



The first data on the study of the influence of waste products of semiaquatic birds on planktonic crustaceans and fish (laboratory experiments)

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This paper presents the results of a study of the effect of metabolic products of semiaquatic birds on planktonic crustaceans and fish in chronic laboratory experiments. The results of the studies showed that the waste products of birds in a concentration of from 0.5 to 2.5 g/l stimulate the fecundity of cladocerans, in the tissues of which the amount of lipids increases. The consumption of such cladocerans by fish causes a greater increase in their mass, and also contributes to an increase in their lipid content.

Keywords: chronic laboratory experiments, bird excrement, *Anas platyrhynchos domesticus*, cladocerans, *Daphnia (Ctenodaphnia) magna*, *Ceriodaphnia dubia*, fish, *Danio rerio*, fecundity, lipids.

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Introduction

The results of field studies revealed a change in the quantitative and qualitative composition of planktonic aquatic organisms living in an environment with the products of vital activity of colonial settlements of aquatic and semiaquatic birds (Krylov et al., 2011b; Sakharova and Korneva, 2015). In addition, it was shown that in the zone of influence of the colony of semiaquatic birds, the size and weight characteristics of juvenile fish exceeded those in the background area (Krylov et al., 2018; Stolbunov et al., 2017). However, in some periods, the difference between the size and weight characteristics of juvenile fish in two coastal areas was reduced, or they were identical. Apparently, this was due to the active or passive movement of fry from one biotope to another. Thus, it became necessary to conduct a series of experiments that exclude the possibility of migration. The aim of this work was an experimental study of the effect of excrement of semiaquatic birds on juvenile fish and their food objects.

Material and methods

The experiment was carried out using cladoceran cultures (*Daphnia (Ctenodaphnia) magna* (Straus, 1820)) and fish (*Danio rerio* (Hamilton, 1822)) contained in the laboratory of physiology and toxicology of aquatic animals of the I.D. Papanin Institute for Biology of Inland Waters, Russian Academy of Sciences. The excrement of mallard ducks (*Anas platyrhynchos domesticus* Linnaeus, 1758) was used as the semiaquatic bird's life activity product (SBP). Birds were reared domestically on feeds including fish. Periodically, they were fed in a natural reservoir with duckweed, aquatic invertebrates and amphibians.

Fish between the ages of 9 and 12 months were placed, 30 specimens each, in a 30-liter bath tub. Two versions of the experiment were performed:

I (control) – the fish were in clean, settled tap water, the food was cladocerans grown in control water, as well as dry food for tank fish (*TetraMin*);

II (experiment) – the fish were in clean, settled tap

water, the food was cladocerans grown in water with the addition of SBP, as well as dry food for tank fish.

The optimal concentration of SBP, providing the highest fecundity of cladocerans, was determined by biotesting on *Ceriodaphnia dubia* (Richard, 1894) (Metodika opredeleniya toksichnosti vody..., 2007).

During the experiment, the fish were fed every day, alternating live (*Daphnia magna*) and dry food at the rate: feed weight 10% of the total weight of the fish. The required amount of *Daphnia* was caught using a net from cages in which they were kept in control water or under the influence of SBP, and weighed before being added to the bath with the fish. The duration of the experiment was 21 days. Unfortunately, weighing each individual at this stage of research was impossible; therefore, at the beginning and at the end of the experiment, the total weight of the fish was determined.

To determine the lipid content of the fish and daphnia, a standard technique was used modified for the laboratory of physiology and toxicology of aquatic animals of the I.D. Papanin Institute for Biology of Inland Waters, Russian Academy of Sciences (Metody opredeleniya zhira... GOST 15113.9-77, 2003).

Statistical data processing, after checking the nor-

mality of the distribution using a Kolmogorov – Smirnov test, was performed using one-way analysis of variance ($p < 0.05$, ANOVA), multiple comparisons of group means – the least significant difference test (LSD-test).

