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Hydrobiology

THE ZOOPLANKTON REMOVAL FROM LAKES BY THE RIVER PŁONIA

ZOOPLANKTON WYNOŠZONY Z JEZIOR PRZEZ RZEKĘ PŁONIĘ

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The zooplankton species composition, abundance and biomass in places of the river Płonia's outflow from lakes were investigated. The zooplankton density and biomass were found to reach 2 million individuals/m³ and 11 g/m³, respectively. A number of seasonal phenomena as well as diurnal abundance fluctuations were found out. The zooplankton removed from lakes was quickly reduced in the river.

INTRODUCTION

The zooplankton workers unanimously state a paucity of the river zooplankton with respect to both its species composition and biomass (Siemińska, 1956; Cabejszak et al., 1956; Greze, 1957). Certain rivers, however, have their origin in lakes. If this is a case, the zooplankton removed from the lake can be encountered in a river. The literature dealing with zooplankton removed from lakes is very scarce and the views expressed contradict one another. In Woltereck's opinion (1908), planktonic animals usually are not carried away from a lake, while Odum (1963) states that lowland rivers do remove the zooplankton from lakes. Szlauer (1974) found even small streams to remove considerable numbers of animals from lakes.

The present paper was aimed at studying, as comprehensively as possible, the zooplankton of a river in a place adjoining its outflow from a lake.

STUDY AREA AND METHODS

The studies were carried out at two sites in the river Płonia (Northwestern Poland, Szczecin District). Site I was located 100 m off the lake Płoń, whereas Site II was placed

1500 m off the lake Żelewko, both sites occupying places where the river bed significantly narrowed beneath bridges. The water flow was calculated, the temperature measured, and quantitative plankton samples collected from 200 l of water using a 10–1 calibrated bucket and a No 25 bolting gauze plankton net. When counting the animals, the eggs were also taken into account; length of the individuals of each species was measured. The data thus obtained served to the zooplankton biomass computations. The tables by Kosova (1961) and Cislenco's nommograms (1968) were mainly used in length – weight conversions. The biomass assessment was based on Hillbricht-Ilkowska and Patalas (1967).

The studies described above were carried out at Site I and II from October 1971 through October 1972 during the daytime. Additionally, the plankton was sampled at night at ca 1.5 hrs and 3 hrs after sunset at Site I and II, respectively.

The supplementary studies comprised:

- 1) diurnal plankton sampling in July and September 1972 at Site I at 4-hr intervals (using the above-described methods);
- 2) following the quantitative and qualitative changes in zooplankton in the river Płonia between the lakes Płoń and Miedwie in August 1972;
- 3) one-time zooplankton studies with simultaneous thermal and chemical recordings in the lakes Płoń (July 19, 1972) and Żelewko (July 24, 1972).

RESULTS

Both the lakes Płoń and Żelewko as water bodies providing the river Płonia with plankton were taken into consideration when studying the latter. The lake Płoń plankton (July 1972) was dominated by *Cladocera* and *Copepoda*, *Bosmina coregoni coregoni* and *Chydorus sphaericus* being the most abundant cladocerans. A mean density of animals as expressed in number of individuals per m^3 of water was 1 794 690, cladocerans, copepods (excl. nauplii) and rotators amounting to 661 250, 127 500, and 880 620 ind./ m^3 , respectively. In terms of biomass, cladocerans were also dominating, leaving copepods and rotifers behind; the respective biomass values were 8.404, 1.641, and 0.203 g/ m^3 . *Daphnia longispina* turned out to have produced the highest biomass amounting to 4.634 g/ m^3 . The total zooplankton biomass was 10.7 g/ m^3 . The vertical distribution of zooplankton showed a certain rarefaction of density within the near-bottom zone.

The Żelewko zooplankton (July 1972) markedly differed from that of the lake Płoń. The typical mid-lacustrine species were accompanied by considerable amounts of such littoral forms as *Sida crystallina*, *Ceriodaphnia quadrangula*, and *Eucyclops* sp. Rotifers and nauplii prevailed. A total number of 1 328 200 zooplankters was counted in 1 m^3 . The total Żelewko zooplankton biomass of 3.865 g/ m^3 was 2.7 times lower than that found in the lake Płoń (10.7 g/ m^3).

Basing on classifications of lakes developed by Stangenberg (1936), Wiszniewski (1953), and Patalas (1954 b), the lake Płoń covering a 790-hectare area and of 4.5 m

Table 1

The zooplankton species found in the river Płonia between September 15, 1971– October 20, 1972

Species		Site	
		I	II
Cladocera	<i>Sida crystallina</i> O.F. Müller		x
	<i>Diaphanosoma brachyurum</i> Lieven	x	
	<i>Daphia longispina</i> O.F. Müller	x	x
	<i>Daphnia cucullata</i> G.O. Sars	x	x
	<i>Ceriodaphnia quadrangula</i> O.F. Müller		x
	<i>Bosmina longirostris</i> O.F. Müller	x	x
	<i>Bosmina coregoni crassicornis</i> Lilljeborg		x
	<i>Bosmina coregoni coregoni</i> Baird	x	
	<i>Eurycercus lamellatus</i> O.F. Müller	x	x
	<i>Acroperus harpae</i> Baird		x
	<i>Alona costata</i> G.O. Sars		x
	<i>Alona quadrangularis</i> O.F. Müller	x	x
	<i>Alona affinis</i> Leydig	x	x
	<i>Graptoleberis testudinaria</i> Fischer		x
	<i>Chydorus sphaericus</i> O.F. Müller	x	x
Copepoda	<i>Polyphemus pediculus</i> Linne		x
	<i>Leptodora kindtii</i> Focke	x	
	<i>Eudiaptomus gracilis</i> G.O. Sars	x	x
	<i>Eudiaptomus graciloides</i> Lilljeborg		x
	<i>Eucyclops lilljeborgi</i> G.O. Sars	x	x
	<i>Cyclops vicinus</i> Uljanin	x	x
	<i>Cyclops kolensis</i> Lilljeborg	x	x
	<i>Megacyclops viridis</i> Jurine	x	x
	<i>Diacyclops bicuspidatus</i> Claus		x
	<i>Mesocyclops leuckarti</i> Claus	x	x
Rotatoria	<i>Thermocyclops oithonoides</i> G.O. Sars		x
	<i>Thermocyclops hyalinus</i> Rehberg	x	x
	<i>Trichocerca (Diurella) similis</i> (Wierzejski)	x	
	<i>Trichocerca capucina</i> (Wierzejski et Zacharias)	x	x
	<i>Synchaeta pectinata</i> Ehrenberg	x	x
	<i>Polyarthra</i> Ehrenberg	x	x
	<i>Asplanchna priodonta</i> Gosse	x	x
	<i>Euchlanis dilatata</i> Ehrenberg	x	x
	<i>Brachionus calyciflorus</i> Pallas		x
	<i>Brachionus angularis</i> Gosse	x	x
	<i>Keratella cochlearis</i> (Gosse)	x	x
	<i>Keratella quadrata</i> (Müller)	x	x
	<i>Kellicottia longispina</i> (Kellicott)	x	x
	<i>Notholca squamula</i> (Müller)	x	x
	<i>Notholca acuminata</i> (Ehrenberg)		x
	<i>Filinia longiseta</i> (Ehrenberg)	x	x
	<i>Rotatoria</i> n.d.	x	x

