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Populacje wioślarek (*Cladocera*) i widłonogów (*Copepoda*) w zbiornikach zaporowych południowej Polski

Populations of *Cladocera* and *Copepoda* in dam reservoirs of southern Poland

Mémoire présenté le 5 avril 1971 dans la séance de la Commission Biologique de l'Académie Polonaise des Sciences, Cracovie

A b s t r a c t — Population of planktonic crustaceans were investigated in 10 dam reservoirs on rivers lying in the Vistula basin. 90 species were found in them (37 *Rotatoria*, 32 *Cladocera*, and 21 *Copepoda*). The most varied crustacean plankton occurred in the water of water steps, where the diversity index amounted to 23—25, and the most uniform in the lowland reservoir at Kozłowa Góra and in the submontane one at Rożnów (2). The magnitude of zooplankton production depended on the rate of water exchange and on the age of the reservoir. Three types of curves of the development of populations in the course of the season were distinguished. In the majority of reservoirs seasonal maxima were simultaneously attained by two populations. In the populations of *Cladocera* mature individuals prevailed and among *Copepoda* particular stages of development.

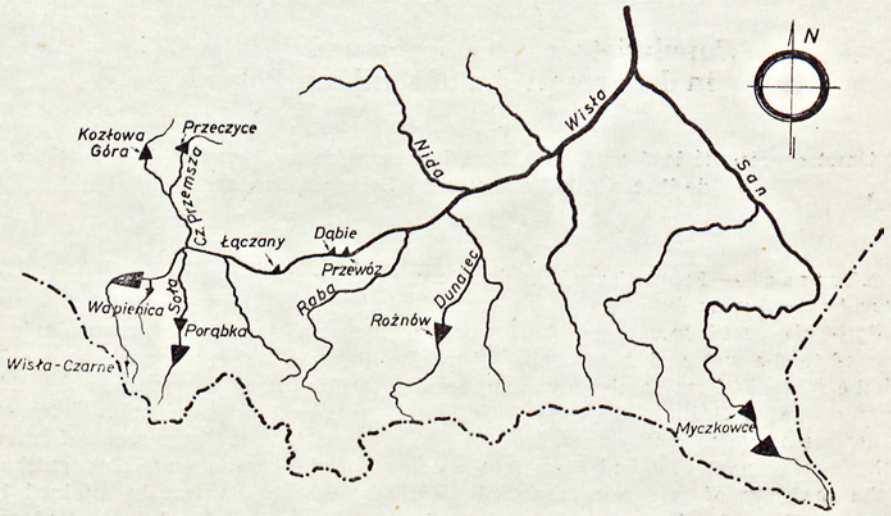
Dam reservoirs, built more and more frequently on rivers in southern Poland, have as yet been little investigated with regard to their fauna. Fauna communities on the one hand reflect the external environment, and on the other exert a considerable influence on it, determining the usefulness of the water for technical, water-supply, and fish farming purposes.

The aim of the present work was to investigate the qualitative and quantitative composition of zooplankton in dam reservoirs and to analyse the features of the dominant populations of *Cladocera* and *Copepoda*.

Samples of zooplankton were taken in the investigated reservoirs at monthly intervals in the period free from ice cover. The plankton was caught, according to the size of the reservoir, in vertical section from several sampling places in the pelagic and littoral zones, and from the bottom with the aid of a sampler of Patalas type and of plankton nets.

The results of the present work were based on 80 catches made in the course of four years' investigations.

The investigations were carried out on 7 dam reservoirs and 3 water steps in southern Poland in the years 1965—1968. Various types of dam reservoirs were chosen for these investigations: typically lowland ones (limnic), as e.g. at Przeczyce on the Czarna Przemsza and at Kozłowa Góra on the Brynica, rheolimnic at Porąbka on the river Soła, Myczkowce on the San, Wapienica on the river Wapienica, and Rożnów on the Dunajec, and finally a mountain reservoir of entirely swift-flowing water at Wisła--Czarna. Simultaneously, for comparison, the zooplankton of small water steps was investigated on the Vistula at Łączany, Dąbie, and Przewóz. All these reservoirs lie in the Vistula basin (fig. 1).



Ryc. 1. Położenie badanych zbiorników
Fig. 1. Situation of the investigated reservoirs

Of all these reservoirs observations on zooplankton had previously been carried out only at Kozłowa Góra, Porąbka, and Rożnów (Otto 1957, Czapik 1958, Smagowicz 1962, Olszewski 1964, Siemińska 1952, 1966, Biernacka 1963, Krzanowski 1965).

Table I lists the most important features of the investigated reservoirs, reported in the works of Kołder (1964), Starmach (1958), and Wajdowicz (1958, 1966, 1968).

Przeczyce and Kozłowa Góra are typically limnic reservoirs, lying on lowland, slow-flowing rivers. They are distinguished by a slow exchange of water (at Przeczyce the water is exchanged twice a year and at Kozłowa Góra five times). The characteristic trait of the reservoir at Kozłowa Góra are the considerable fluctuations of the water level in the course of the year. The upper part of the reservoir is often dried up, which has a considerable influence on its tropic conditions.

Tabela I. Opis i cechy fizyczne zbiorników

Table I. Description and physical feature of reservoirs

Zbiornik Reservoir	Rzeka, na której znajduje się zbiornik River on which the reservoir is found	Wysokość w m n.p.m. Height in m above sea-level	Rok budowy Year of construction	Maksymalna powierzchnia w ha Maximum area in ha	Maksymalna głębokość w m Maximum depth in m	Okres całkowitej wymiany wody w dniach Period of total exchange of water	Typ limnologiczny zbiornika Limnological type of the reservoir	Przeznaczenie zbiornika Purpose of the reservoir
Przeczyce	Czarna Przemsza	ok. 150	1963	420	11,5	190	nizinny limnic	energetyczny power
Kozłowa Góra	Brynica	ok. 180	1935-1939	537	5.5	.72	nizinny limnic	wodociągowy water-supply
Porąbka	Soła	320	1936	380	15.0	30	reolimniczny rheolimnic	energetyczny power
Wapienica	Wapienica	380	1941	18	18,0	15	reolimniczny rheolimnic	wodociągowy water-supply
Rożnów	Dunajec	ok. 350	1943	1900	28,0	32	reolimniczny rheolimnic	energetyczny power
Myczkowce	San	350	1961	270	15,0	6	reolimniczny rheolimnic	energetyczny power
Wisła Czarne	Wisła	450	1949	1.6	5.0	7	reolimniczny rheolimnic	osadzanie żwiru deposition of gravel

On the other hand, no such strong fluctuations, either daily or annual, were observed at Przeczyce. Moreover, a strong influence of spring waters was marked there, owing to which the water in summer had a relatively low temperature.

