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SHORT COMMUNICATIONS

Experimental Study of the Influence of the Time Spent on Land of Semiaquatic Bird Excreta on the Number of Copepoda and the Fecundity of Cladocera

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Abstract—In the course of a laboratory experiment in microcosms, it is shown that the input of semiaquatic bird droppings promotes an increase in Copepoda abundance. The number of Copepoda decreases with increasing time of excreta drying in the air, but remains above the control values. The results of water biotesting from the microcosm using *Ceriodaphnia dubia* Richard demonstrate that the fecundity of the Cladocera increases with the increasing duration of excrement in the air. An assumption is made that the predominance of one or another group of Crustacea is determined by the rate of inflow of bird excrements and may indirectly depend on the ratio of nitrogen and phosphorus in water and, consequently, in feeding objects of crustaceans.

Keywords: Copepoda, Cladocera, bird droppings, microcosm

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It is known that the abundance of a certain group of plankton crustaceans depends not only on top-down and bottom-up control, but on the stoichiometric ratio of nitrogen and phosphorus in their food objects as well [7, 8, 14]. We associate the predominance of Copepoda [2] in plankton with a high nitrogen content in bird excrements [10–12, etc.] that are transferred into the water in locations of the colonies. However, in certain cases, Cladocera reach high abundance in the areas of bird influence. The degree of macrophytes growth in water objects, as well as time spent in air and the input of bird waste products (BWPs) into water, were demonstrated to play a certain role in this phenomenon. Established associations between atmospheric precipitation, which facilitate quicker washout of BWPs, and Copepoda abundance indirectly indicated it [2].

The goal of the present study was to experimentally evaluate the influence of the duration of BWPs in air and their input into the water on the concentration of nitrogen and phosphorus in it, the abundance of Copepoda, and the fecundity of Cladocera.

The experiment was conducted for 49 days in 5-L microcosms, in which we placed adult specimens of *Acanthocyclops americanus* (Marsh), *A. vernalis* (Fischer), *Eucyclops serrulatus* (Fischer), *Macrocyclops albidus* (Jurine), and *Mesocyclops leuckarti* (Claus) (15 specimens in total), previously caught and adapted in 1 month. They inhabited the microcosms together with *Ceriodaphnia dubia* Richard and *Daphnia magna* Straus. Cultures of *Chlorella vulgaris* Beijer and *Paramecium caudatum* Ehrenberg were added into the water daily as food sources for Cladocera and Copepoda, respectively.

The experiment included a control (three repeats) and three versions (in three repeats each). In each microcosm of version 1, fresh BWPs were added every 7 days in a concentration of 1.5 g/L; version 2 received a similar quantity of BWPs that spent 7 days in air in a shadow, and version 3 received BWPs dried for 14 days. Droppings of ducks *Anas platyrhynchos* Linnaeus, which were grown with diet that included fish and sometimes duckweed, aquatic invertebrates, and amphibians in a natural water body, were used as BWPs.

Once every 7 days, an integral water probe was taken from all microcosms of each experimental version to determine nitrogen and phosphorus concentrations [1, 4], as well as for *Ceriodaphnia dubia* biotesting in the beginning and the end of the experiment [6]. The studied water was filtered through a gauze with 64-μm mesh; animals caught in the net were released back. The copepods were collected at the end of the experiment by filtering all water volume through gauze with 64-μm mesh and fixed in 4% formalin.

† Deceased.

Table 1. Average nitrogen (N) and phosphorus (P) contents in the water and their ratio in different versions of the experiment

Version	N_{total}, mg/dm^3	P_{total}, mg/dm^3	N/P
Control	2.93	2.05	1.43
1 day	7.73	5.19	1.49
7 days	6.35	5.01	1.27
14 days	4.59	4.17	1.10

Laboratory investigations of the samples were conducted by standard methods [5].

The significance of differences in the numbers of copepods were evaluated by a Kruskal–Wallis test and biotesting results were evaluated by LSD test; the Spearman rank correlation coefficient was calculated as well ($p < 0.05$).

The nitrogen and phosphorus content was higher in the water of experimental microcosms under the influence of BWPs than in the control (Table 1). We discovered a tendency of a decrease in the nitrogen and phosphorus contents with the increase in time excrements spent in air; the N/P value was significantly decreasing ($r = -0.65$). It is known that the longer bird droppings spend in air, the more nitrogen they lose [9, 11, 13]. Obviously, therefore, the average loss in phosphorus that was transferred into the water with excrements after drying for 7 days was 0.18 mg/L and 1.02 mg/L after 14 days, while average nitrogen loss was 1.38 and 3.14 mg/L, respectively (Table 1).