maximum depth was ascribed to an advanced-eutrophication natural pond type. On the other hand, the lake Żelewko (68 hectares, 6.5 m maximum depth) was difficult to ascribe to any of the limnologic types. This is a lake of a *Characeae*-overgrown bottom, intensively fluxed by waters from the mesotrophic lake Miedwie.

The river Płonia (Site I) leaves the lake Płoń via an artificial soft-bottom channel devoid of any submerged vegetation. The maximum depth at Site I ranged within 0.49–0.89 m; the mean annual flow amounted to 1.579 m³/sec. The river Płonia leaving the lake Żelewko (Site II) has a fairly fast current; the maximum depth range was 0.83–1.40 m. The mean annual flow amounted to 2.51 m³/s. In summertime the river was completely overgrown by macrovegetation disappearing in winter.

The temperature measurements recorded showed the water in the river Płonia behind Płoń to cool faster in autumn and warm quicker in spring, higher temperatures being reached in summer as opposed to Site II.

The qualitative composition of the river Płonia zooplankton is summarized in Table 1. Times of occurrence and abundances of species listed in Table 1 are presented in Tables 2 and 3. As a supplement to the data comprised in Table 2 (Site I), it should be explained that the *Daphnia* group consists of two species here: *Daphnia cucullata* and *D. longispina*. The first was rather rare, found only in October, June and August with an August maximum density of 360 000 ind./m³. The other occurred as a "varietas" morphologically closest to the description of *Daphnia longispina galeata* G.O. Sars; a bluntly ended head in summer differed from the typical form. The entry "Bosmina" comprises data combined for *Bosmina longirostris* found only in May 1972 (1600 ind./m³) and *Bosmina coregoni coregoni*. The "other cladocerans" group encompassing *Alona* sp. and *Leptodora kindti* did not play any significant role in the plankton examined. The "Cyclops" group contained the biologically similar species: *Cyclops kolensis* and *C. vicinus*. *Eucyclops lilljeborgi*, *Megacyclops viridis* copepodites, *Thermocyclops oithonoides* and unidentified cyclopoid copepodites were all placed in the "other Copepoda" group. The "other Rotatoria" comprise all the rotifer species listed in Table 1 (for Site I) except for Asplanchna, together with many species of naked rotifers.

The total abundance of zooplankters in the river Płonia behind the lake Płoń is very impressive. During the period of maximum growth (August) 2 035 500 individuals were counted in 1 m³ of water. The other peak (802 500 ind./m³) occurred in April. Even during the March minimum there were still 75 058 ind./m³.

The species predominating in a particular month are shown in Table 2. Having this aspect in mind, the animals were divided into two size groups: crustaceans and smaller animals (Rotatoria and nauplii). Among the crustaceans, *Bosmina* spp. were the most frequent dominants prevailing in October, November and December 1971, and in January 1972. *Daphnia* spp. predominated in May and September, while *Chydorus sphaericus* in August and October 1972. *Eudiaptomus gracilis* prevailed in February when the plankton was generally poor, while *Masocyclops leuckarti* was most abundant in June and July. *Cyclops* spp. were most numerous in April and "other Copepoda" in March. As to the smaller zooplankters, nauplii prevailed from September through January, the

Abundance of zooplankton in river Płonia Site I (ind./m³);
mean diurnal numbers

Table 2

Date, Species	15.X.71	29.XI.71	17.XII.71	14.I.72	17.II.72	16.III.72	15.IV.72	24.V.72	15.VI.72	19.VII.72	18.VIII.72	6.IX.72	20.X.72
Daphnia	10000	7958	1688	2188	313	94	1250	2363375	16875	0	94500	20188	9250
Bosmina	64375	22041	14000	6500	313	62	313	4025	25125	0	6000	375	4375
Chydorus sphaericus	42000	1250	2563	0	0	0	1250	3075	2375	10813	505500	16875	60375
Other Cladocerans	5745	542	0	0	250	31	313	700	2515	0	4500	0	0
Eudiaptomus gracilis	4330	5166	5125	4188	6438	250	4688	4625	9500	1750	0	500	9500
Mesocyclops leuckarti	14208	0	0	0	0	0	8750	5425	26625	30500	241707	2750	2750
Cyclops	0	3374	2938	813	375	2937	13125	0	0	0	0	0	14000
Other Copepoda	1393	1084	0	625	14875	8594	1563	12775	20875	1188	19293	11552	18125
Asplanchna priodonta	1580	10458	22000	151888	29313	7875	24688	225	16875	0	0	2125	375
Other Rotatoria	98998	24750	43250	20938	100500	34748	386250	78900	81625	54875	718500	65375	101250
Cladocera total	122120	31790	18250	8688	875	187	3125	244175	46890	10813	610500	37438	74000
Copepoda total	19930	9623	8063	5625	21688	11780	28125	22825	57000	33438	261000	14802	44375
Nauplii	43645	54667	98563	65063	82375	20469	360313	34850	66500	51375	445500	192563	196125
Rotatoria total	100578	35208	65250	36125	129813	42623	410938	79125	98500	54875	718500	67500	101625
Grand total	286237	131287	190125	115500	234750	75058	802500	380975	268890	150500	2035500	312302	416125

