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Effect of Various Types of Phytoplankton on Fertility, Egg Size and Duration of Postembryonic Growth of a Few Plankton Representatives of Cladocera (Crustacea)

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Abstract

We examined the effect of different food types, such as algae - *Chlorella pyrenoidosa* and *Scenedesmus acutus*, fungus - *Saccharomyces cerevisiae* and bacterium - *Bacillus subtilis*, and their concentrations on the body size of females, number and size of laid eggs and the postembryonic period duration of *Daphnia hyalina*, *Daphnia magna* and *Simocephalus vetulus*.

The study has revealed that the body length of females and the number of eggs increase, and the postembryonic period is shortened when the food concentration increases. The more eggs are laid, the smaller size they are.

The highest values of the parameters examined were observed in the females which fed on algae, the lowest in those feeding on bacterium *Bacillus subtilis*.

Keywords: plankton crustaceans, nutrition, size of females, number and size of eggs, postembryonic development

Introduction

Phytoplankton in every water reservoir contains bacteria, lower aquatic fungi and algae. Cladocera representatives, as filtrators, together with Copepoda specimens are the main zooplankton components which feed mainly on algae plankton [1-4]. Although it may seem that the quantitative contribution of phytoplankton to the food of Cladocera representatives is well known [5], it still arouses interest of many investigators [6-8]. A number of papers have appeared on the role of bacterioplankton in the nutrition of filtrators [9-12]. However, except for some fragmentary data, the involvement of lower aquatic fungi, a phytoplankton component, is at the preliminary stage of research [13].

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As revealed by our few years' studies the fertility of various zooplankton species depends largely on food abundance in a particular water reservoir [14-16]. In the lakes of oligotrophic-like type, the fertility of both Cladocera and Copepoda representatives is the lowest, while in eutrophic and polytrophic lakes it is the highest.

In this context, we were interested in the effect of the quality and quantity of food of bacterial, fungal and alga type on the body length of females, eggs size and duration of postembryonic growth of certain zooplankton species, Cladocera representatives.

Material and Methods

The study was performed using specimens of *Daphnia hyalina* Leydig, *Daphnia magna* Straus and *Simocephalus vetulus* Müller - genetically identical generations, obtained from parthenogenetic reproduction of one female "mother" of each species.

The specimens were bred in 200 ml beakers, 10 in each, in AdaM medium ($NaHCO_3$ - 19.2g; $CaSO_4$ x $2H_2O$ - 2.4g; $MgSO_4$ x $7H_2O$ - 24.6g l^{-1}) at a constant temperature of 20°C and alternating light (16 h - 1300 lux, 8 h - darkness).

Beakers with AdaM medium and specimens of a respective species without food served as control. All the experiments were done three times. The AdaM medium containing food was changed every 24 h, and as in our previous study [16], body length of female, number and size of eggs, and duration of postembryonic growth of young specimens were determined. Therefore, 30-50 females of each crustacean species were studied.

The food for the crustaceans contained alga cells *Chlorella pyrenoidosa* Chick and *Scenedesmus acutus* Meyen, yeast cells *Saccharomyces cerevisiae* Hansem and hay bacterium *Bacillus subtilis* Fisher. Alga culture was carried out on the Chu medium ($Ca(NO_3)$ x $4H_2O$ - 86.3g; $MgS0_4$ x $7H_2O$ - 150g; KC1 - 10g; Na_2CO_3 - 40g; Na_2SiO_3 x $5H_2O$ - 1.5g; K_2HPO_4 - 13.1g l^{-1}), *Saccharomyces cerevisiae* cells were dilluted in distilled water, cultures of *Bacillus subtilis* on natural medium. Food concentrations (algae, yeast, bacteria) was calculated using a Bürker's camera and an optical microscope [17]. The size of food cells used in the experiment ranged between 4 µm (*Chlorella pyrenoidosa*) and 11 µm (*Scenedesmus acutus*).

The results were subjected to statistical analysis [18].

Results

In the females of *Daphnia hyalina, Daphnia magna* and *Simocephalus vetulus*, the elevated concentration of all four food types was accompanied by an increase in body length and the number of eggs, and shortening of the postembryonic period (Tables 1-3, Fig. 1-3). Most values differences of this parameters are important statistically. However, unimportant statistically are differences of the mean size of eggs. A tendency exists that the more eggs are laid, the smaller their size. As shown in Table 4, *Daphnia hyalina* females were on average the longest when fed on *Scenedesmus acutus*, had the largest number of eggs which were the largest size when fed on

Table 1. Body size (in mm), number (per one fertile female), egg size (in mm) and postembryonic development length (in days) of *Daphnia hyalina* specimens by various and different concentrations of food.

Specification	Mean and SD	Range	SE
Chlorella pyrenoidosa - 200 · 10^3 · ml^{-1}			
Mean length of female	*2.110±0.0162	2.100-2.140	0.0031
Mean number of eggs	*1.357±0.4881	1.000-2.000	0.0922
Mean size of eggs	0.317±1.2084	0.335-0.399	0.0283
Length of postembryonic development	*10.929± 1.0158	10.000-13.000	0.1919
Ch. pyrenoidosa - 400 · 10^3 · ml^{-1}			
Mean length of female	*2.559±0.0102	2.259-2.580	0.0019
Mean number of eggs	*4.357±0.6215	3.000-8.000	0.1174
Mean size of eggs	0.385±1.9212	0.346-0.385	0.2441
Length of postembryonic development	*8.393±0.5669	7.000-9.000	0.1071
Ch. pyrenoidosa - 800 · 10^3 · ml^{-1}			
Mean length of female	*2.793±0.0081	2.700-3.160	0.0015
Mean number of eggs	*6.179±1.3068	3.000-11.000	0.2469
Mean size of eggs	0.399±1.9925	0.301-0.349	0.9434
Length of postembryonic development	*5.950±0.6048	5.000-7.000	0.1352
Scenedesmus acutus - 150 · 10^3 · ml^{-1}			
Mean length of female	*2.471±0.0010	2.470-2.472	0.0003
Mean number of eggs	*0.357±0.4880	0.0-1.000	0.0922
Mean size of eggs	0.300±0.0	0.0-3.000	0.0
Length of postembryonic development	*14.000±1.5943	0.0-14.000	0.2462

Table 1 continues on next page...