The dam reservoirs at Rożnów, Wapienica, Myczkowce, and Porąbka have features of rheolimnic reservoirs, lying on swiftly flowing submontane rivers. The period of total exchange of water is much shorter in them than in the lowland reservoirs (e.g. at Rożnów it takes place 11 times within the year, and at Myczkowce even every week).

Of all the investigated reservoirs the most different in character are the water steps on the Vistula and the reservoir at Wisła Czarna. The water steps are built in such a way that the withdrawn Vistula water forms a channel of varying length according to the reservoir. The conditions prevailing in these reservoirs recall on the one hand rivers (constant, daily exchange of water) and on the other dam reservoirs.

The most reminiscent of a river is the small reservoir at Wisła-Czarna. It has strongly swift-flowing water and only in its western part in a small bend is the water partly still.

Tabela II. Lista gatunków wraz z frekwencją występowania w badanych zbiornikach zaporowych

Table II. List of species and frequency of occurrence in the investigated dam reservoirs

Gatunki Species	Przeczyce			Kozłowa Góra		Porąbka		Wapienica		Rożnów	Myczkowce			Wisła-Czarne	Łączany	Dąbie	Przewóz
	1965	1966	1968	1967	1968	1967	1968	1966	1968	1968	1965	1966	1968	1967	1966	1966	1966
Rotatoria																	
Argonotholca foliacea (Ehrb.)									1								
Asplanchna priodonta Gosse	53	31	8	76		46			12	25	4	4	83	0,1	26	15	33
Brachionus angularis Gosse	23	28	33	41		10		1	3	6	4	3	50	1	16	10	32
- calyciflorus Pallas		5				1								0,5	21		12
- diversicornis (Daday)															1		4
- quadridentatus Hermann										2					3		7
- urceolaris O.F.Müller				29											5	5	5
Cephalodella sp.						1			7								
Colurella sp.						3			5								
Euchlanis alata Voronkov															3		10
- dilatata Ehrb.		3				3				5	5			0,1			10
- oropha Gosse														0,1			
Filina longiseta (Ehrb.)	11	2		2		1				2	5	2	8		5		8
Kellicottia longispina (Kellicott.)	4	58	100	63				1	3	2	1	7		0,5	1		15
Keratella cochlearis (Gosse)	68	76	58	88		71		1	3	29	1	8	83		21		32
- quadrata (O.F.Müller)	17	40	66	50		4			6	3	6	4	16		4	15	17
Lecane rhenana Haller						3						20					
- sp.	3	14							2	3		20	16	0,1			
Lepadella acuminata (Ehrb.)																	
- ovalis (O.F.Müller)																	
- patella (O.F.Müller)								1	2								
Notholca acuminata (Ehrb.)				2		1						2	8				
- limnetica (Levander)																	
- striata (O.F.Müller)									1	2				2			
- sp.	3											8					
Pleosoma lynceus (Ehrb.)									7								
Polyarthra dolichoptera Idelson	85	62		44				100	57	38	8	5	100	5	21	15	15
- major Burckhardt	2			32					5	4			100				
- minor Voigt				17					9	2	1				1	5	1
- platyptera Skorikov						7				4			25		8		

Rotatoria elongata (Weber)														1	2		
- rotatoria (Pallas)														3			
Synchaeta grandis Zacharias				4		36			6								1
- litoralis Rousselet									8								
- sp						1											
Trichocerca sp																	1
Trichotria tetractis (Ehrb.)				1		1											
Cladocera																	
Acroperus harpae Baird	2	4		1													
Alona affinis Leydig	4	4		5	12				5		1	4	6	0,5	1	5	
oostata G.O.Sars				3	12	2		1	4	2				0,1			
guttata G.O.Sars				1													1
quadrangularis O.F.Müller	7	3		6	37	3		2	7	2	4	2		0,1	16		1
Alonella nana Baird				2		1		3	21								
Bosmina coregoni Baird		52	83	83	90				1	15				0,1		5	7
- longirostris O.F.Müller	73	30	11	11		55		64	26	68	12	13	100	0,1	13	1	15
Camptocercus rectirostris Schoedler		1		1		2								0,1			
Ceriodaphnia quadrangula O.F.Müller	63	48		15	37	38		95	39	40	1	1	35	0,2	16	5	7
Chydorus ovalis Kurz		1				8			7						1		
- piger G.O.Sars		2															
- sphericus O.F.Müller	15	2	75	15	50	6		1	19	2	1			7	8		7
Daphnia cucullata G.O.Sars	68	59	41	75	62	33	93			68	4	3		0,1	15	40	18
- longispina O.F.Müller	15	30	83	21	25	17		42	39	41			53		17	10	1
- pulex de Geer		1													1		
Diaphanosoma brachyurum Lieven	39	37	8	5	30	15	6		1			1					4
Eurycercus lamellatus O.F.Müller			1			1											
Iliocryptus agilis Kurz				2					1								
Leptodora kindtii Focke			8	13		5	31			2	8						
Leydigia leydigii Fischer						1			1	5				20			
Moina rectirostris Leydig															5		1
Monospilus dispar G.O.Sars				1													
Peracantha truncata O.F.Müller		1													1		1
Pleuroxus aduncus Jurine		1		1		1		1	7	2					1		
uncinatus Baird						1											
Polyphemus pediculus Linne		1		4		2	12								1		
Rhynchotalona rostrata Koch				3		1											
Scapholeberis mucronata O.F.Müller		1		2	1	1											
Sida crystallina O.F.Müller				13		3											