Abundance of zooplankton in river Płonia Site II (ind./m³)
mean diurnal numbers

Table 3

Date	15 X	29 XI	17 XII	14 I	17 II	16 III	15 IV	24 V	15 VI	17 VII	18 VIII	15 IX	20 X
Species	1971			1972									
Bosmina	2535	14060	1563	625	125	150	94	3000	30750	5375	6438	910	1200
Ceriodaphnia quadrangula	1343	0	0	0	0	0	0	0	0	13125	5000	2063	275
Other Cladocera	373	270	213	38	25	0	0	0	2250	2688	735	540	550
Eudiaptomus	843	853	1338	788	275	300	1094	325	875	188	0	268	500
Thermocyclops	813	1469	1875	0	0	350	4531	2208	56750	15013	1548	0	375
Mesocyclops leuckarti	250	219	75	100	0	0	0	0	625	3288	1390	338	0
Other Copepoda	1375	5145	9663	2075	1500	1850	6218	4083	1750	15313	7625	2013	500
Asplanchna priodonta	8688	708	688	50	425	450	375	29208	14625	125	188	7388	1600
Other Rotatoria	25985	35782	36800	11463	14950	23713	98562	228460	151750	43063	15063	25795	18200
Cladocera total	4248	14330	1775	663	150	150	94	3000	33000	21188	12173	3513	2025
Copepoda total	3280	7685	12950	2963	1775	2500	11843	6615	60000	33800	10563	2618	1375
Nauplius	6248	5518	5738	1525	6050	6638	32344	31540	19750	53188	49938	11630	4375
Rotatoria total	34673	36489	37488	11513	15375	24163	98938	257668	166375	43188	15250	33183	19800
Grand total	48448	64021	57950	16663	23350	33450	143216	298823	279125	151363	87923	50943	27575

remaining months shownig a domination of rotifers, a very slight one in February, April and July.

As a supplement to Table 3 (Site II), it should be added that under "Bosmina" the data concerning two morphologically similar species, *Bosmina longirostris* and *B. coregoni* crassicornis were placed. *Eudiaptomus gracilis* and *E. graciloides* were treated jointly as "Eudiaptomus". The data concerning "Thermocyclops" are mainly those for *T. oithonoides*; *T. hyalinus* was found only in July and August with a maximum density of 1074 ind./m³ in July. The "Other cladocerans" group played no significant part in the zooplankton studied. The "Other Copepoda" consisted of *Megacyclops viridis*, *Dia-cyclops bicuspidatus*, *Cyclops kolensis*, and *C. vicinus*.

In general, the zooplankters of the river Płonia behind the lake Żelewko (Site II) reached their maximum occurrence in May and June, the respective abundances being 298 823 and 279 125 ind./m³. During the January minimum, only 16 603 animals were found to occur in 1 m³.

The dominating position was occupied by various species throughout the year (Table 3). Of the crustaceans, the most frequent dominant was the polyspecific group of "Other Copepoda" prevailing from January through May ad then in July, August and December. In December and March the group consisted exclusively of *Cyclops kolensis* and *C. vicinus*. In June, *Thermocyclops oithonoides* was a dominant crustacean. The remaining two months (October and November) showed the domination of *Bosmina spp.*, while *Ceriodaphnia sp.* together with "Other Copepoda" were most abundant in September. Thus copepods were found to be by far the prevailing crustaceans in the zooplankton of the river Płonia beyond Żelewko throughout the year. In the other group of zooplankters (*Rotatoria* and nauplii), the rotifers were decidedly dominant during ten months, only July and August bringing nauplii up to the prevailing position (Table 3).

The age composition within a particular species' population and sizes of individuals varied throughout the year, which bore a considerable effect on the zooplankton biomass. These changes will be discussed taking a few crustacean species of Site I as examples. The population of *Bosmina coregoni coregoni* contained a very small proportion of young individuals, or was completely devoid of them, from November through April; in the summer month, as a rule the young individuals prevailed. Young *Daphnia longispina* prevailed in the population almost every month, the greatest predominance (almost 40-fold) being observed in June. Also *Mesocyclops leuckarti* showed its copepodite stages permanently dominating over the adults, this domination being most pronounced in June and October. In *Cyclops spp.*, the adults were most abundant from December through February, while the copepodites in spring and autumn.

Table 4 presents diurnal fluctuations in the zooplakton abundance at Site I in July 1972. The crustacean abundance diurnal variations are best observed in the last two columns of the table. The most numerous species, *Chydorus sphaericus* and *Mesocyclops leuckarti*, were the decisive factors in the geeral diurnal picture of occurrence of cladocerans and copepods. The nauplii and *Rotatoria* occurred more evenly when

Zooplankton abundance (ind./m³) in river Płonia Site I at various times of day;
July 19 and 20, 1972

Species	Day			Night			Mean	
	hour							
	6 ⁰⁰	12 ⁰⁰	18 ⁰⁰	22 ⁰⁰	24 ⁰⁰	2 ⁰⁰	day	night
Daphnia longispina juv.	0	500	0	0	0	500	166	166
Bosmina coregoni juv.	250	250	0	0	0	0	166	0
Chydorus sphaericus juv.	6000	18520	6625	7000	4000	6750	10292	5916
Chydorus sphaericus ♀	4750	2250	2250	5750	3000	3750	3083	4166
Eudiaptomus gracilis cop. ♀, ♂	4250	2625	1000	2500	1000	750	2624	1416
Megacyclops viridis cop.	500	375	125	2250	2750	2500	333	2500
Mesocyclops leuckarti cop.	33500	13875	17000	32250	27750	42500	21458	34166
Mesocyclops leuckarti ♀, ♂	9500	1375	500	11250	4500	11750	3791	9166
Harpacticoida n. d.	250	0	500	250	0	250	250	166
Cladocera total	11000	21250	8875	12750	7000	11000	13708	10250
Copepoda total	48000	18250	19125	48500	36000	57750	28458	47416
Nauplii total	53000	56750	55750	47000	35250	48500	55167	43583
Rotatoria total	49000	40250	47000	62750	52250	58000	45417	57667
Grand total	161000	136500	130750	171000	130500	175250	142750	158917