Results and discussion

Data obtained during several series of biotests on *Ceriodaphnia dubia* showed that SBP at a concentration of 0.5–2.5 g/l had a stimulating effect on crustacean fertility, causing a significant increase in the average number of juveniles per female over 7 days (Fig. 1, Table 1). Based on the results of the biotesting, the optimal concentration of SBP for *Daphnia magna* was determined to be 1.5 g/l, which was further used in the cultivation of the fodder batch of crustaceans for experiment. Possible reasons for the increase in fecundity, as well as the number of planktonic crustaceans, were discussed by us earlier (Krylov et al., 2012). Primarily this is an increase in the food supply of crustaceans due to an increase in the concentration of biogenic substances in water, as well as a change in the quality of food objects due to a shift in the stoichiometric ratio of nitrogen and phosphorus in them, depending on which copepods or cladocerans are used. It should be noted that the stimulating effect

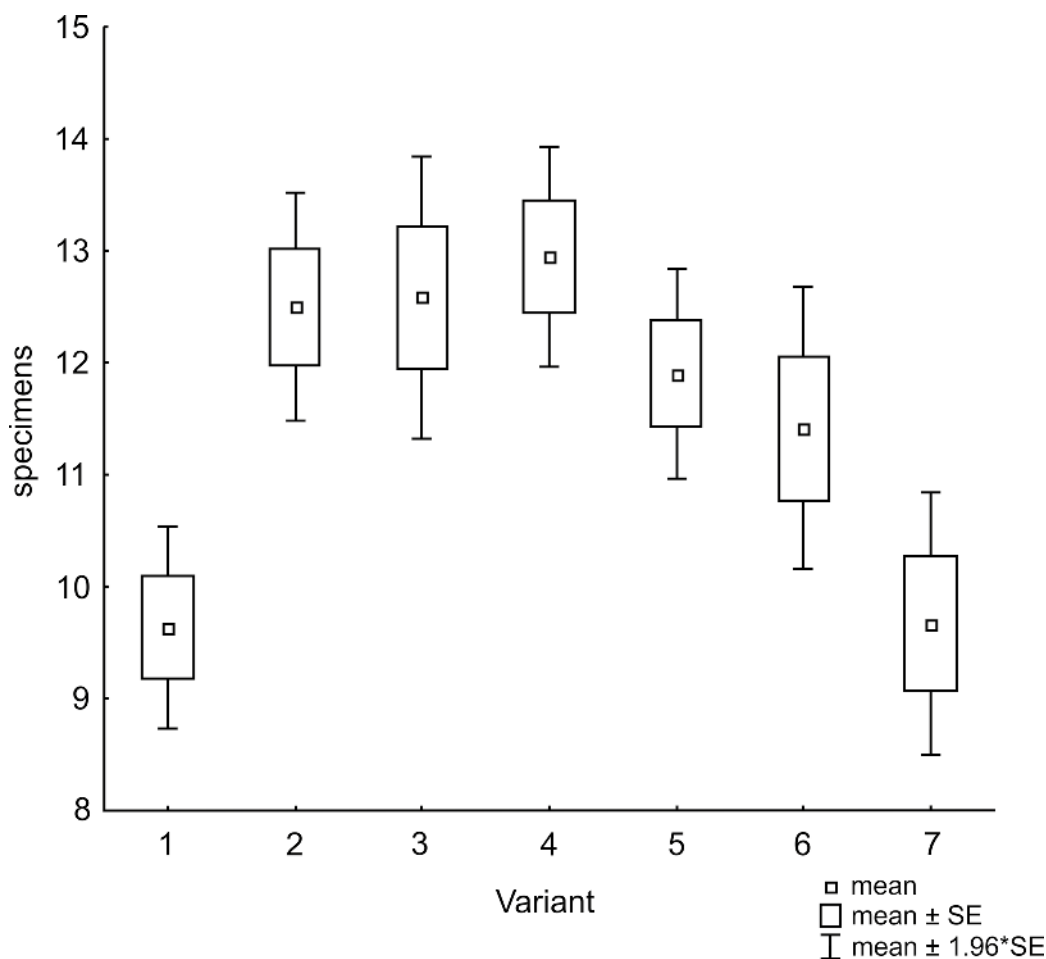


Fig. 1. Average number of juveniles from one female of *Ceriodaphnia dubia* for 7 days in water with different contents of semiaquatic bird waste products. Control – settled tap water (1), tested concentrations of animal products – 0.5 (2), 1.0 (3), 1.5 (4), 2.0 (5), 2.5 (6) and 3.0 (7) g/l.

of SBP was not manifested when their concentration was more than 2.5 g/l. A change in the response of planktonic organisms with an increase in the density of aquatic bird colonies to 200–250 individuals per 1 ha, that is, with an increase in the amount of excrement received, has already been noted. Such changes were observed both in the study of zooplankton in fish ponds, where the method of growing geese and carp together was used (Ivanova et al., 2000), and in nature (Krylov et al., 2012).