S. acutus - 300 · 10^3 · ml^{-1}			
Mean length of female	*2.523±0.0047	2.513-2.534	0.0008
Mean number of eggs	*2.179±0.5480	1.000-3.000	0.1035
Mean size of eggs	0.288±1.6651	0.286-2.292	0.3146
Length of postembryonic development	*8.571±0.5040	8.000-9.000	0.0952
S. acutus - 600 · 10^3 · ml^{-1}			
Mean length of female	*2.566±0.029	2.530-2.600	0.0039
Mean number of eggs	*3.750±1.3506	2.000-8.000	0.2552
Mean size of eggs	0.365±0.4721	0.300-0.340	0.0467
Length of postembryonic development	*6.571±0.5040	6.000-7.000	0.0952
Saccharomyces cerevisiae - 300 · 10^3 · ml^{-1}			
Mean length of female	*2.413±0.0287	2.380-2.460	0.0090
Mean number of eggs	*0.0	0.0-0.0	0.0
Mean size of eggs	0.0	0.0-0.0	0.0
Length of postembryonic development	*0.0	0.0-0.0	0.0
S. cerevisiae - 600 · 10^3 · ml^{-1}			
Mean length of female	*2.477±0.0067	2.470-2.490	0.0021
Mean number of eggs	*1.700±0.6497	2.000-3.000	0.2134
Mean size of eggs	0.346±0.4944	0.340-0.352	0.0788
Length of postembryonic development	*14.000±0.6667	13.000-15.000	0.2108
*S. cerevisia*e - 900 · 10^3 · ml^{-1}			
Mean length of female	*2.526±0.0165	2.500-2.540	0.0052
Mean number of eggs	*2.900±0.8756	2.000-4.000	0.2768
Mean size of eggs	0.325±1.3944	0.321-0.335	0.7571
Length of postembryonic development	*9.800±0.7888	9.000-11.000	0.2494
Bacillus subtilis - 1200 · 10^3 · ml^{-1}			
Mean length of female	*2.250±0.0685	2.280-2.320	0.0198
Mean number of eggs	0.345±0.5124	0.325-0.365	0.1216
Mean size of eggs	0.289±0.9136	0.164-0.294	0.2024
Length of postembryonic development	*15.650±0.6172	13.060-16.200	0.1830
B. subtilis - 2400 · 10^3 · ml^{-1}			
Mean length of female	*2.305±0.0505	2.210-2.424	0.0198
Mean number of eggs	0.355±0.6320	0.298-0.382	0.1404
Mean size of eggs	0.295±1.0124	0.282-0.312	0.5102
Length of postembryonic development	*13.850±0.8106	13.000-14.620	0.1916
B. subtilis - 3600 · 10^3 · ml^{-1}			
Mean length of female	*2.415±0.0402	2.310-2.506	0.0210
Mean number of eggs	0.372±0.4128	0.308-4.012	0.1896
Mean size of eggs	0.310±0.8224	0.284-0.340	0.3148
Length of postembryonic development	*10.220±0.1228	9.810-12.460	0.2102

* Asterisks indicate differences significant at the 0.5% level

Table 2. Body size (in mm), number (per one fertile female), egg size (in mm) and postembryonic development length (in days) of *Daphnia magna* specimens by various and different concentrations of food.

Specification	Mean and SD	Range	SE
Chlorella pyrenoidosa - 200 · 10^3 · ml^{-1}			
Mean length of female	*3.275±0.1372	2.948-3.400	0.0306
Mean number of eggs	*1.150±0.3664	1.000-2.000	0.0819
Mean size of eggs	0.375±2.4352	0.365-0.385	0.9917
Length of postembryonic development	*10.300±1.1286	8.000-12.000	0.2523
Ch. pyrenoidosa - 400 · 10^3 · ml^{-1}			
Mean length of female	*3.488±0.1037	3.300-3.600	0.0231
Mean number of eggs	*4.350±1.0894	2.000-6.000	0.1436
Mean size of eggs	0.370±1.2096	0.360-0.380	0.5540
Length of postembryonic development	*8.650±0.5871	8.000-10.000	0.1312
Ch. pyrenoidosa - 800 · 10^3 · ml^{-1}			
Mean length of female	*4.145±0.1514	3.950-4.460	0.0282
Mean number of eggs	*17.000±2.1026	14.000-22.000	0.4701
Mean size of eggs	0.344±1.7754	0.330-0.350	0.2914
Length of postembryonic development	*6.071±0.8133	5.000-7.000	0.1536
Scenedesmus acutus - 150 · 10^3 · ml^{-1}			
Mean length of female	*2.933±0.1031	2.900-3.100	0.023
Mean number of eggs	*1.000±0.0	1.000-1.000	0.0
Mean size of eggs	0.375±0.0	0.375-0.375	0.0
Length of postembryonic development	*14.000±0.0	14.000-14.000	0.0
S. acutus - 300 · 10^3 · ml^{-1}			
Mean length of female	*3.363±0.0556	3.300-3.450	0.0124
Mean number of eggs	*3.300±0.9234	2.000-5.000	0.2064
Mean size of eggs	0.368±1.4623	0.365-0.372	0.5506
Length of postembryonic development	*10.450±0.7590	9.000-12.000	0.1697
S. acutus - 600 · 10^3 · ml^{-1}			
Mean length of female	*3.800±0.0918	3.600-3.900	0.0205
Mean number of eggs	*9.400±1.5694	6.000-12.000	0.3509
Mean size of eggs	0.327±0.0947	0.320-0.339	0.1168
Length of postembryonic development	*8.550±0.6863	7.000-10.000	0.1534
Saccharomyces cerevisiae - 300 · 10^3 · ml^{-1}			
Mean length of female	*3.100±0.0	3.100-3.100	0.0
Mean number of eggs	*1.00±0.0	1.000-1.000	0.0
Mean size of eggs	0.380±0.0	0.380-0.380	0.0
Length of postembryonic development	*16.000±0.0	16.000-16.000	0.0
S. cerevisiae - 600 · 10^3 · ml^{-1}			
Mean length of female	*3.205±0.1284	3.000-3.400	0.0280

Table 2 continues on next page...