Table 5

Seasonal changes in body length of zooplankters at Site I and II
(length in mm)

Species	Date	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX
	Water temperature (°C)	1971			1972								
		10.8	2.8	4.7	0.0	1.5	3.0	9.2	17.0	17.3	22.2	19.4	15.5
<i>Bosmina longirostris</i> ♀		0.341	0.360	0.333	0.369	0.387	—	—	0.323	0.305	0.288	0.285	0.333
<i>Bosmina coregoni</i> <i>crassicornis</i> ♀		0.423	0.408	0.446	0.444	0.454	0.485	0.504	0.399	0.369	0.355	0.387	0.445
<i>Bosmina coregoni</i> <i>coregoni</i> ♀		0.514	0.509	0.535	0.548	0.569	0.603	—	0.499	0.484	—	0.487	0.483
<i>Eudiaptomus gracilis</i> ♀		1.289	1.323	1.278	1.263	1.265	1.116	1.228	1.325	1.269	—	1.134	—
<i>Eudiaptomus gracilis</i> ♂		1.182	1.192	1.156	1.162	1.199	—	1.207	1.179	1.215	—	—	—
<i>Mesocyclops leuckarti</i> ♀		0.996	—	—	—	—	—	0.860	1.017	1.080	0.932	0.941	0.964
<i>Mesocyclops leuckarti</i> ♂		—	—	—	—	—	—	0.738	0.785	0.736	0.717	0.714	0.696
<i>Keratella quadrata</i> ♀		0.145	0.140	0.129	0.141	0.139	0.142	0.151	0.153	0.143	0.139	0.146	0.138
<i>Keratella cochlearis</i> ♀		0.095	0.097	0.101	0.104	0.108	0.107	0.103	0.098	0.091	0.087	0.083	0.086

Table 6

Biomass of river Płonia zooplankton at Site 1 (behind lake Płoń)
(wet weight in g/m³); mean diurnal values

Species \ Date	15 X 71	29 XI 71	17 XII 71	14 I 72	17 II 72	16 III 72	15 IV 72	24 V 72	15 VI 72	19 VII 72	18 VIII 72	6 IX 72	20 X 72	Annual mean
Daphnia	0.078	0.257	0.055	0.103	0.008	0.002	0.107	3.850	0.279	0.0	3.198	0.820	0.358	0.701
Bosmina	1.177	1.068	0.644	0.350	0.019	0.002	0.020	0.017	0.212	0.0	0.062	0.003	0.109	0.283
Chydorus sphaericus	0.155	0.007	0.019	0.0	0.0	0.0	0.003	0.014	0.007	0.023	3.193	0.085	0.338	0.296
Other Cladocera	0.115	0.018	0.0	0.0	0.004	0.002	0.006	0.008	0.125	0.0	0.675	0.0	0.0	0.073
Eudiaptomus	0.120	0.114	0.132	0.194	0.306	0.005	0.151	0.155	0.353	0.021	0.0	0.006	0.364	0.148
Mesocyclops leuckarti	0.248	0.0	0.0	0.0	0.0	0.0	0.123	0.109	0.358	0.239	3.431	0.037	0.047	0.353
Cyclops	0.0	0.218	0.169	0.067	0.030	0.093	0.677	0.0	0.0	0.0	0.0	0.0	0.471	0.133
Other Copepoda	0.13	0.022	0.0	0.006	0.149	0.086	0.015	0.219	0.524	0.043	0.251	0.083	0.191	0.123
Asplanchna	0.098	0.240	0.506	0.304	0.469	0.118	0.691	0.006	1.046	0.0	0.0	0.016	0.003	0.269
Other Rotatoria	0.046	0.015	0.024	0.030	0.101	0.019	0.144	0.045	0.047	0.018	0.254	0.021	0.044	0.062
Total Cladocera	1.526	1.351	0.718	0.453	0.030	0.006	0.137	3.890	0.624	0.023	7.129	0.907	0.805	1.354
Total Copepoda	0.381	0.354	0.301	0.268	0.484	0.185	0.966	0.483	1.236	0.303	3.682	0.126	1.073	0.757
Nauplii	0.039	0.037	0.065	0.215	0.338	0.075	1.237	0.027	0.215	0.074	0.223	0.098	0.670	0.255
Rotatoria total	0.144	0.256	0.529	0.334	0.570	0.137	0.835	0.051	1.093	0.018	0.254	0.037	0.047	0.331
Grand total	2.091	1.999	1.614	1.270	1.423	0.404	3.176	4.452	3.169	0.418	11.289	1.169	2.595	2.697

compared to the crustaceans. The total abundance of the zooplankton as a whole showed no greater diurnal variation. The maximum density of 175 250 ind./m³ at 2 a.m. was only by 26% greater than the minimum of 130 500 ind./m³ at midnight.

The day- and nighttime sampling in every month gave an opportunity to follow the diurnal changes in the zooplankton over the year. The detailed data allowed some generalizations to be made. Cladocerans and copepods were found to occur at two sites mainly at night, for instance 7 and 8 times more *Daphnia longispina* occurred at Site I at night than during the daytime. This phenomenon was more clearly marked in summer, whereas in a cooler season and in winter the crustaceans often occurred more abundantly during the day, e.g., *Daphnia longispina* and *Bosmina coregoni coregoni* at Site I, and *Bosmina longirostris* and *B. coregoni crassicornis* at Site II. The other regularity is a generally more numerous occurrence of young cladocerans during the daytime than at night. As opposed to large crustaceans, small zooplankters (nauplii and *Rotatoria*) were present in more or less equal amounts during the day and at night all the year through.

In the course of the studies discussed, seasonal changes in body length were formed in the species of cladocerans, copepods and rotifers listed in Table 5 and in *Ceriodaphnia quadrangula*, *Thermocyclops oithonoides* and *Asplanchna priodonta*. The data contained in the table are mean values derived from measurements of 20 mature individuals at least. The length of the body without spines was measured. Again the detailed data from Table 5 allow certain generalizations to be made, that is the zooplankters were showing the smallest size when the higher temperatures were prevailing and vice versa, the body sizes enlarged in cooler seasons of the year. All the cladocerans listed, *Thermocyclops oithonoides* and *Keratella cochlearis* fully conformed to this rule as opposed to *Eudiaptomus* sp. and *Mesocyclops* sp. The differences between the extremal sizes in the same species were found to be small. It should be borne in mind, however, that these differences in length correspond to much greater differences in body weights and thus are definitely reflected in the zooplankton biomass.

