksu Wielkich Jezior Mazurskich (tab. I) stwierdzono:

1. Zespoły zooplanktonu wykazują duże podobieństwo w składzie gatunkowym (rys. 1) i strukturze dominacyjnej (tab. II, III). Jedynie zespoły w mezotroficznym jeziorze Mamry Północne i polimiktycznym jeziorze Śniardwy różnią się dość znacznie od pozostałych.

2. W ogólnej liczebności zespołów najwyższy udział mają wrotki (zawsze powyżej 60%). Ich udział w łącznej biomasie nie przekracza 12% (rys. 2).

3. Wraz ze wzrostem wartości wskaźnika stanu trofii TSI_{SD} rośnie liczebność i biomasa *Cyclopoida* wraz liczebność *Rotatoria*. Nie stwierdzono takiej zależności dla *Cladocera*, całych zespołów *Crustacea* ani poszczególnych gatunków filtratorów planktonowych.

4. Rosnącym wartościom wskaźnika stanu trofii towarzyszy wzrost zróżnicowania gatunkowego w zespołach niedrapieżnych *Cladocera*, całych zespołach *Crustacea* i *Rotatoria* (tab. IV).

5. Wraz ze wzrostem presji drapieżnych skorupiaków wzrasta zróżnicowanie gatunkowe w populacjach ich potencjalnych ofiar – niedrapieżnych garunków wioślarek i skorupiaków (rys. 3).

7. REFERENCES

1. Allan J. D. 1974 – Balancing predation and competition in cladocerans – Ecology, 55: 622–629.
2. Bowkiewicz J. 1938 – O pewnych prawidłowościach w składzie jakościowym zooplanktonu jezior [On certain regularities in lake zooplankton composition] – Fragm. faun. Mus. Zool. Pol. 3: 345–408.
3. Brooks J. L. 1969 – Eutrophication and changes in the composition of the zooplankton (In: Eutrophication: causes, consequences, correctives) – Nat. Acad. Sci. Publ. No. 1700: 236–255.
4. Carlson R. E. 1977 – A trophic state index for lakes – Limnol. Oceanogr. 22: 361–369.
5. Connel J. M., Orias E. 1964 – The ecological regulation of species diversity – Am. Nat. 98: 399–414.
6. Gieysztor M. 1959 – On a continuous series of lakes – Pol. Arch. Hydrobiol. 6: 175–187.
7. Gliwicz Z. M. 1969a – Studies on the feeding of pelagic zooplankton in lakes with varying trophy – Ekol. pol. A, 17: 663–708.
8. Gliwicz Z. M. 1969b – Wykorzystanie produkcji pierwotnej przez konsumentów planktonowych w zależności od długości łańcucha pokarmowego [Utilization of primary production by plankton consumers depending on the length of the food chain] – Ekol. pol. B, 15: 63–70.
9. Gliwicz Z. M. 1977 – Food size selection and seasonal succession of filter feeding zooplankton in an eutrophic lake – Ekol. pol. 25: 179–225.
10. Gliwicz Z. M., Hillbricht-Ilkowska A., Węgleńska T. 1978 – The contribution of fish and invertebrate predation to the elimination of zooplankton biomass in two Polish lakes – Verh. int. Verein. Limnol. 20: 1007–1011.
11. Gliwicz Z. M., Kowalczewski A., Ozimek T., Pieczyńska E., Prejs A., Prejs K., Rybak J. I. (in press) – Ocena stopnia eutrofizacji Wielkich Jezior Mazurskich [Evaluation of the degree of eutrophication of Great Masurian Lakes] – Wydawnictwa Inst. Kształtowania Środowiska.
12. Łuczak J. 1963 – Differences in the structure of communities of web spiders in one type of environment (young pine forest) – Ekol. pol. A, 11: 159–221.
13. Margalef D. R. 1958 – Information theory in ecology – Gen. Syst. 3: 36–71.
14. McNaught D. C. 1975 – A hypothesis to explain the succession from calanoids to cladocerans during eutrophication – Verh. int. Verein. Limnol. 19: 724–731.
15. Nauwerck A. 1963 – Die Beziehungen zwischen Zooplankton und Phytoplankton im See Erken – Symb. bot. upsal. 17: 1–163.
16. Odum E. P. 1975 – Diversity as function of energy flow (In: Unifying concepts in ecology, Eds. W. H. Van Dobben, R. H. Mc-Connel) – W. Junk Publishers, Hague, 302 pp.

17. P a t a l a s K. 1954 – Zespoły skorupiaków pelagicznych 28 jezior pomorskich [Pelagic crustacean communities of 28 Pomeranian lakes] – Ekol. Pol. 2: 61–92.
18. P a t a l a s K. 1966 – Niektóre aspekty produkcji zooplanktonu w jeziorach [Some aspects of zooplankton production in lakes] [In: Produktywność ekosystemów wodnych (Productivity of water ecosystems)] – Zesz. probl. Kosmosu, 13: 57–68.
19. P e n n a k R. W. 1957 – Species composition of limnetic zooplankton communities – Limnol. Oceanogr. 2: 222–232.
20. P i j a n o w s k a J. 1978 – Zespoły zooplanktonu pelagicznego w Wielkich Jeziorach Mazurskich [Zooplankton communities in Great Masurian Lakes] – M.Sc. Thesis, University of Warsaw, Warsaw, 44 pp.
21. R y l o v V. M. 1963 – Freshwater Cyclopoida (In: Fauna of USSR) – Jerusalem, Vol. III, No. 3, 314 pp.
22. S p o d n i e w s k a I. 1978 – Phytoplankton as an indicator of lake eutrophication. I. Summer situation in 34 Masurian lakes in 1973 – Ekol. Pol. 26: 53–70.
23. Z a r e t T. M. 1970 – Predators, invisible prey, and the nature of polymorphism in the Cladocera (class Crustacea) – Limnol. Oceanogr. 17: 171–184.