Mean number of eggs	*1.762±0.5390	1.000-3.000	0.1176
Mean size of eggs	0.369±0.3599	0.350-0.390	0.4789
Length of postembryonic development	*12.857±0.5732	12.000-14.000	0.1250
S. cerevisiae - 900 · 10^3 · ml^{-1}			
Mean length of female	*3.514±0.0854	3.400-3.600	0.0186
Mean number of eggs	*7.333±1.1106	6.000-9.000	0.2423
Mean size of eggs	0.326±1.9231	0.320-0.334	0.8560
Length of postembryonic development	*10.619±0.4976	10.000-11.000	0.1085
Bacillus subtilis - 1200 · 10^3 · ml^{-1}			
Mean length of female	*3.000±0.0	3.000-3.000	0.0
Mean number of eggs	*1.000±0.0	1.000-1.000	0.0
Mean size of eggs	0.280±0.0	0.0-0.280	0.0
Length of postembryonic development	*18.000±0.0	18.000-18.000	0.0
B. subtilis - 2400 · 10^3 · ml^{-1}			
Mean length of female	*3.006±0.0748	2.900-3.100	0.0181
Mean number of eggs	*1.294±0.4697	1.000-2.000	0.1139
Mean size of eggs	0.329±0.9663	3.000-3.330	0.6895
Length of postembryonic development	*16.882±0.9275	15.000-18.000	0.2249
B. subtilis - 3600 · 10^3 · ml^{-1}			
Mean length of female	*3.512±0.0697	3.400-3.6 00	0.0179
Mean number of eggs	*3.750±0.5879	3.000-5.000	0.1443
Mean size of eggs	0.317±1.5371	0.298-0.325	0.3454
Length of postembryonic development	*12.375±1.8411	10.000-15.000	0.4643

* Asterisks indicate differences significant at the 0.5% level

Chlorella pyrenoidosa, and needed the shortest postembryonic period with *Saccharomyces cerevisiae. Daphnia hyalina* females were the shortest, had the smallest number of eggs and the longest postembryonic period when fed on *Bacillus subtilis*. However, the longest body and the largest number and size of laid eggs were observed in *Daphnia magna* and *Simocephalus vetulus* females, which fed on *Chlorella pyrenoidosa*. The lowest values of these parameters were noted in the females which fed on *Bacillus subtilis*. Only the postembryonic period of *Simocephalus vetulus* was the longest when they fed on *Saccharomyces cerevisiae* cells. The postembryonic period of the crustaceans examined varied according to the concentration of food. Moreover, feature length of postembryonic development differed in all studied species of zooplanktons which feed on *Chlorella pyrenoidosa*.

The range of this parameter was the greatest *Daphnia hyalina* specimens when they fed on *Scenedesmus acutus*, for *Daphnia magna* feeding on *Bacillus subtilis* and for *Simocephalus vetulus Chlorella pyrenoidosa* (Table 5).

Discussion

As revealed by the present study, the body length of the three species of Cladocera females, acting as filtrators, the number and size of eggs and the postembryonic period duration depend on the type of food and its concentration. Generally speaking, *Chlorella pyrenoidosa* had the greatest influence on these parameters, while *Bacillus subtilis* - the slightest. However, in the case of all four food types the body length of the crustacean females and the number of laid eggs (with a tendency to size reduction) increased with the rise in food concentration. Moreover, the postembryonic period was shortened. While studying the fertility of plankton crustaceans in the lakes of varied trophicity in northeastern Poland, we observed a similar phenomenon concerning the number and size of eggs in natural conditions [14-16]. This correlation has been later confirmed by other investigators in different latitudes [19-23]. In natural conditions, apart from food concentration and availability, a number of abiotic factors affect the size and fertility of the crustacean plankton, including water temperature [24, 25] and oxygen content [26, 27]. As in

Table 3. Body size (in mm), number (per one fertile female), egg size (in mm) and postembryonic development length (in days) of *Simocephalus vetulus* specimens by various and different concentrations of food.