The river Płonia zooplankton biomass expressed as g wet weight/m³ is summarized in Tables 6 and 7. The biomass at Site I was made up mainly by crustaceans, particularly *Daphnia* spp., *Bosmina* spp., *Chydorus* spp. and the copepod *Mesocyclops leuckarti* (Table 6). Mean biomasses of these, derived from the year-round data amounted to 0.701, 0.283, 0.296, and 0.353 g/m³, respectively. The biomass, of rotifers was lower, amounting in average to 0.331 g/m³, the greatest share of which (0.269 g/m³) being contributed by the largest of the species, *Asplanchna* sp. The highest and lowest zooplankton biomasses were recorded in August and March, respectively, with the respective values of 11.289 and 0.404 g/m³. Apart from seasonal fluctuations of biomass, also the diurnal ones were noted. The latter resulted to a large extent from the diurnal abundance fluctuations of the species present.

The zooplankton biomass in the river Płonia beyond the lake Żelewko was much lower than that recorded at Site I (Table 7). Even in its peak observed in May and June, the total biomass did not exceed 1 g/m³.

Biomass of river Płonia zooplankton at Site II (behind lake Żelewko)
(wet weight in g/m³); mean diurnal values

Table 7

Date	15 X	29 XI	17 XII	14 I	17 II	16 III	15 IV	24 V	15 IV	17 VII	18 VIII	15 IX	20 X	Średnia roczna
Species	1971			1972										
Bosmina	0.011	0.071	0.008	0.007	0.001	0.002	0.002	0.012	0.098	0.010	0.010	0.002	0.008	0.019
Ceriodaphnia quadrangula	0.011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.043	0.013	0.006	0.003	0.006
Other Cladocera	0.009	0.001	0.003	0.001	0.001	0.0	0.0	0.0	0.022	0.091	0.006	0.002	0.006	0.011
Eudiaptomus	0.015	0.018	0.029	0.022	0.006	0.010	0.028	0.011	0.026	0.009	0.0	0.005	0.010	0.015
Thermocyclops	0.008	0.007	0.009	0.0	0.0	0.004	0.045	0.031	0.571	0.159	0.015	0.0	0.004	0.066
Mesocyclops leuckarti	0.004	0.002	0.001	0.001	0.0	0.0	0.0	0.0	0.006	0.052	0.014	0.004	0.0	0.006
Other Copepoda	0.014	0.087	0.164	0.010	0.007	0.023	0.081	0.051	0.025	0.171	0.038	0.010	0.003	0.053
Asplanchna	0.071	0.008	0.011	0.001	0.006	0.006	0.007	0.496	0.183	0.001	0.002	0.052	0.014	0.066
Other Rotatoria	0.016	0.058	0.038	0.025	0.027	0.046	0.133	0.203	0.049	0.017	0.014	0.022	0.014	0.051
Cladocera total	0.031	0.073	0.011	0.008	0.002	0.002	0.002	0.012	0.120	0.145	0.030	0.011	0.018	0.036
Copepoda total	0.041	0.115	0.203	0.032	0.014	0.036	0.155	0.093	0.624	0.390	0.067	0.019	0.017	0.140
Nauplii	0.004	0.005	0.004	0.005	0.021	0.025	0.114	0.025	0.016	0.035	0.027	0.011	0.004	0.023
Rotatoria total	0.088	0.066	0.049	0.026	0.033	0.052	0.140	0.700	0.232	0.019	0.017	0.074	0.029	0.117
Grand total	0.164	0.259	0.268	0.074	0.070	0.115	0.412	0.833	0.998	0.596	0.141	0.117	0.068	0.316

Table 8

Zooplankton of river Płonia between lakes Płoń and Miedwie on August 30, 1972
(Distances between Sites I, II, III, and IV and lake Płoń: 0.1, 5, 8 and 10 km,
respectively)

Species	Number of individuals per 1 m ³ at sites				Biomass in g/m ³ at sites			
	I	II	III	IV	I	II	III	IV
Daphnia longispina juv ♀	750 750	500 500	0 0	335 0	0.060	0.041	0.0	0.005
Daphnia cucullata juv ♀♂	32250 1500	15000 500	1250 0	335 0	0.253	0.122	0.007	0.002
Chydorus sphaericus juv ♀	13500 28500	22500 52500	10750 23250	14650 15815	0.300	0.541	0.242	0.187
Other Cladocera	3000	0	0	165	0.017	0.0	0.0	0.001
Mesocyclops leuckarti cop. ♀♂	36750 12000	8500 9000	500 250	0 830	0.744	0.367	0.009	0.025
Nauplii	420000	21500	3500	830	0.216	0.011	0.002	0.0004
Asplanchna priodonta	16500	2000	250	0	0.247	0.030	0.004	0.0
Other Rotatoria	62250	33500	33500	29530	0.027	0.010	0.011	0.009
Cladocera total (Chydorus sp. excl.)	38250	16500	1250	835	0.331	0.163	0.007	0.008
Total Rotatoria	81750	35500	33750	29530	0.275	0.040	0.015	0.009
Grand total	630750	166000	73250	62490	1.865	1.136	0.279	0.237

Table 8 answers the question of the fate of zooplankton removed from the lake Płon. The changes occurring in this plankton were studied at Sites I–IV located at respective distances of 0.1, 5, 8, and 10 km from the lake Płon. The last site (IV) was situated a several hundred metres off the lake Miedwie. The table shows the zooplankton abundance and biomass to fall with the distance from the "source", i.e., the lake Płon. The zooplankton abundance diminished 10 times over the 10-km section of the river, the biomass decreasing 8 times. Various factors jointly contributed to this general picture of the zooplankton decrease. The attention should be paid to a quick reduction in the crustaceans' abundance. Their numbers were much smaller at Site II, and a complete lack occurred sometimes at Sites III and IV. The above findings did not concern the cladocerans *Chydorus sphaericus*; no clear decrease was found in this species' abundance. A very low decrease was also recorded in numbers of minute rotifers contained in "Other Rotatoria". It should be emphasized, however, that the abundance of the largest rotifers, *Asplanchna* sp., was falling as fast as that of most crustaceans.