Cd. tabeli II

Gatunki / Species	Przeczyce			Kozłowa Góra		Porąbka		Wapienica		Rożnów	Myczkowce			Wisła-Czarne	Łączany	Dąbie	Przewóz
	1965	1966	1968	1967	1968	1967	1968	1966	1968	1968	1965	1966	1968	1967	1966	1966	1966
Simocephalus expinosus Koch															1		1
- vetulus O.F.Müller	2	1		1		1			3								
Copepoda																	
Calanoida																	
Eudiaptomus gracilis G.O.Sars	71	48	58		2	47	56	100	72		1				13	40	20
Cyclopoida																	
Acanthocyclops bicuspidatus (Claus)	2	5													1		1
- bisetosus (Rehberg)															1		1
- vernalis Fischer (Fischer)	3	3	75			1		1	3	68				0,1	7		14
Cyclops furcifer Claus		2							18								
- kolensis Lill.	4	21				1			2						9		1
- strenuus landei (Koźmiński)	10		25					1	8						3	1	15
- - strenuus (Fischer)	19	25		21	12	26	50			2	1	1					
- vicinus Uljanine	26	19	50	5		4					1				8		3
Eucyclops macruroides Lilljeborg	1	1		1										12			
- macrurus G.O.Sars				3		1			1								
- serrulatus Fischer	3	5		4		4			7		1	1		39	8		23
Macrocyclops albidus Jurine	3			2		9		1	8	2	1	1		1	2		4
- distinctus I.Richard									1								2
- fuscus Jurine									1					1			
Megacyclops viridis Jurine	4	8							1		1	1	1	7	3	10	5
Mesocyclops leuckarti Claus	55	42	100	75	100	75	87			46	1	1	95		6	15	13
- oithonoides G.O.Sars	2	1													1		1
Paracyclops fimbriatus Fischer	10	2	25			6				6	7	7		14	1		11
Thermocyclops crassus (Fisch.)	19	44	75	61	100	49	87				1	1			6	45	7
Canthocamptus sp.	1	1				1			4			1		0,1			

Qualitative composition

In the investigated reservoirs altogether 90 species were determined (37 *Rotatoria*, 32 *Cladocera*, and 21 *Copepoda*). Of all the species occurring only some were distinguished by a high frequency of occurrence (Table II). Furthermore, those caught in the majority of or in all reservoirs were distinguished at the same time by a high frequency within the particular reservoirs.

The majority of the species determined were cosmopolites and ubiquitous species occurring in the plankton of reservoirs lying in a similar latitude.

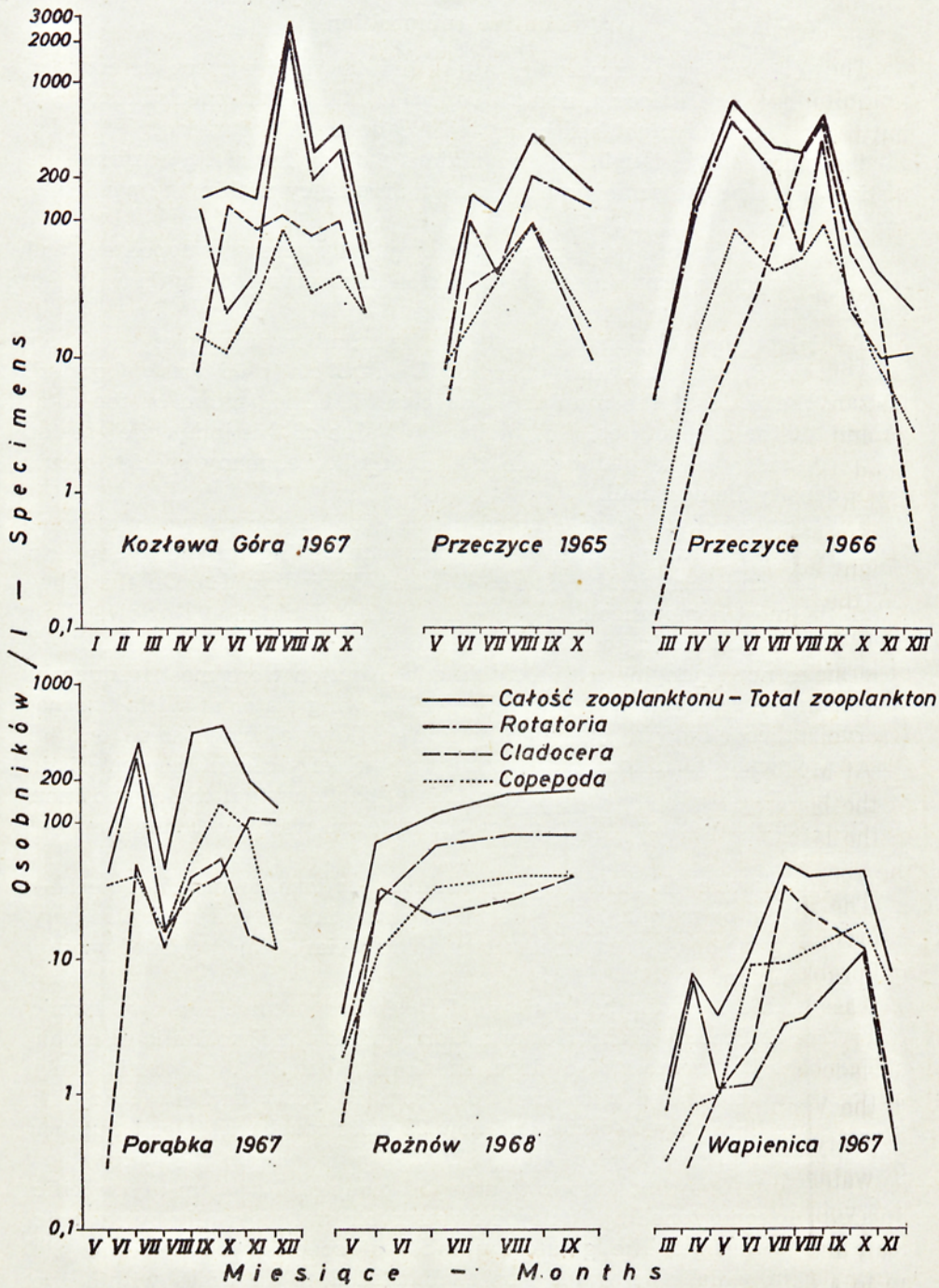
To detect the relationship between the number of species and their density, the density index introduced by D i e t r i c h (1966) was elaborated. This is the ratio of the number of species to the logarithm of the total density of the zooplankton. The higher the value of this index the greater is the diversity of zooplankton in the reservoir, i.e. many species occur, their density being small.