Specification	Mean and SD	Range	SE
Chlorella pyrenoidosa - 200 · 10^3 · ml^{-1}			
Mean length of female	*2.091±0.1119	2.000-2.280	0.0250
Mean number of eggs	*1.200±0.4104	1.000-2.000	0.0917
Mean size of eggs	0.325±1.6945	0.290-0.375	0.6025
Length of postembryonic development	*11.050±1.3169	9.000-14.000	0.2944
Ch. pyrenoidosa - 400 · 10^3 · ml^{-1}			
Mean length of female	*2.440±0.0411	2.360-2.550	0.0092
Mean number of eggs	*6.650±1.3485	4.000-9.000	0.3015
Mean size of eggs	0.299±1.3219	0.285-0.340	0.9558
Length of postembryonic development	*8.600±0.6806	8.000-10.000	0.1521
Ch. pyrenoidosa - 800 · 10^3 · ml^{-1}			
Mean length of female	*2.760±0.1569	2.500-3.000	0.0350
Mean number of eggs	*14.200±2.7453	10.000-18.000	0.6138
Mean size of eggs	0.254±2.1958	0.248-0.268	0.6890
Length of postembryonic development	*6.050±0.6122	5.000-7.000	0.1983
Scenedesmus acutus - 150 · 10^3 · ml^{-1}			
Mean length of female	*2.000±0.1000	1.900-2.200	0.0301
Mean number of eggs	*1.000±0.6325	0.0-1.000	0.1906
Mean size of eggs	0.301±0.4320	0.0-0.301	0.3116
Length of postembryonic development	8.909±1.4599	0.0-12.000	0.3447
S. acutus - 300 · 10^3 · ml^{-1}			
Mean length of female	*2.427±0.1272	2.200-2.600	0.0383
Mean number of eggs	*5.273±1.1909	3.000-7.000	0.3590
Mean size of eggs	0.301±1.2843	0.297-0.310	0.6887
Length of postembryonic development	8.636±0.6742	8.000-11.000	0.2032
S. acutus - 600 · 10^3 · ml^{-1}			
Mean length of female	*2.727±1.0453	2.600-2.900	0.7273
Mean number of eggs	*10.909±1.8684	8.000-14.000	0.5633
Mean size of eggs	0.254±1.6440	0.248-0.264	0.7017
Length of postembryonic development	8.455±0.8202	7.000-10.000	0.2473
Saccharomyces cerevisiae - 300 · 10^3 · ml^{-1}			
Mean length of female	*1.980±0.0789	1.900-2.100	0.0249
Mean number of eggs	*1.000±0.000	1.000-1.000	0.0
Mean size of eggs	0.266±1.1640	0.260-0.270	0.6329
Length of postembryonic development	*14.600±0.6992	14.000-16.000	0.2211
S. cerevisiae - 600 · 10^3 · ml^{-1}			
Mean length of female	*2.200±0.0817	2.100-2.300	0.0258

Table 3 continues on next page...

Mean number of eggs	*2.000±0.4714	1.000-3.000	0.1490
Mean size of eggs	0.271±1.2589	0.260-0.280	0.6629
Length of postembryonic development	*12.600±0.6992	11.000-13.000	0.2211
S. cerevisiae - 900 · 10^3 · ml^{-1}			
Mean length of female	*2.470±0.0483	2.400-2.500	0.0152
Mean number of eggs	*3.600±0.5163	3.000-4.000	0.1632
Mean size of eggs	0.257±1.7495	0.250-0.270	0.7343
Length of postembryonic development	*10.500±0.9718	9.000-12.000	0.3073
Bacillus subtilis - 1200 · 10^3 · ml^{-1}			
Mean length of female	*2.000±0.1000	1.200-1.500	0.0268
Mean number of eggs	*1.000±0.6325	0.0-0.000	0.0
Mean size of eggs	0.301±04320	0.0-0.000	0.0
Length of postembryonic development	*8.909±1.4599	0.0-0.000	0.0
B. subtilis - 2400 · 10^3 · ml^{-1}			
Mean length of female	1.990±0.0876	1.800-2.100	0.0276
Mean number of eggs	*1.200±0.4216	1.000-2.000	0.1333
Mean size of eggs	0.255±1.2705	0.250-0.260	0.6667
Length of postembryonic development	*13.500±0.5270	13.000-14.000	0.1616
B. subtilis - 3600 · 10^3 · ml^{-1}			
Mean length of female	*2.260±0.0966	2.100-2.400	0.0305
Mean number of eggs	*3.400±0.6992	2.000-4.000	0.2211
Mean size of eggs	0.249±1.7560	0.240-0.270	0.7688
Length of postembryonic development	*11.600±0.5163	11.000-12.000	0.1632

* Asterisks indicate differences significant at the 0.5% level

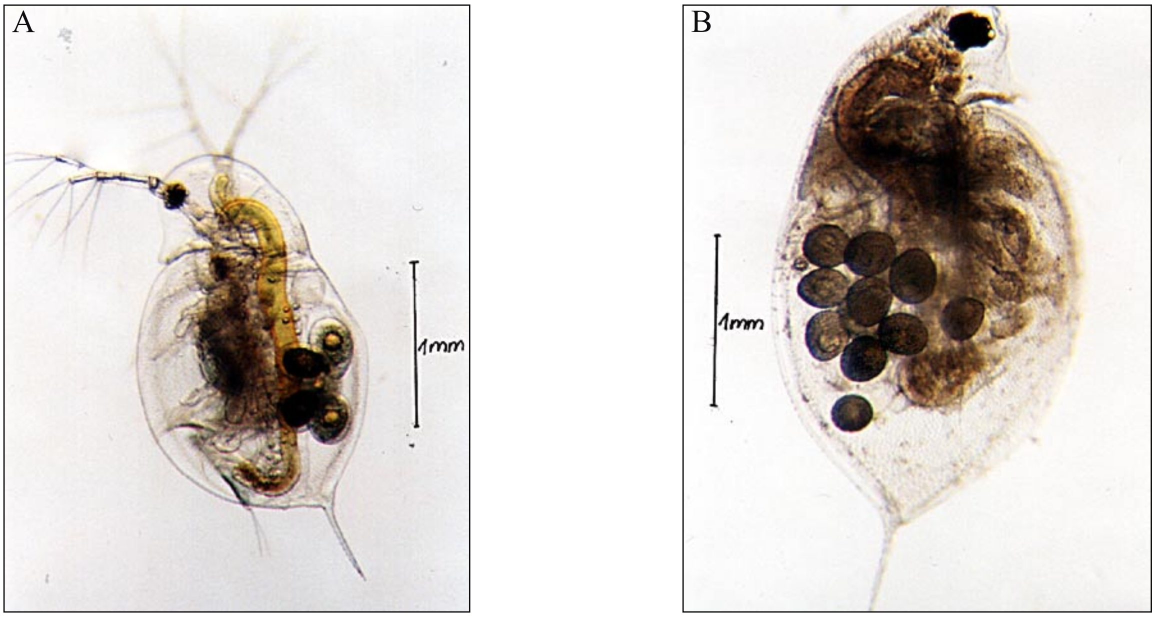

Fig. 1. Number of eggs in female of *Daphnia hyalina*: A - from 5 eggs, food: cells of *Chlorella pyrenoidosa*, concentration 400 · 10^3 ml^{-1}; B - from 11 eggs, food: cells of *Chlorella pyrenoidosa*, concentration 800 · 10^3 ml^{-1}.