DISCUSSION

The zooplankton of the river Płonia, studied at the sites beyond the lakes Płon and Żelewko, differed in many respects. The plankton removed from Żelewko was richer as far as the number of species is concerned. 24 crustacean and 14 rotifer species were recorded here against 17 crustacean and 13 rotifer species observed in the river zooplankton beyond the lake Płon. No forms typical of lakes, like *Diaphanosoma brachyurum* and *Leptodora kindti* present at Site I, were found beyond Żelewko (Site II); 6 typically littoral species (*Sida crystallina*, *Ceriodaphnia quadrangula*, *Acroperus harpae*, *Alona costata*, *Graptoleberis testudinaria*, *Polyphemus pediculus*) absent from Site I were recorded instead. The list of the copepods was richer at Site II by *Eudiaptomus graciloides*, *Diacyclops bicuspidatus* and *Thermocyclops hyalinus*. The smallest quantitative differences were observed in *Rotatoria* (Table 1). Also different species predominated at each site. In various months at Site I, the dominating position was occupied by: *Bosmina coregoni coregoni*, *Daphnia longispina*, *Chydorus sphaericus*, *Mesocyclops leuckarti*, *Eudiaptomus gracilis*, *Cyclops* spp., while at Site II usually the copepods *Thermocyclops oithonoides* and *Cyclops* spp., prevailed. Further differences between the sites are observed in times of presence and vanishing of certain species; for instance *Mesocyclops leuckarti* appeared at Site I two months earlier than at Site II and disappeared earlier. The stocks of zooplankton as measured by its abundance and biomass were completely different at the two sites. Much more planktonic organisms were found to occur in the river Płonia beyond Płon. The summarized entries in Tables 2 and 3 clearly point out to these differences; from the figures given the mean annual abundances of cladocerans, copepods, nauplii, rotifers, and total zooplankton at Site I can be calculated: 92 989, 41 406, 131 639, 149 282, and 415370 ind./m³, respectively. In the river Płonia beyond the lake Żelewko (Site II) the respective mean abundances were: 7408, 12 151, 18 037, 61 086, and 98 681 ind./m³. Thus the number of

cladocerans at Site I exceeded those at Site II thirteen times, copepods – there times, nauplii – seven times, rotifers – two times, and the zooplankton in general was four times more abundant. Still greater differences were found in biomasses at the two sites. The mean annual biomass of the zooplankton at Site I was 2.697 g/m^3 , while only 0.316 were found at Site II. It must be stressed that at Site I mostly crustaceans, mainly the cladocerans, contributed to the total biomass, whereas the copepods and rotifers were the major contributors at Site II.

A different composition of the zooplankton at both sites could be accounted for mainly by different limnologic nature of the lakes Płoń and Żelewko, which stocked the river Płonia with zooplankton. The differences in abundances and biomasses of the zooplankton at the sites studied should be attributed to the resources of plankton in both lakes. The lake Żelewko zooplankton was poorer, particularly its biomass was low in comparison with that in lake Płoń (3.8 and 10.7 g/m^3 , respectively; the July data). The other cause for the less abundant occurrence of zooplankton at Site II could be found in fish and invertebrate predation within the $1 - \text{km}$ long section of the river before the Site. Large shoals of planktophagous bleak and young cyprinids were found to dwell there.

The plankton of the river Płonia, sampled at Sites I and II, is considered here as a river plankton. It would be hard to believe, however, that the character of the Site I plankton underwent a transformation during its four minutes' stay in a river after it had left the lake. On the contrary, it was all the time directly influenced by the lake. Therefore, basing on commonly known phenomena taking place in the lake itself, a number of events observed in the Płonia plankton at Site I can be explained. The seasonal succession of species, observed in Płonia, fully reflects the seasonal changes taking place in the lake Płoń plankton. The changes result from the occurrence of warm- and cold-water zooplankton species in the lake. The first disappear from the plankton in autumn remaining in anabiosis to regain their activity next spring. The other are active during the cold season, the summer months being spent in the state of anabiosis. Some deviations from these regularities can be encountered, e.g., a warm-water species over-wintering in an active state. This was found in Płonia at Site I. Large amounts of warm-water cladocerans, *Bosmina coregoni coregoni* and *Daphnia longispina* (Table 2) occurred in winter. A particularly abundant occurrence of *Bosmina coregoni coregoni* at the beginning of winter could be explained by the species' maximum in late autumn (November). Therefore a very numerous population was over-wintering. The cladocerans remaining in winter were found to reproduce at a very slow rate as evidenced by sparse eggs and small numbers of young individuals, especially in *B. coregoni coregoni*. The cladoceran occurrence in winter is quoted in the literature (Szlauek and Widuto, 1966). Green (1961) attributed their slow reproduction to low temperatures prevailing at that time. The retarded reproduction results in the cladoceran population being reduced, which was observed in the river Płonia in *Daphnia longispina* and *Bosmina coregoni coregoni* towards the end of winter.

Two peaks of abundance are typical of lacustrine planktonic crustaceans. The first usually occurs in spring and the other at the end of summer as well as in early autumn. The river Płonia plankton at Site I closely follows these regularities; the two peaks were found in *Daphnia longispina*, *Bosmina coregoni coregoni*, *Chydorus sphaericus*, *Eudiaptomus gracilis*, nauplii, *Rotatoria*, as well as in the zooplankton as a whole.

Seasonal changes in body size noted in the planktonic animals of the river Płonia as well as other phenomena observed here are not typical of a river; this kind of cyclic changes is specific for the lacustrine zooplankton (Hutchinson, 1967). An increase in sizes of many warm-water species was noteworthy because of its occurrence during a developmental depression of these species in the cold season. A retardation in metabolism and reproduction as well as a life-span prolongation are a few of possible reasons for that (Allee et al., 1958; Green, 1961).

At Site II in the river Płonia behind the lake Żelewko, a number of phenomena similar to those in lakes were observed too.