The greatest diversity was noted in the zooplankton on water steps at Łączany and Przewóz (the diversity index amounting on the average to 25 and 23), and then at Myczkowce (17) and Wapienica (11). On the other hand, the most homogeneous was the crustacean plankton at Kozłowa Góra and Rożnów (amounting on the average to 2).

Species not belonging to the eulimnetic plankton were most frequently caught in the reservoir with strongly swift-flowing water at Wisła-Czarna. On the other hand, in the slightly slower flowing water steps on the Vistula typically planktonic crustaceans were chiefly caught, characteristic of large reservoirs of standing water. Hence it follows that the composition of crustaceans was conditioned by the rate of water exchange in the reservoir.

At Myczkowce, in the first years of investigations, forms characteristic of the bottom or marginal zone of water reservoirs prevailed. It was only in the last year of observations that pelagic species formed a chief part of the zooplankton.

The greatest qualitative variety of *Cladocera* occurred in two limnic reservoirs at Przeczyce and Kozłowa Góra and in the rheolimnic reservoir at Porąbka. The number of cladocer species at Kozłowa Góra considerably increased as compared with the data from 10 years earlier (C z a p i k 1958), since then only 6 species and now 23 were caught. The least number of cladoceran species were caught at Wisła-Czarna and on the water steps on the Vistula. Hence it follows that in the group of *Cladocera* the specific diversity is conditioned by the type of reservoir and especially by the rate of water exchange. The greatest number of species was noted in the reservoir in which the water was exchanged 2 to 10 times within the year, and the smallest in reservoirs in which this took place from 12 times up to a daily exchange.



Ryc. 2. Zmiany liczebności badanych grup zooplanktonu w zbiornikach
Fig. 2. Changes in the number of investigated groups of zooplankton in the reservoirs

Quantitative data

In contradistinction to the relatively small qualitative differences, considerable quantitative differences were observed between the investigated reservoirs. Detailed data concerning the density and biomass of the particular groups of zooplankton are presented in Table III.

In the reservoir at Przeczyce a marked systematic increase in biomass was noted in the group of *Crustacea* in the successive seasons of observations, whereas *Rotatoria* were characterized by the largest biomass in the second year of investigations. One distinct peak of increased density of all the investigated groups was observed in this reservoir in the season of 1965, followed by a rapid fall towards autumn (fig. 2). Moreover, in the group of *Rotatoria* a slight increase in density was observed in June. The curve of changes in numbers in the following year ran slightly differently. In the group of *Rotatoria* and *Copepoda* two peaks of increased density were noted (in June and September), whereas in the group of *Cladocera* only one peak occurred in September.

Taken as a whole *Rotatoria* prevailed in number, especially during the second season. Among *Crustacea* more *Cladocera* were caught in the summer of the year 1965 and 1966, *Copepoda* being more numerous in spring and autumn.

Tabela III. Średnie zagęszczenie i biomasa Rotatoria, Cladocera, Copepoda

Table III. Mean density and biomass of Rotatoria, Cladocera, and Copepoda

Zbiornik Reservoir	Zagęszczenie Density					Biomasa Biomass				
	Rok Year	Rotatoria	Cladocera	Copepoda	Razem Total	Rok Year	Rotatoria	Cladocera	Copepoda	Razem Total
Przeczyce	1965 1966 1968	247 483 175	117 63 96	101 103 129	465 649 400	1965 1966 1968	0,05 0,29 0,07	1,0 2,0 3,5	0,6 0,7 2,1	1,65 2,99 5,67
Kozłowa Góra	1967	501	81	31	613	1967	1,5	3,07	0,7	5,27
Porąbka	1967	154	28	58	240	1967	0,14	0,5	1,0	1,64
Wapienica	1967	5	15	9	29	1967	0,004	2,4	0,23	2,634
Rożnów	1968	204	95	103	402	1968	0,37	0,94	0,91	2,22
Myczkowce	1965 1966 1968	0,2 5,3 61	0,1 0,1 34	0,2 0,2 13	0,5 5,6 108,0	1965 1966 1968	0,005 0,03 0,05	0,004 0,006 0,36	0,0008 0,0005 0,15	0,0098 0,0365 0,56
Wisła-Czarne	1967	0,2	3,3	15,5	19,0	1967	0,005	0,03	0,07	0,105
Łączany Dąbie Przewóz	1965 1966	7	10	20	37	1965 1966	0,06	0,3	0,4	0,76

The second richest after Przeczyce with regard to the production of zooplankton proved to be the reservoir at Kozłowa Góra. *Rotatoria* prevailed here numerically, but *Cladocera* had the largest biomass. In the density of the whole zooplankton a distinct maximum occurred in August (fig. 2). Another slight increase in number was noted in October. The greatest seasonal variations occurred in the group of *Rotatoria*. Broadly speaking,

the curves illustrating the changes in number of the three groups are similar to each other.

Taking into consideration the data presented above, the zooplankton of the reservoir at Kozlowa Góra can be characterized as rotifer-crustacean with a predominance of cladocerans.

A slightly different development of zooplankton was noted during the investigated season in the reservoir at Rożnów, where the density of all the examined groups gradually increased from May to September. On the average, rotifers prevailed numerically in the course of the year and it was only in June that crustacean were decidedly predominant (fig. 2).

Among the submontane rheolimnic reservoirs the reservoir at Rożnów was distinguished by the greatest density of the whole zooplankton.