the case of other hydrobionts [28-30], such pigments as haemoglobin [31] or carotenoids [32, 33] enable plankton crustaceans to use niches abundant in food and poor in oxygen. Food intake by filtrators depends largely on the structure of a filtration apparatus in a particular species [34,35], especially on the filter mesh size [36-39], and on the size and shape of cells [1]. Therefore, filtrators take filter mesh size food selectively [40]. In our study, cells of the phytoplankton species varied in shape and size, although their size did not exceed the size of filter mesh of the crustacean specimens acting as effective microfiltrators which arrest nanoplankton cells up to 12 μm [41]. Thus, the size of the phytoplankton cells used in the experiments had no effect on its availability. The differences found in the size of crustacean females and their fertility were caused by food quality. It is known that

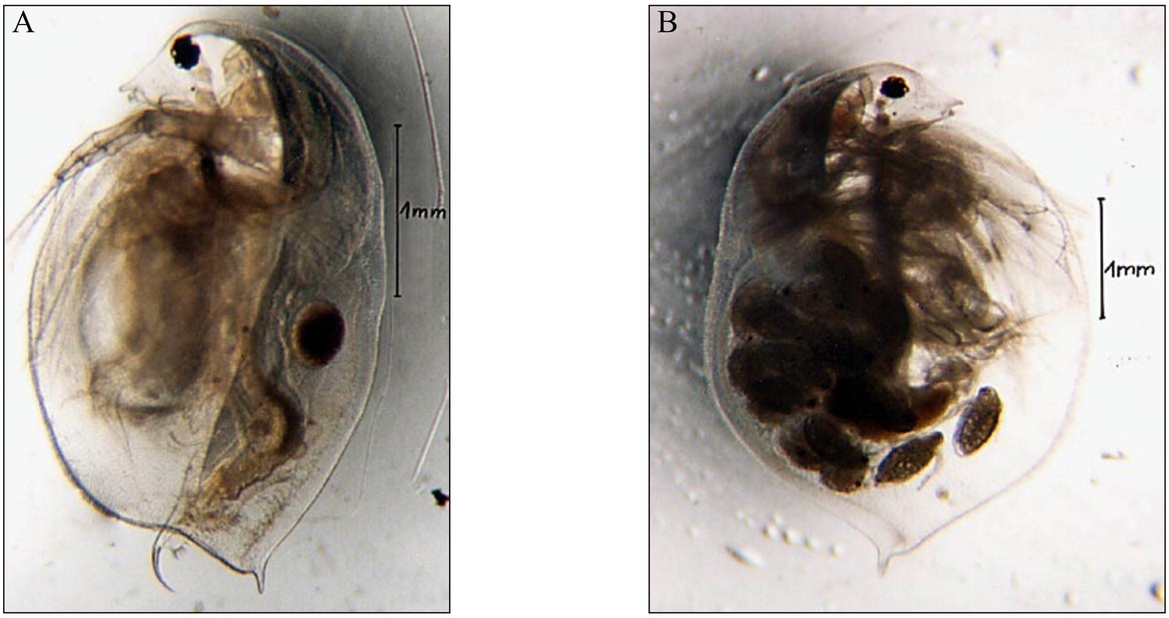

Fig. 2. Number of eggs in female of *Daphnia magna*: A - from l egg, food: cells of *Chlorella pyrenoidosa*, concentration 200 · 10^3 ml $^{-1}$; B - from 18 embryonics, food: cells of *Chlorella pyrenoidosa*, concentration 800 · 10^3 ml $^{-1}$.