The above consideration underline many convergencies between the lacustrine plankton and that of the outflowing river. A question arises then whether the outflowing plankton can be regarded as identical with that of the lake. The studies presented cannot offer any definite answer though, because no systematic comparison of the river and lake was made. Such a comparison was carried out only once. On July 19, 1972, plankton samples were taken from the lake Płoń and from Site I in the river Płonia. No *Daphnia longispina*, *Bosmina coregoni coregoni*, or *Leptodora kindti* were found in the outflowing river, whereas the species listed were abundant in the lake, e.g., numbers of *B. coregoni coregoni*, *Daphnia longispina*, and *L. kindti* were 276 250, 590 350, and 600 individuals/m³, respectively. Different species were dominant in the samples: *Chydorus sphaericus* with *Bosmina coregoni coregoni* as a sub-dominant were prevailing in the lake, while *Mesocyclops leuckarti* and *Ch. sphaericus* in the river. The *Rotatoria*/nauplii ratios were also different for the lacustrine and river plankton. It should be added here that the day of July 19, 1972 was an exceptional one because of the highest water temperature recorded for the river, the lowest flow and the slowest current, the respective values being 27°C, 0.947 m³/sec. and 0.576 m/sec. Presumably these factors were decisive for the lack of removal of the cladoceran species listed from the lake. The comparative studies described indicate the necessity of certain precautions to be taken when interpreting an occurrence of a particular species in a river. Not always the absence of a species from an outflow corresponds to the species' absence from the lake.

The patterns of diurnal changes in the river Płonia plankton, outlined in the present paper, were not always equally clear. Many irregularities were found. The causes of the diurnal changes in the river should be looked for in the vertical distribution in the lake and in the vertical migrations of the zooplankton. The published papers concerning this subject state that adult crustaceans dwell in deeper layers of the lake at the daytime, while in the evening they ascend to the surface zone and remain there during the night (Patalas, 1954 a). Young crustaceans (except for the youngest larval stages) exhibit a

similar distribution, occurring above the adults at the daytime (Szlaue, 1963). Such distribution of the crustacean zooplankton in the lake accounts for the observed diurnal changes in the plankton of the outflowing river, assuming that the outflow collects the surface layer of the lake. However, fairly often adult crustaceans were found in Płonia during the day. Such a situation is natural in the river outflowing from the lakes Płoń and Żelewko. Both lakes are very shallow water bodies of a gently-sloping bottom, with no deep layers that could be a crustacean refuge in the daytime as it is the case in deeper lakes. Thus the river Płonia could collect plankton both from the surface and bottom, layers. Profound effects of wind (mixing) on the plankton removed by the river should be taken into account as well. A more intensive removal of crustaceans during the daytime, observed in autumn and winter in *Daphnia longispina* and *Bosmina coregoni coregoni* of Site I as well as in *Bosmina longirostris* and *B. coregoni crassicornis* of Site II is more difficult to explain. The explanation should be sought again in the vertical distribution of these crustaceans in the lake. Presumably these warm-water forms tended to inhabit the upper layers of water during the day and thus large numbers of them were subject to removal by the river.

In order to obtain a relative estimation of the river Płonia planktonic resources, they were compared to those found in other water bodies. As related to Site I with the zooplankton abundance and biomass ranging within 2 035 500–75 058 ind./m³ 11.289–0.404 g/m³, respectively, these values for other water bodies were as follows: Petrović (1954) computed biomasses for oligo-, meso-, and eutrophic lakes to amount to 0.62, 1.96, and 3.86 g/m³, respectively. According to Pečen (1965), in deep, very transparent lakes of mean summer water temperatures of 17°C, the summer zooplankton biomass amounts to 0.4 g/m³, whereas it reaches 4 g/m³ in summer in lakes of poor transparency and high summer temperatures (22°C). Petrović (1968) found various zooplankton biomasses in lakes, depending on their trophic character. His data for the vegetative period of mesotrophic, eutrophic and intermediate-type lakes are as follows: 1.35, 4.75, and 3.74 g of zooplankton/m³, respectively. The winter biomasses were 2–3 and 20–30 times lower in meso- and eutrophic lakes, respectively. Greze (1957) gives the value of 0.035 g/m³ as a biomass of zooplankton of the lower Yenisey. Cabejszak et.al. (1956) described the river Bug plankton as quantitatively poor, 11 000 – 123 000 ind./m³ being found in June. In the reservoirs of rivers Ob and Irtysh, Salazkin and Ustielenceva (1965) found the biomass range of 0.07 – 14.0 g/m³ depending on the flow rate. Against this background, the planktonic resources of the river Płonia Site I should be estimated as high. They exceed many rivers and lakes in this respect and equal to water bodies of a pond type, very rich in plankton.

It should be stressed however, that the zooplankton rich in numbers and species occurred only in places just behind the lakes, which would be regarded as points against the length of the river. Site I contained presumably the richest zooplankton stock in the whole river. Such plankton-rich places occur certainly in other rivers flowing through lakes and can be easily overlooked when studying the rivers. This is why the zooplankton

of rivers is commonly, and basically with a certain degree of justification, regarded as poor.

The example of Płonia indicates to a quick degradation of lacustrine zooplankton after it has got to non-typical environmental conditions of a river. This very abundant and highbiomass zooplankton of a large variety of species leaving the lake Płoń (Site I) was transformed into a poor one consisting essentially of minute rotifers and the smallest cladoceran, *Chydorus sphaericus*. Its composition is similar to that found in ponds where a strong feeding stress of fishes is felt (Grygierek, 1965). These changes were caused mainly by grazing of young cyprinids occurring in masses in the studied part of the river and feeding on the zooplankton carried in. A part of the zooplankton could have been consumed by invertebrates living in the river and/or died out due to some abiotic factors' influence.

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ZOOPLANKTON WYNOŚZONY Z JEZIOR PRZEZ RZEKĘ PŁONIĘ

Streszczenie

W latach 1971–1972 badano zooplankton rzeki Płoni tuż za miejscem jej wypływania z jez. Płoń – stanowisko I oraz za jez. Żelewko – stanowisko II. Liczebność zooplanktonu na st. I była średnio czterokrotnie wyższa, a biomasa – dziesięciokrotnie wyższa, w porównaniu ze stanowiskiem II. Inny też był skład gatunkowy i układ dominantów na obu stanowiskach (tab. 2 i 3).