Much poorer with regard to the production of zooplankton proved to be the reservoir at Porąbka. Two peaks of increased density were observed in this reservoir. The most intensive development of *Crustacea* occurred in September and of *Rotatoria* in June. In the group of *Crustacea* the percentage share of *Copepoda* was almost always higher than that of *Cladocera*, except in June. Thus, the zooplankton of the dam reservoir at Porąbka is of crustacean-rotifer character with a predominance of copepods. The above data were corroborated in a control investigation in the following season, in which copepods also prevailed numerically.

The other submontane reservoirs, such as those at Myczkowce, Wapienica, and Wisła-Czarna were characterized by a very poor zooplankton. Even as compared with the extremely oligotrophic Tatra lakes (Woźniczka 1965), the mean quantities of planktonic organisms at Wisła-Czarna and in the two first seasons of observations at Myczkowce were several times lower.

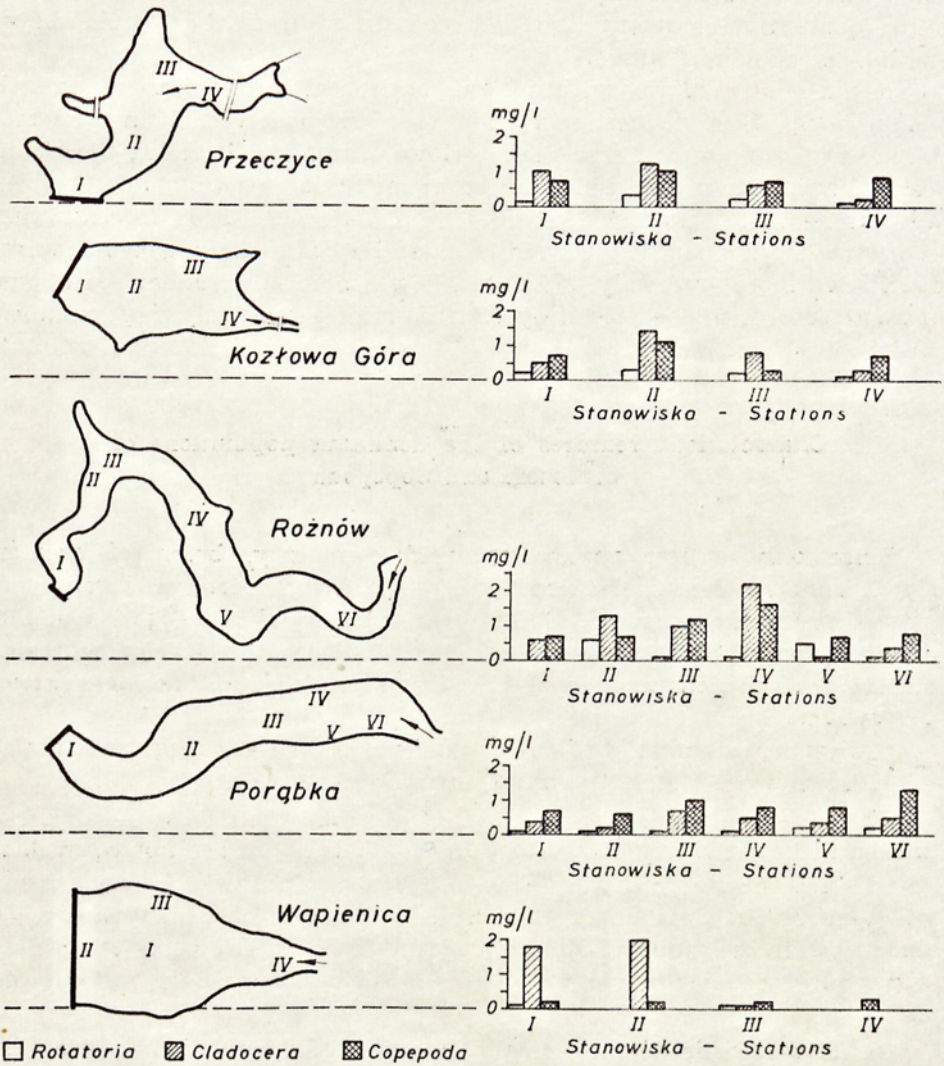
A systematic increase in number and thereby in biomass was observed at Myczkowce in each successive season of investigations. In 1968 the density of all examined organisms increased by more than 200 times as compared with the year 1965. In the last year of investigations cladocerans developed most intensively, their share in the biomass being then the greatest. This characteristic increase in density referred to relatively few intensively developing populations of crustaceans.

Taken as a whole, the animal plankton of the dam reservoir at Myczkowce was of rotifer-crustacean character. The mean percentage share of rotifers in all three seasons was larger than that of crustaceans. However, a distinct increase in the number of the latter was noted in each of the following seasons. In the years 1965 and 1966 copepods were most often the dominant forms among crustaceans, whereas in August 1968 cladocerans prevailed. Thus, with the ageing of the reservoir the share of crustaceans, especially of cladocerans, increased.

The water of the reservoirs at Wapienica and Wisła-Czarna was characterized by a minimal density of rotifers (on the average from 0.2

to 5 individuals in one litre of water). Thus, the zooplankton of these two reservoirs was of crustacean character with a marked predominance of copepods at Wisła-Czarna and of cladocerans at Wapienica.

The curves illustrating the changes in number of the particular groups of plankton in the reservoir at Wapienica differed from one another essentially (fig. 2). In the group of *Rotatoria* two peaks of increased density were noted in spring and in autumn. The maximum density of *Copepoda*



Ryc. 3. Rozmieszczenie poziome zooplanktonu
Fig. 3. Horizontal distribution of zooplankton

occurred in October and that of *Cladocera* in July, followed towards autumn by a systematic decrease.

A characteristic trait of the water of water steps on the Vistula at Łączany, Dąbie, and Przewóz were the considerable variations in the density of zooplankton, especially in the group of *Cladocera* and *Copepoda*. In 1966 at Łączany the maximum density amounted to 91 individuals per litre and the minimum to only 0.2 individuals per litre. Moreover, it was found that in the investigated water steps there occurred no differences, either qualitative or quantitative, between the water in the Vistula above the barrier and the channel.