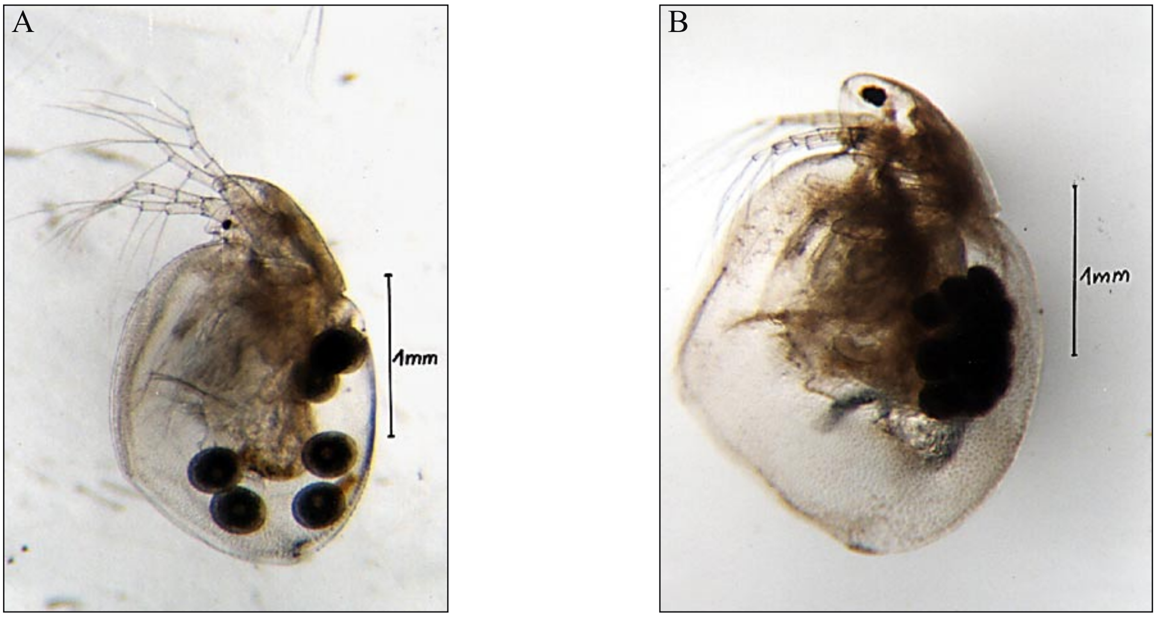

Fig. 3. Number of eggs in female of *Simocephalus vetulus*: A - from 7 eggs, food: cells of *Chlorella pyrenoidosa*, concentration 400 · ·10^3 ml $^{-1}$; B - from 12 eggs, food: cells of *Chlorella pyrenoidosa*, concentration 800 · 10^3 ml $^{-1}$.

Table 4. Mean body size (in mm), number (per one fertile female), egg size (in mm) and postembryonic development length (in days) of investigated specimens by various and different concentrations of food.

Specification	*Chlorella pyrenoidosa*	*Scenedesmus acutus*	*Saccharomyces cerevisiae*	*Bacillus subtilis*
Daphnia hyaline				
Mean length of female	*2.487	2.520	2.472	2.323
Mean number of eggs	*3.964	*2.095	*1.533	*0.357
Mean size of eggs	0.367	0.318	0.224	0.298
Length of postembryonic development	8.424	*9.714	*7.933	*13.240
Daphnia magna				
Mean length of female	*3.636	3.365	3.273	*3.172
Mean number of eggs	*7.500	*4.567	*3.365	*2.015
Mean size of eggs	0.363	0.357	0.358	0.309
Length of postembryonic development	8.340	*11.000	*13.159	*15.752
Simocephalus vetulus				
Mean length of female	*2.430	2.385	2.217	*1.867
Mean number of eggs	*7.350	*5.727	*2.200	*1.533
Mean size of eggs	0.293	0.285	0.265	0.168
Length of postembryonic development	8.567	*8.667	*12.567	*8.367

* Asterisks indicate differences significant at the 0.5% level

Table 5. Difference of length postembryonic development (in days) of investigated species by various food.

Food	Length of postembryonic development	Difference
Daphnia hyalina		
Chlorella pyrenoidosa	10.929-5.950	4.979
Scenedesmus acutus	14.000-6.571	7.429
Saccharomyces cerevisiae	14.000-9.800	4.200
Bacillus subtilis	15.650-10.220	5.430
Daphnia magna		
Chlorella pyrenoidosa	10.300-6.071	4.229
Scenedesmus acutus	14.000-8.550	5.450
Saccharomyces cerevisiae	16.000-10.619	5.381
Bacillus subtilis	18.000-12.375	5.625
Simocephalus vetulus		
Chlorella pyrenoidosa	11.050-6.050	5.000
Scenedesmus acutus	8.909-8.455	0.454
Saccharomyces cerevisiae	14.600-10.500	4.100
Bacillus subtilis	13.150-11.600	1.900

plankton crustaceans eagerly use lipids to grow. *Chlorella pyrenoidosa* cells appeared most abundant in lipids, with fat content reaching 78% [42]. *Bacillus subtilis* cells have a thick 15-20 nm cellular wall built up of many layers of murein and tejchonic acids, constituting approximately 20-38% dry mass. The average lipid content in *Bacillus subtilis* cells ranges only within 10-19% of dry mass [43]. In natural conditions, water contains a suspension of different food types, and thus in the initial phase of the filtrator growth, algae are the most important source of food. However, when their biomass gets reduced, other groups of phytoplankton, particularly bacteria began to prevail [9]. Thus, food selectivity can be observed in filtrators

[44-46], although the role of bacterioplankton in their nutrition in natural conditions is significant [9-12, 35, 40, 45] which has been mentioned in the majority of monographs on trophic chains of lakes [47, 48]. Also detrital, the organic material, is used as food [21, 23, 49, 50].

Worth noting is the relatively high nutritional value of yeast cells for the filtrators examined. This is an important observation, considering the fact that the contribution of plankton fungi has been rather neglected [5,13].

In the case of all the four food types, the postembryonic period of the filtrator species examined was shortened when the concentration of cells increased.

Up to the present, literature data referred mainly to light intensity [51], effect of temperature and food type on the postembryonic growth of the filtrating zooplankton representatives [51-53]. Based on our current experiments, apart from light, temperature and food quality, also food abundance appears to be an important factor.

In natural conditions, apart from the above-mentioned factors, the size and fertility of specimens in certain water reservoirs can be largely affected by lower zoosporic fungi, which are sometimes found in abundance on the specimens of the species included in zooplankton [54, 55]. Some of these zoosporic fungi growing on eggs of plankton crustaceans greatly reduce the populations of both Cladocera [56] and Copepoda [57] species.