Do gatunków najliczniej występujących w obrębie skorupiaków na st. I należały: *Daphnia longispina* (maksimum w maju 236 375 osobn./m³), *Bosmina coregoni coregoni* (maks. w październiku 64 375 osobn./m³), *Chydorus sphaericus* (maks. w sierpniu 505 500 osobn./m³), *Eudiaptomus gracilis* (maks. w czerwcu i październiku po 9500 osobn./m³), *Mesocyclops leuckarti* (maks. w sierpniu 241 700 osobn./m³), *Cyclops* (maks. w październiku i kwietniu po około 14 000 osobn./m³). Ogólne maksimum zooplanktonu przypadło tu w sierpniu (2 035 500 osobn./m³, tab. 2).

Największą biomasę tworzyły na stanowisku I wioślarki z rodzaju *Daphnia*, *Bosmina*, *Chydorus* oraz widłonóg – *Mesocyclops leuckarti*. Najwyższą biomasę (11,289 g/m³) tworzył zooplankton w miesiącu sierpniu, minimum (0,404 g/m³) przypadło na marzec, średnioroczna biomasa wyniosła 2,697 g/m³ wody (tab. 6).

Stwierdzono sezonowe zmiany wymiarów u gatunków: *Bosmina coregoni coregoni*, *Eudiaptomus gracilis*, *Mesocyclops leuckarti*, *Keratella cochlearis*, *Keratella quadrata*, *Asplanchna priodonta*. Różnice pomiędzy ciężarami największych i najmniejszych osobników były nawet kilkakrotne (tab. 5).

Zaobserwowano w rzece Płoni dobowe zmiany liczebności wioślarek i widłonogów oraz brak takich zmian u naupliusów i wrotków. Zarówno na st. I jak i II więcej wioślarek i widłonogów występowało w okresie nocnym niż dziennym. Powyższe stwierdzenie odnosi się jednak tylko do ciepłego okresu roku i do dorosłych osobników. Młodościan skorupiaci zdradzały tendencję do liczniejszego występowania w okresie dziennym podczas całego roku. Późną jesienią i zimą również dorosłe osobniki *Daphnia* i *Bosmina* przeważały w okresie dziennym.

Zooplankton, wypływający z jeziora Płoń ulegał degradacji w dziesięciokilometrowym odcinku rzeki, pomiędzy jeziorami Płoń i Miedwie (tab. 8). Już w odległości 8 km od jez. Płoń doszło do prawie całkowitego ustąpienia z planktonu rzeki dużych skorupiaków – *Daphnia* i *Mesocyclops* oraz nauplius. W odległości 10 km od jeziora nastąpiła prawie dziesięciokrotna redukcja liczebności całego zooplanktonu oraz ośmiokrotne zmniejszenie jego biomasy. W przeciwieństwie do dużych skoru-

пиаków, nie stwierdzono w rzecze tak szybkiej redukcji liczebności wrotków (z wyjątkiem *Asplanchna*) oraz małej wiosłarki *Chydorus sphaericus*. Główną przyczyną opisanej degradacji zooplanktonu w rzecze było żerowanie narybku.

Б. Шляуэр

ЗООПЛАНКТОН, ВЫНОСИМЫЙ ИЗ ОЗЁР РЕКОЙ ПЛОНЬ

Р е з ю м е

В 1971-72 гг. исследовали зоопланктон реки Плонь на участке, расположенном вблизи её выхода из озера Плонь (I опытный участок) и за озером Желевко (II опытный участок). Численность зоопланктона на I опытном участке была в среднем в 4 раза большей, а его биомасса - в 10 раз больше, чем на II опытном участке. Иными были также видовой состав и система доминантов на обоих участках (табл. 2 и 3).

Наиболее многочисленными ракообразными на, опытном участке были: *Daphnia longispina* (максимальное их количество приходилось на май - 236 375 особей на m^3), *Bosmina coregoni coregoni* (максимум в октябре - 64 375 особей на m^3), *Chydorus sphaericus* (максимум в августе - 505 500 особей на m^3), *Eudiaptomus gracilis* (максимум в июне и октябре - по 9500 особей на m^3), *Mesocyclops leuckarti* (максимум в августе - 241 700 особей на m^3), *Cyclops* (максимум в октябре и апреле - по 14 000 особей на m^3). Общее максимальное количество зоопланктона приходилось на август (2 035 500 особей на m^3 , табл. 2).

Самую большую биомассу составляли на опытном участке ракообразные из рода *Daphnia*, *Bosmina*, *Chydorus* и веслоногий рачок *Mesocyclops leuckarti*. Наибольшую биомассу составлял зоопланктон в августе месяце (11,289 г/ m^3), минимум приходился на март месяца (0,404 г/ m^3). Среднегодовая биомасса составляла - 2,697 г/ m^3 воды (табл. 6).

Отмечены сезонные изменения размеров и видов: *Bosmina coregoni coregoni*, *Eudiaptomus gracilis*, *Mesocyclops leuckarti*, *Keratella cochlearis*, *Keratella quadrata*, *Asplanchna priodonta*. Разницы между весом самых крупных и самых мелких особей довольно значительными (табл. 5).

В р. Плонь замечены суточные изменения численности веслоногих рачков, а также отсутствие таких изменений у науплиусов и коловраток. Как на I, так и на II участке больше всего веслоногих рачков было в ночное время. Вышесказанное касается, однако, только тёплого периода и только взрослых особей. Молодь ракообразных проявляла тенденцию к большей численности в дневное время в течение всего года. Поздней осенью и зимой взрослые особи *Daphnia* и *Bosmina* преобладали также в дневное время.

Зоопланктон, попадающий из оз. Плонь, подвергался деградации на десятикилометровом участке реки, между озёрами Плонь и Медве (табл. 8). Уже на расстоянии 8 км от оз. Плонь почти полностью исчезли из речного планктона крупные ракообразные *Daphnia* и *Mesocyclops*, а также науплиус. На расстоянии 10 км от озера наступила почти десятикратная редукция численности всего зоопланктона и восьмикратное уменьшение его биомассы. Что касается мелких ракообразных, то столь быстрая редукция численности коловраток (за исключением *Asplanchna*) и мелкого рачка *Chydorus sphaericus* не отмечена. Основной причиной вышеупомянутой деградации зоопланктона в реке был нагул молоди рыб.

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