In the control, the total initial weight of the fish was 4.95 g, in the experiment 4.79 g, at the end of the experiment 6.72 and 7.01 g, respectively (Fig. 2). Thus, in the control version, the mass gain during the experiment was 1.77 g (35.8%), in the experimental version 2.22 g (46.3%). Consequently, the nutrition of fish with crustaceans grown under the influence of SBP, contributed to a more intensive increase in their biomass.

The observed effect may be associated with an increase in the quality of fodder characteristics of *Daphnia magna*. This is indicated by the fact that when growing crustaceans in tanks with the addition of SBP, they were found to have a higher lipid content of 13.2 mg/g, compared to 9.0 mg/g in the control variant (Fig. 3).

Similar differences were found in the lipid content in fish grown on control feed and on feed from tanks with 132.0 mg/g and 144.4 mg/g of SBP added, respectively (Fig. 4).

Thus, the first experimental data showed that fish receiving planktonic crustaceans grown in water containing SBP feeds, even during a short-term experiment, have a greater weight gain. Consequently, crustaceans that live under the influence of SBP are

better feed. This is mainly due to an increase in their content of lipid, which provides about twice as much energy as proteins and carbohydrates. It is known that a special role is played by polyunsaturated fatty acids of the omega-3 family, in particular, docosahexaenoic acid (22: 6n-3), whose high content in zooplankton characterizes them as a feed better for fish (Copeman et al., 2002). The high content of polyunsaturated fatty acids in aquatic organisms living in the zone of influence of the colonial settlements of aquatic and near-water birds is evidenced by data obtained in the littoral zone of a number of reservoirs (Krylov et al., 2011a; Krylov et al., 2018).

Based on the research, preliminary conclusions can be drawn:

- vital products of birds in concentrations from 0.5 to 2.5 g/l stimulate the fecundity of cladocerans;
- under the influence of SBP, the amount of lipids in them increases;
- the consumption of such cladocerans by fish causes a more intensive increase in their mass and contributes to an increase in their lipid content.

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Compliance with ethical standards

All applicable international, national, and/or institutional guidelines for animal care and use have been followed.

Table 1. The results of the LSD-test of the average number of offspring from one female *Ceriodaphnia dubia* for 7 days ($n = 60$). Statistically significant differences are shown in bold.

Concentration of SBP, g/l	0.5	1.0	1.5	2.0	2.5	3.0
Control	0.000278	0.000185	0.000027	0.003946	0.023078	0.966018
0.5	–	0.915180	0.565274	0.443330	0.166667	0.000327
1.0	–	–	0.639376	0.382685	0.136460	0.000218
1.5	–	–	–	0.180072	0.050559	0.000033
2.0	–	–	–	–	0.536838	0.004505
2.5	–	–	–	–	–	0.025752