References

1. BERNARDI R., GIUSSANI G. Are blue-green algae a suitable food for zooplankton? An overview.- Hydrobiologia, **200/201**, 29, **1990**.
2. FULTON III, R. S., JONES R. C. Growth and reproductive responses of *Daphnia* to cyanobacterial blooms on the Potomac River.- Inter. Revue ges. Hydrobiol., **76**, 5, **1991**.
3. GIANI A. The nutritive value of different algae as food for two *Daphnia* species. -Verh. Internat. Verein. Limnol, **24**, 2788, **1991**.
4. CONNOR T. E., JONES Ch. Survival and reproduction by *Bosmina longirostris* fed two species of green algae.- Verh. Internat. Verein. Limnol., **26**, 1913, **1998**.
5. SUŠČENIA L. M. Količestwiennye zakonomernosti pitaia rakoobraznych (Quantitative rules in the nutrition of crustaceans). - Nauka, Mińsk. 208 pp. **1975**. (In Russian).
6. CAUCHIE H. M., JOAQUIM-JUSTO C., HOFFMANN L., THOME J. P., THYS J. A note on the use of fluorescently labelled algae for the determination of passage time in *Bosmina* and *Daphnia*. - Verh. Internat. Verein. Limnol., **27**, 2987, **2000**.
7. GREY J. Trophic fractionation and the effects of diet switch on the carbon stable isotopic “signatures” of pelagic consumers.- Verh. Internat. Verein. Limnol., **27**, 3187, **2000**.
8. KURMAYER R. Nutritive vs. interfering effects of *Anabaena* on *Daphnia* and *Ceriodaphnia*. -Verh. Internat. Verein. Limnol., **27**, 3001, **2000**.
9. BŘRSHEIM K. Y., OLSEN Y. Grazing activities by *Daphnia pulex* on natural populations of bacteria and algae.- Verh. Internat. Verein. Limnol., **22**, 644, **1984**.
10. BRENDELBERGER H. Filter mesh size of cladocerans predicts retention efficiency for bacteria.- Limnol. Oceanogr., **36**, 884, **1991**.
11. JÜRGENS K. Impact of *Daphnia* on planktonic microbial food webs.-A revier.- Mar. Microb. Food Webs, **8**, 295, **1994**.
12. JÜRGENS K., GASOL J. M., MASSANA R., PEDRÓS-ALIÓ C. Control of heterotrophic bacteria and protozoans by *Daphnia pulex* in the epilimnion of Lake Cisó.- Arch. Hydrobiol., **131**, 55, **1994**.
13. BURNS C. W., RIGLER F. H. Comparison of filtering rates of *Daphnia rosea* in lake water and suspensions of yeast.- Limnol. Oceanogr., **12**, 492, **1967**.
14. CZECZUGA B. Oviposition in *Eudiaptomus gracilis* G.O. Sars and *E. gracilloides* Lilljeborg (Diaptomidae, Crustacea) in relation to season and trophic level of lakes.- Bull. de L’Acad. Pol. des Sci. Cl. II, **7**, 227, **1959**.
15. CZECZUGA B. Changes in fertility of some representative of the zooplankton I. *Crustacea* from the Rajgrodzkie lakes.- Pol. Arch. Hydrobiol., **7**, 61, **1960**.
16. CZECZUGA B., BOBIATYŃSKA - KSOK E. Selectivity, food intake, energy use of *Ceriodaphnia quadrangula* (O. F. Müller). - News Internat. Biol. Progr., London, **17**, 24, **1969**.
17. CZECZUGA B., KOZŁOWSKA M. Fertility of *Eudiaptomus*, *Bosmina* and *Daphnia* (Crustacea) representatives in the lakes of varied trophic state in the Suwałki District.- Pol. J. Environ. St, **11**, 23, **2002**.
18. PODANI J. Introduction to the exploration of multivariate biological data.- Leiden, Backhuys Publishers, pp. 407, **2000**.
19. IVANOVA M. B., VASSILENKO S. Relationship between number of eggs, brood weight and female body weight in Crustacea.- Inter. Revue ges. Hydrobiol., **72**, 147, **1987**.
20. URABE J. Effect of food concentration on growth, reproduction and survivorship of *Bosmina longirostris* (Cladocera): an experimental study.- Freshwat. Biol., **25**, l, **1991**.
21. OJALA A., KANKAALA P., KAIRESALO T., SALONEN K. Growth of *Daphnia longispina* L. in a polyhumic lake under various availabilities of algal, bacterial and detrital food.- Hydrobiologia, **315**, 119, **1995**.
22. ALEKSEEV V.R., UMNOV A. A. The role of trophic and signal factors in diapause induction and seasonal dynamics in a *Daphnia longispina* population : a simulation model.- Verh. Internat. Verein. Limnol., **27**, 3926, **2001**.
23. TAKEMURA N., MIKAMI H., HOUKI A., NAKAGAWA M. How did replacement of the dominant fish community influence water quality and plankton community structure in an oligotrophic lake in Japan?- Verh. Internat. Verein. Limnol., **27**, 3319, **2001**.
24. SUŠČENIA L. M., TRUBETSKOVA I. L. The feeding rate of *Daphnia magna* Straus under longterm acclimation to temperature.- Zhurn. Obsh. Biol., **42**, 669, **1981**. (In Russian).
25. MCKEE D., EBERT D. The effect of temperature on matu-