In the course of investigating the horizontal distribution of animal plankton (fig. 3) in all these reservoirs one could observe that in the large ones, such as those at Przeczyce, Kozłowa Góra, and Rożnów, the main mass of zooplankton was concentrated in the middle part of the reservoir, whereas near the dam and the banks the plankton was poor. In reservoirs of a smaller area and narrow, as e.g. at Porąbka, the organisms were distributed more uniformly. Moreover, it was noted that under conditions of swift current in the proximity of tributaries a relatively large number of copepods were caught.

Characteristic features of the dominant populations of Cladocera and Copepoda

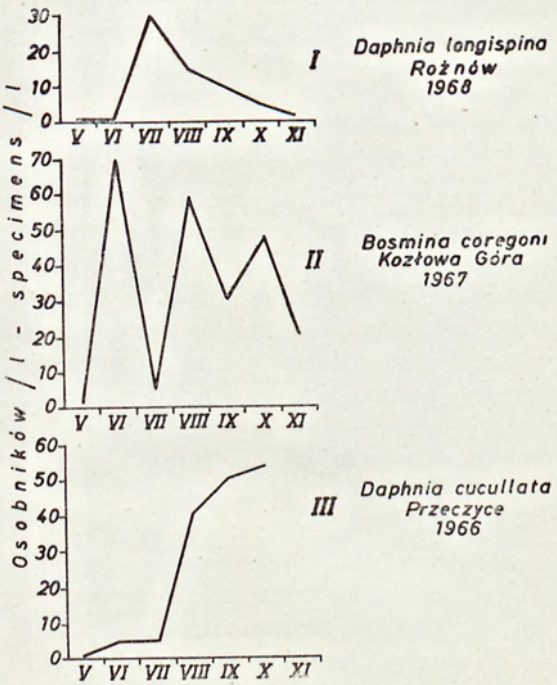
Since only a few species occurred commonly, being of greater significance in the whole biocenosis, while others occurred rarely and played no important role, it would seem that a close investigation of the dominant populations would be sufficient to learn the development and structure of the community of crustacean plankton in the investigated reservoirs.

Changes in the density of the population, as well as its age and spatial distribution were closely examined in the present work.

The observed changes in the density of populations illustrate in great measure the curve of the increase in population, but are not equivalent to it, since the material was taken at too great intervals. In populations of copepods the data obtained concerning changes of density are more exact than in the group of cladocerans, since ontogenesis in this group lasts about 3 to 4 weeks, whereas in cladocerans this period is much shorter (some days).

A characteristic feature of the investigated populations were the considerable variations of density, occurring both between the particular reservoirs and between the successive catches. The most numerous populations were noted among *Cladocera* (*Bosmina coregoni* 145 individuals per litre, *Daphnia cucullata* and *Ceriodaphnia quadrangula*

110 individuals per litre, *Bosmina longirostris* 76 individuals per litre, *Daphnia longispina* 34 individuals per litre, and *Diaphanosoma brachyurum* 24 individuals per litre). Slightly lower values occurred in the group of *Copepoda* (*Mesocyclops leuckarti* 81 individuals per litre, *Acanthocyclops vernalis* 48 individuals per litre, *Thermocyclops crassus* 63 individuals per litre, and *Eudiaptomus gracilis* 19 individuals per litre). These magnitudes as compared with ponds or other natural lakes in Poland should be regarded as medium high (Ferenska-Lewkowicz 1966, Krzeczkowska-Wołoszyn 1961, Patalas 1954) On the other hand, they are many times lower as compared with the large dam reservoirs from the territories of the USSR (Morduchaj-Boltovskoj 1953, 1958, Voronina 1960).



Ryc. 4. Sezonowe zmiany liczebności dominujących populacji *Crustacea*
Fig. 4. Seasonal changes in the number of dominant populations of *Crustacea*

On the basis of observations carried out, three types of curves can be distinguished, representing the changes of density of the investigated populations of *Cladocera* (fig. 4).

a) The development of populations began in May (from 1 individual per litre on the average). There then occurred a rapid increase in density until a maximum was attained, after which an equally rapid decrease was observed towards autumn. Such was the course of development of

populations of *Daphnia cucullata* at Przeczyce in 1965, of *Bosmina longirostris* at Przeczyce, Porąbka, and Rożnów, of *Daphnia longispina* at Porąbka and Rożnów, of *Ceriodaphnia quadrangula* at Porąbka, Wapienica, and Przeczyce and of *Diaphanosoma brachyurum* at Przeczyce.

b) The development of populations began in spring, but in the course of the season there occurred several peaks of increased density. This type of change was observed only in the population of *Bosmina coregoni* at Kozłowa Góra.

c) The development of populations also began in May, but their density increased slowly and more systematically, a maximum occurring in autumn. This type of change was noted in the population of *Daphnia cucullata* at Przeczyce in 1966 and of *Ceriodaphnia quadrangula* at Wapienica.

The same three types of quantitative changes occurred in the group of *Copepoda*. According to the first type, *Thermocyclops crassus* developed at Kozłowa Góra and Przeczyce in 1965, and *Mesocyclops leuckarti* also at Przeczyce. According to the second type, the population of *Mesocyclops leuckarti and Thermocyclops crassus* developed at Porąbka, and according to the third type the population of *Mesocyclops leuckarti* at Rożnów.

The most frequently occurring type of change in the density of populations in all the investigated reservoirs was the first one. It is according to this scheme that the development of the majority of populations of animal organisms takes place (O d u m 1963, A l l e e et al. 1968). There occurs here an intensive increase in populations up to a certain moment, and then, after attaining a maximum under favourable conditions, the density of populations rapidly decreases till it almost entirely disappears.

The development of populations according to the second scheme was most rarely observed in the group of *Cladocera* and according to the third scheme among *Copepoda*.