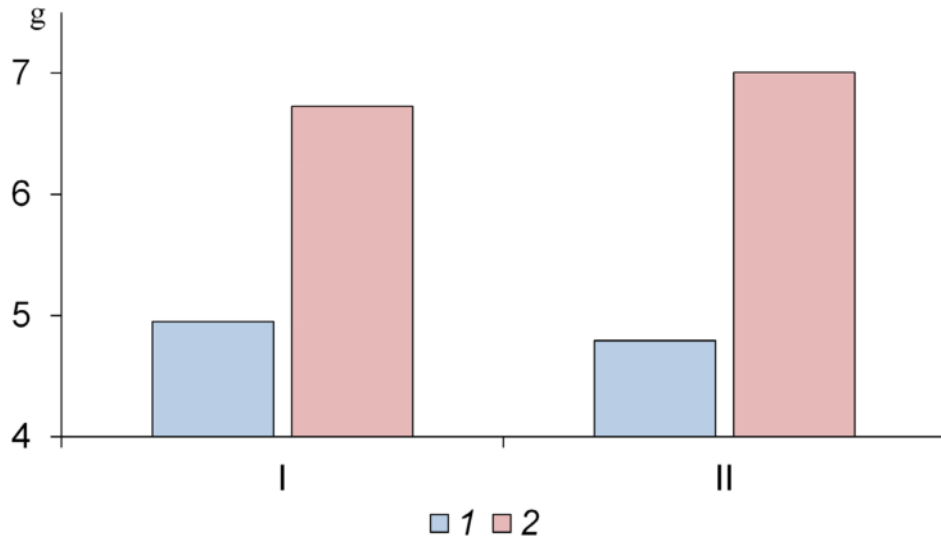


Fig. 2. Mass of fish at the beginning (1) and at the end (2) of the experiment. I – control, II – experiment.

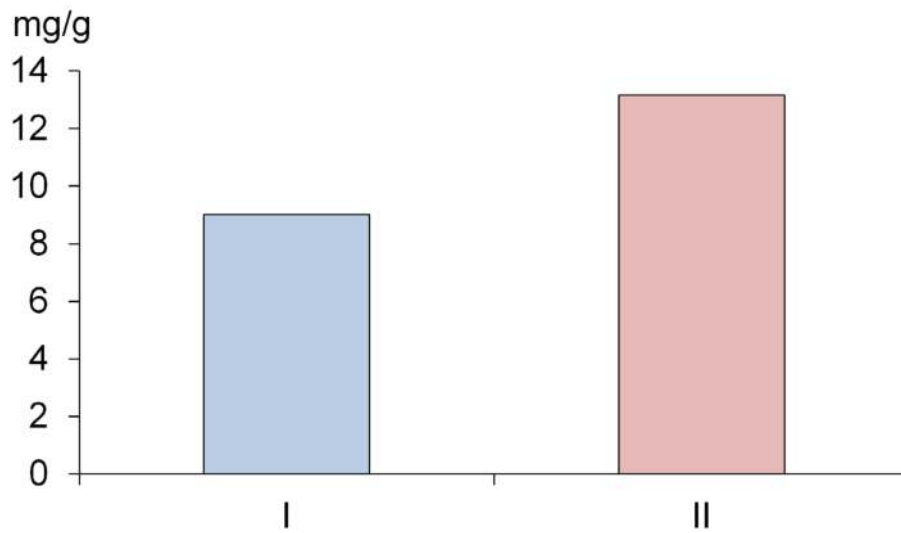


Fig. 3. Lipid content in the tissues of *Daphnia magna* at the end of the experiment. I – control, II – experiment.

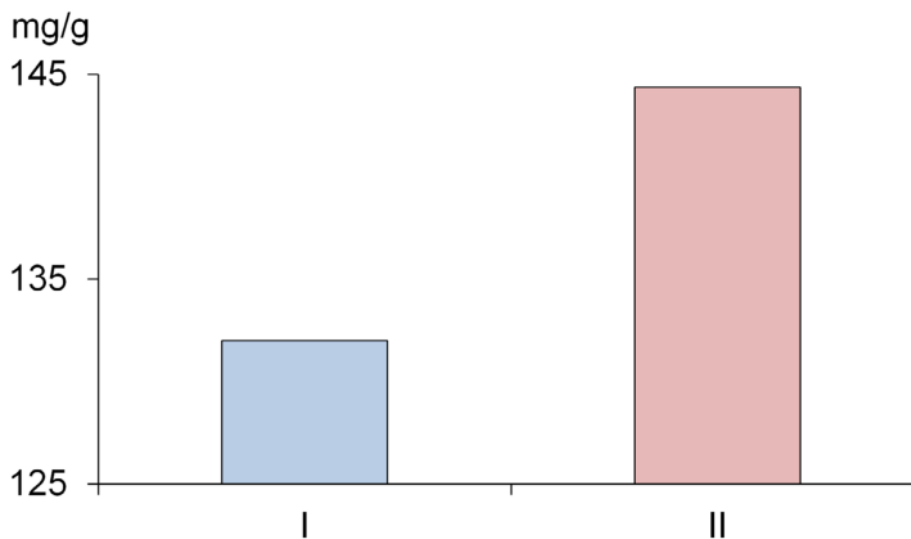


Fig. 4. Lipid content in *Danio rerio* tissues at the end of the experiment. I – control, II – experiment.

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