ration threshold body length in *Daphnia magna*.- Oecologia, **108**, 627, **1996**.
26. NEBEKER A.V., ONJUKKA S. L, STEVENS D. G., CHAPMAN G. A., DOMINGUEZ S. E. Effects of low dissolved oxygen on survival, growth and reproduction of *Daphnia hyalella* and *Gammarus*. - Emdron. Toxicol. Chem., **11**, 373,**1992**.
27. HANAZATO T. Combined effect of food shortage and oxygen deficiency on life history characteristics and filtering screens of *Daphnia*.- J. Plankton Res., **5**, 757, **1996**.
28. CZECZUGA B. Haemoglobin content of *Tendipes f. l. plumosus* L. larvae from various levels of bed sediment.- Nature (London), **186** (4723), 484, **1960**.
29. CZECZUGA B. Haemoglobin in the *Chironomus* (*Tendipes*) *annularius* Meig. larvae from various growth classes.- Die Naturwissenschaften, **48** (20), 651, **1961**.
30. CZECZUGA B., CZERPAK R. The presence of carotenoids in eggs deposits of the *Chironomus annularius* Meig. (Diptera : Chironomidae).- Experientia, **25**, 1037, **1969**.
31. CZECZUGA B. Haemoglobin in *Ceriodaphnia quadrangula* (O. F. Müller).- Nature (London), **208** (5013), 907, **1965**.
32. CZECZUGA B. Carotenoid content of *Artemia* eggs and vitality of the young specimens of this crustacean.- In: Persone G., Sorgeloos P., Roels D. and Jaspers E.(eds), The Brine Shrimp 2: 664.Wetteren, Belgium, Universa Press, **1980**.
33. CZECZUGA B., KOZŁOWSKA M., CZECZUGA - SEMENIUK E. Adaptative role of carotenoids and carotenoproteins in *Cyclops kolensis* Lilljeborg (Crustacea : Copepoda) specimens to extremely eutrophical conditions. - Folia biol. (Kraków), **48**, 77, **2000**.
34. JÜRGENS K., STOLPE G. Seasonal dynamics of crustacean zooplankton, heterotrophic nanoflagellates and bacteria in a shallow, eutrophic lake.- Freshwat. Biol., **33**, 27, **1995**.
35. G.-TOTH L., KATO K., ABE D. Grazing of *Daphnia galeata* (Crustacea, Cladocera) on epi- and hypolimnetic bacteria in the mesotrophic Lake Kizaki, Japan.-Verh. Internat. Verein. Limnol., **27**, 3712, **2001**.
36. GELLER W., MÜLLER H. The filtration apparatus of Cladocera: filter mesh-size and their implications on food selectivity.- Oecologia, **49**, 316, **1981**.
37. De MOTT W. R. C. Relations between filter mesh-size, feeding mode and capture efficiency for cladocerans feeding on ultrafine particles.- Arch. Hydrobiol. Beihm. Ergeb. Limnol., **21**, 125, **1985**
38. WIEDNER C., VARESCHI E. Evaluation of a fluorescent microparticle technique for measuring filtering rates of *Daphnia*.- Hydrobiologia, **302**, 89, **1995**.
39. LAMPERT W., BRANDELBERGER H. Strategies of phenotypic low-food adaptation in *Daphnia*: filter screens, mesh sizes and appendage beat rates.- Limnol. Oceanogr., **41**, 216, **1996**.
40. G.-TÓTH L., KATO K. Size-selective grazing of bacteria by *Bosmina longirostris* - an image - analysis study.- J. Plankton Res., **19**, 1477, **1997**.
41. MÜLLER H. The nickes of *Bosmina coregoni* and *Bosmina longirostris* in the ecosystem of Lake Constance.- Verh. Internat. Verein. Limnol., **22**, 3137, **1985**.
42. UPITIS W. Makro- i mikroelementy w optimalizacji mineralnovo pitanija mikrowodoroslej. - Wyd. Zinatie, Ryga, pp. 128, **1983**. (In Russian).
43. ZARĘBA M. L., BOROWSKI J. Mikrobiologia lekarska: 121-132.-Warszawa, Wydaw. Lek., **1997**. (In Polish).
44. HORN W. Investigations in to the food selectivity of the planktic crustaceans *Daphnia hyalina, Eudiaptomus gracilis* and *Cyclops vicinus*.- Inter. Revue, ges. Hydrobiol., **70**, 603, **1985**.
45. BOERSHEIM K.Y., ANDERSEN S. Grazing and food size selection by crustacean zooplankton compared to production of bacteria and phytoplankton in a shallow Norwegian mountain lake.- J. Plankton Res., **9**, 367, **1987**.
46. JAYANTHI M. The impact of food quality and selective feeding on the growth and development of *Heliodiaptomus viduus*.- Verh. Internat. Verein. Limnol, **27**, 3682, **2001**.
47. SAJIO Y., HAYASHI H. Lake Kizaki. Limnology and Ecology a Japanese Lake.- Leiden, Backhaus Publishers, pp. 428, **2001**.
48. HĹKANSON L., BOULION U. U. The Lake Foodweb, modelling predation and abiotic / biotic interactions.- Leiden, Backhaus Publishers, pp. 352, **2002**.
49. JONES R. L, GREY J., QUARMBY C., SLEEP D. An assassment using stable isotopes of the importance of allochthonous organic carbon sources to the pelagic food web in Loch Ness.- Proc. Roy. Soc., B., **265**, 105, **1998**.
50. JONES R. L, GREY J., SLEEP D., ARVOLA L. Stable isotope analysis of zooplankton carbon in nutrition humic lakes.- Oikos, **86**, 97, **1999**.
51. STARKWEATHER P. L. Influence of light regime on postembrionic development in two strains of *Daphnia pulex*.- Limnol. Oceanogr., **21**, 830, **1976**.
52. KORINEK V. The embryonic and postembryonic developming of *Daphnia hyalina* Leydig (Crustacea, Cladocera) from Lake Maggiore.- Mem. Ist. Ital. Idrobiol., **26**, 85, **1970**.
53. LANGELAND A., KOKSVIK J. I., OLSEN Y. Post-embryonic development and growth rates of *Daphnia pulex* De Geer and *Daphnia galeata* Sars under natural food conditions.- Verh. Internat. Verein. Limnol., **22**, 3124, **1985**
54. CZECZUGA B., GODLEWSKA A., KOZLOWSKA M. Zoosporic fungi growing on the carapace of dead zooplankton organisms.- Limnologica, **30**, 37, **2000**.
55. CZECZUGA B., KOZŁOWSKA M., GODLEWSKA A. Zoosporic aquatic fungi growing on dead specimens of 29 freshwater crustacean species.- Limnologica, **32**, 180, **2002**.
56. BENGTSSON J., EBERT D. Distributions and impact of microparasites on *Daphnia* in a rockpool metapopulation.- Oecologia, **115**, 213, **1998**.
57. ROSSETTI G., FRATTA E., TIRENI F., VIGLIOLI S. Impact of a fungal parasite on the reproductive potential of the freshwater calanoid *Eudiaptomus intermedius*. - Verh. Internat. Verein. Limnol., **28**, 387, **2002**.