The results of biotesting demonstrated that the one-time input of excreta into the microcosms did not have stimulating or suppressing effects of the test object *Ceriodaphnia dubia* (Table 2). However, a significant increase of the mean number of birthed specimens was noted at the end of the experiment in all its versions, both relative to the control value and to the data obtained at the beginning. A significantly higher fecundity of crustaceans was registered in the case of an input of excrement after 14 days in the air.

The number of Copepoda was significantly larger in the microcosms with BWPs relative to the control. The highest density of copepods was reached in microcosms that received excrements on the first day (Fig. 1). However, no significant differences were found in the number of Copepoda in microcosms receiving BWPs after 7 and 14 days of drying.

Thus, the predominance of a certain crustacean group under the influence of bird colonies is determined by how long the excrements stay in air and when they enter the water. This could lead to a change in the stoichiometric ratio of nitrogen and phosphorus in the water and food objects, which was noted in the field studies [3]. As a result, Copepoda gain an advantage during the quick input of excrement rich in nitrogen, while Cladocera has advantage with increased stay of excrements in the air and the loss of nitrogen.

CONCLUSIONS

Under the prolongation of bird excrements in air, the amount of nitrogen and, to a lesser extent, phosphorus decreases in the water that the excrements enter and the fecundity of Cladocera increases. The bird droppings facilitate the increase in density of Copepoda; however, with an increased duration of excrements in the air, their numbers decrease, albeit they remain higher than that in the control.

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Table 2. Mean ($M \pm SD$) number of *Ceriodaphnia dubia* offspring birthed by a female in 7 days of water biotesting in the beginning ($_{beg}$) and the end ($_{end}$) of the experiment in the control (C) and during excrement input on the 1st (1), 7th (7), and 14th (14) days and the significance of mean differences (LSD test)

Version	C_{beg}	1_{beg}	7_{beg}	14_{beg}	C_{end}	1_{end}	7_{end}	14_{end}
$M \pm SD$	10.2 ± 2.6	11.8 ± 4.2	11.3 ± 3.0	12.4 ± 3.7	12.1 ± 1.1	19.8 ± 1.7	22.0 ± 4.3	26.9 ± 4.4
K_{beg}	–	0.199748	0.362455	0.075716	0.01373	**0.000000**	**0.000000**	**0.000000**
1_{beg}	–	–	0.069194	0.619178	0.263895	**0.000429**	**0.000000**	**0.000000**
7_{beg}	–	–	–	0.185669	0.080981	**0.000000**	**0.000000**	**0.000000**
14_{beg}	–	–	–	–	0.147866	**0.000000**	**0.000000**	**0.000000**
K_{end}	–	–	–	–	–	**0.000004**	**0.000000**	**0.000000**
1_{end}	–	–	–	–	–	–	0.063142	**0.000000**
7_{end}	–	–	–	–	–	–		**0.000064**
14_{end}	–	–	–	–	–	–	–	–

Significant differences are in bold.

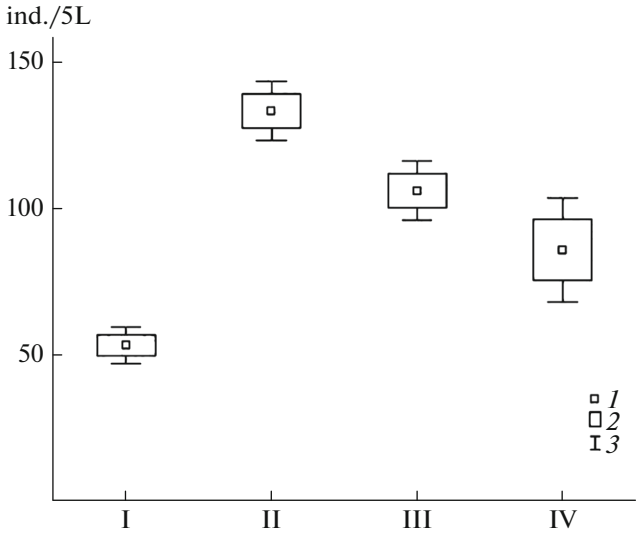

Fig. 1. Mean number of copepods in the control (I) and in microcosms with excrement input on the 1st (II), 7th (III), and 14th (IV) days by the end of the experiment: (*1*) *M*, (*2*) $M \pm SE$, and (*3*) $M \pm SD$.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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