Moreover, it was found that the curves of development of the same population were sometimes different in the different reservoirs (e.g. *Daphnia cucullata* or *Mesocyclops leuckarti*). On the other hand, *Bosmina longirostris* and *Ceriodaphnia* developed according to the same scheme in all reservoirs. These data probably indicate that in some species internal factors play the most prominent role (E l g m o r k 1959), e.g. in *Bosmina longirostris* and *Ceriodaphnia quadrangula*, whereas in others the conditions of the environment are more important (*Mesocyclops leuckarti, Daphnia cucullata*).

In the majority of the investigated reservoirs two populations attained a seasonal maximum simultaneously. It was only at Przeczyce that as many as 5 populations attained their developmental maximum at the same time (in August). This shows that this reservoir was highly productive then, which is in accordance with the quantitative data (magnitude of the biomass). According to P a t a l a s (1961), a characteristic feature of the

dynamics of the population of planktonic crustaceans in deep lakes is the simultaneous occurrence of developmental maxima of the majority of species, whereas in shallow and small lakes only 3 species attain their maxima at the same time.

A feature much more difficult to investigate in populations of zooplankton organisms under natural conditions is the age distribution. For this reason the author tried to present in this work only some very general facts.

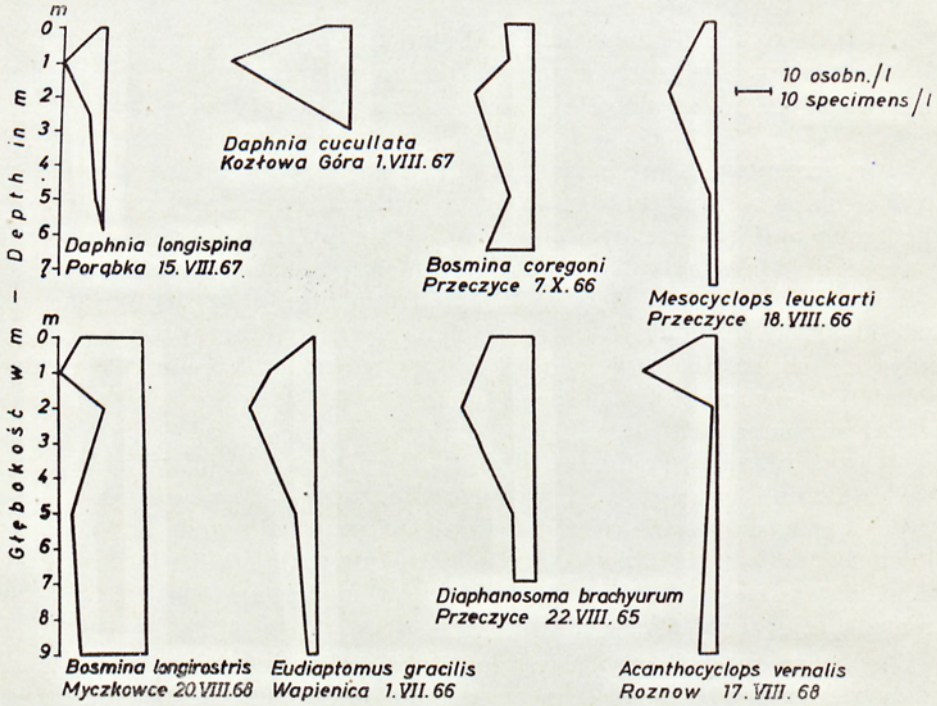
The percentage share of adult individuals within the same population in the course of the year was different in the different reservoirs both in the group of *Cladocera* and *Copepoda*. Generally, however, an increased number of adult individuals was encountered in cladocerans. Especially worthy of note was the regular predominance of sexually mature individuals in *Bosmina longiristris* (80 per cent on the average). It was only in autumn that the density of young individuals in these two populations increased, which seems to indicate that they develop during the winter season as well.

It was found that the greatest number of adult individuals often occurred simultaneously with the maximum density of populations in the given season, as was the case with *Ceriodaphnia quadrangula* and *Diaphanosoma brachyurum*. In populations of *Daphnia cucullata* the largest share of adult individuals occurred during the maximum density, or else immediately preceded it.

In the group of *Copepoda* a greater predominance of particular stages of development was noted than among *Cladocera*. The age distribution of some populations was very similar in several investigated reservoirs, whereas in others it was entirely different. In the population of *Thermocyclops crassus* the largest share of adult individuals was noted in spring (in the reservoir at Porąbka and Kozłowa Góra), after which their number rapidly decreased and then towards the end of summer or in autumn it again increased. The age distribution of *Mesocyclops leuckarti* was identical at Kozłowa Góra and Rożnów, being, however, entirely different at Porąbka, where the density of adult individuals increased in summer. An increase in the number of adult specimens in autumn was also noted in *Acanthocyclops vernalis* at Rożnów.

In the spatial distribution of *Crustacea* particular attention was paid to the vertical distribution. Taken as a whole, all the dominant populations of this group were distinguished by a considerable mobility, being caught everywhere, at various depths and at various stations. Most frequently, however, the majority of populations (*Daphnia cucullata, D. longispina, Bosmina longirostris, Eudiaptomus gracilis, Acanthocyclops vernalis*) showed in all reservoirs a tendency to concentrate in the upper layers of water, avoiding the surface itself. Their greatest concentrations occurred at a depth of 1 or 2.5 m. On the other hand, *Ceriodaphnia quadrangula,*

Diaphanosoma brachyurum and *Thermocyclops crassus* were encountered in the majority of catches and in all reservoirs in the middle layer of water (fig. 5).



Ryc. 5. Rozmieszczenie pionowe dominujących populacji *Crustacea* w badanych zbiornikach zaporowych

Fig. 5. Vertical distribution of dominant populations of *Crustacea* in the investigated dam reservoirs

Moreover, it was noted that some populations during the period of maximum density concentrated most frequently at a particular depth (Grygierek 1958). E.g. *Daphnia cucullata* formed in this period the greatest concentrations in the upper layers of water, and *Bosmina longirostris* just below the water surface. In the other species of *Cladocera* and *Copepoda* this relationship was not observed.

Worthy of note was also the fact of the occurrence in the same layer of water of several populations which were at their maximum development. This phenomenon was encountered at Przeczyce in the season of the year 1966, where populations of *Daphnia cucullata, Bosmina coregoni,* and *Ceriodaphnia quadrangula,* during the period of maximum density in August formed simultaneously the greatest concentrations at same depth of 2.5 m. This would indicate that no competition occurred between these populations.

Some differences concerning the horizontal distribution were considered when dealing with the horizontal distribution of the whole zooplankton.

The above results concerning the features of the investigated populations were based only on observations carried out in reservoirs in which the period of total water exchange lasted the longest, thus at Przeczyce, Kozłowa Góra, Porąbka, Wapienica, and Rożnów. On the other hand, the results of this kind of observation were not interpreted in reservoirs of such swift-flowing water as those at Myczkowce and Wisła-Czarna, or the water steps on the Vistula at Łączany, Dąbie, and Przewóz.

STRESZCZENIE

W latach 1965—68 przeprowadzono czteroletnie obserwacje nad zooplanktonem w 10 zbiornikach zaporowych w południowej Polsce. Z całości zooplanktonu najdokładniej zbadano populacje *Cladocera* i *Copepoda*. *Rotatoria* opracowywano tylko fragmentarycznie. Do badań wybrano różnorodne zbiorniki w celu uchwycenia wpływu najrozmaitszych warunków środowiska na badane organizmy. Były to zbiorniki zaporowe nizinne, limniczne (Przeczyce, Kozłowa Góra), reolimniczne (Porąbka, Wapienica, Rożnów, Myczkowce), górski (Wisła-Czarna) oraz małe stopnie na rzece Wiśle (Łączany, Dąbie, Przewóz), które są w dużym stopniu zanieczyszczone.

W zbiornikach oznaczono 90 gatunków (37 *Rotatoria*, 32 *Cladocera* i 21 *Copepoda*). Nie występowały większe różnice jakościowe pomiędzy poszczególnymi badanymi zbiornikami. Nieco odmienny skład wystąpił w Wapienicy i w Wiśle-Czarnej.

W celu uchwycenia zależności pomiędzy ilością gatunków a zagęszczeniem opracowano dla każdego zbiornika tzw. indeks różnorodności według D i e t r i c h a (1966). Na podstawie powyższego indeksu można powiedzieć, że największą różnorodnością okazał się skład *Crustacea* na stopniach wodnych (w Łączanach i Przewozie wynosił od 23—25), w Myczkowcach (17) i następnie w Wapienicy (11). Natomiast najbardziej jednorodny plankton skorupiakowy występował w Kozłowej Górze i w Rożnowie (2).

Przewagę ilościową *Cladocera* zanotowano w zbiornikach limnicznych, natomiast *Copepoda* w zbiornikach o szybkiej wymianie wody i odznaczających się słabszą eutrofią.

Procentowy udział skorupiaków planktonowych w całym zooplanktonie był różny w poszczególnych zbiornikach. Najwyższy zanotowano w Wiśle-Czarnej (99%) i w Wapienicy (82%). W obu tych zbiornikach zooplankton charakteryzował się spektrum skorupiakowym, natomiast spektrum wrotkowe występowało w zbiornikach w Myczkowcach, Przewozie, Dąbiu i Kozłowej Górze.

Pod względem produkcji zooplanktonu najbogatszym okazał się zbiornik w Przeczycach i Kozłowej Górze (Tab. III). Najniższą biomasę wśród *Crustacea* zanotowano w Myczkowcach podczas dwóch pierwszych lat obserwacji, następnie w Wiśle-Czarnej i Przewozie. Wielkość produkcji ściśle wiąże się z szybkością wymiany wody i z wiekiem zbiornika. Zaobserwowano, że w ciągu badanych sezonów najczęściej występowały jeden lub rzadziej dwa szczyty zwiększonego zagęszczenia pod koniec lata (w sierpniu lub we wrześniu).

Na podstawie przeprowadzonych obserwacji nad populacjami skorupiaków można wyróżnić trzy typy krzywych, przedstawiających zmiany zagęszczenia badanych populacji (ryc. 4). Najliczniejsze populacje występowały w grupie wioślarek (145 osób) 1, nieco niższe w grupie widłonogów (81 osób) 1.

Najczęstszym typem wzrostu badanych populacji był następujący; rozwój populacji rozpoczynał się w maju, potem następował gwałtowny wzrost zagęszczenia.

aż do osiągnięcia maksimum, po którym obserwowano równie szybki spadek w jesieni. Przy czym zaobserwowano, że niekiedy krzywa wzrostu populacji tego samego gatunku przebiegała zupełnie inaczej w dwu różnych zbiornikach. W większości zbiorników maksima sezonowe osiągały równocześnie dwie populacje.

W rozkładzie wiekowym populacji *Cladocera* zaobserwowano, że większość stanowiły osobniki dorosłe. Często najwięcej osobników dorosłych łowiono wtedy, gdy populacja charakteryzowała się najwyższym zagęszczeniem. W grupie *Copepoda* natomiast najczęściej przeważały poszczególne stadia rozwojowe.

Stwierdzono, że wszystkie dominujące populacje skorupiaków odznaczają się dużą ruchliwością, gdyż łowiono je na różnych głębokościach. Większość jednak wykazywała tendencję do gromadzenia się w górnych warstwach wody, omijając samą powierzchnię (ryc. 5). Ponadto zaobserwowano, że wiele populacji w okresie swego maksimum zagęszczenia najchętniej gromadziło się zawsze na tej samej głębokości. Zwrócono również uwagę na fakt występowania kilku populacji będących w okresie najintensywniejszego rozwoju w tej samej warstwie wody. Widocznie więc nie występowało zjawisko konkurencji pomiędzy tymi dwoma populacjami.

Śledząc rozmieszczenie poziome zaobserwowano, że w zbiornikach dużych, takich jak Przeczyce, Kozłowa Góra i Rożnów większość populacji badanych zwierząt planktonowych gromadziła się w środkowej części zbiornika, natomiast blisko samej zapory i przy brzegu łowiono ich niewiele. W zbiornikach o mniejszej powierzchni i wąskich, jak na przykład w Porąbce, organizmy rozmieszczone były bardziej równomiernie.

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