Helminths of amphibians (Amphibia) in beaver ponds in the Central Russia

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Abstract. The European beaver Castor fiber Linnaeus, 1758 is a mammal that determines the composition of the small river ecosystems in Europe and Asia. It influences the environment forcing many other animals to adapt to completely different living conditions. The results of the study are presented on the helminthic fauna of amphibians inhabiting beaver ponds in the National Park "Smolny" (Republic of Mordovia, Russia). Six amphibian species (Pelophylax lessonae (Camerano, 1882), Rana arvalis Nilsson, 1842, Rana temporaria Linnaeus, 1758, Bufo bufo (Linnaeus, 1758), Lissotriton vulgaris (Linnaeus, 1758), Triturus cristatus (Laurenti, 1768)) were examined by complete helminthological autopsy. Amphibians were caught in three ponds with different conditions: 1) lowland and water-abundant pond; 2) percolating and went low pond, restored by beavers after breaking the dam; 3) channel pond, abandoned by beavers because of drought. Nineteen helminth species, belonging to Trematoda (13), Chromadorea (5), and Dorylaimea (1), have been found. The water-abundant pond had the greatest number of helminth species. The pond abandoned by beavers had the smallest number of helminths. The presence of green frogs was an indicator of the pond flourishing and showed the presence of trematodes in this pond. There was a low level of trematodas infestation everywhere.

Key Words: amphibians, beaver ponds, trematodes, nematodes.

Introduction. Today, the European beaver Castor fiber Linnaeus, 1758 in Eurasia is considered an invasive species, and its main activity is to transform the environment. Due to hunting, it was exterminated in most of its range and was absent from its natural habitats for more than 50 years. In the 50-60s of the XX century as a result of extensive re introduction and self-settlement, re-emerged the European beaver has spread widely in the old territories, developed new habitats and has restored its range and population (Dgebuadze 2000; Zavyalov et al 2005; Bashinsky 2009; Bashinskiy & Osipov 2018; Gorczyca et al 2018).

European beaver’s construction and feed production activities lead to environmental transformation and intensive succession processes in ecosystems. New landscape units (beaver ponds) are being formed, the hydrological regime and illumination, the composition of plant communities and hydrobionts are changing, and the heterogeneity of the environment is increasing (Hägglund & Sjöberg 1999; Law et al 2019; Bashinsky 2013, 2014; Logofet et al 2015). The introduction of beavers has a generally positive effect on amphibians in small rivers (Russel et al 1999; Balciauskas et al 2001; Stevens et al 2006; Cunningham et al 2007; Grudzinski et al 2020). Also, stagnant and low-flow reservoirs suitable for spawning are formed, species richness increases, and amphibian population and densities increase (Dalbeck et al 2007; Dalbeck & Weinberg 2009; Karraker & Gibbs 2009; Bashinsky 2014; Anderson et al 2015; Bashinsky & Osipov 2016; Osipov et al 2017). There is no information about the impact of the European beaver on the helminth fauna of amphibians.
This study is aimed to characterize the composition and structure of the amphibian helminth community, as well as the infestation of amphibians inhabiting beaver ponds.

Material and Method

*Location.* The material for this study was our collection of helminths from 113 specimens of amphibians of six species: *Pelophylax lessonae* (Camerano, 1882), *Rana arvalis* Nilsson, 1842, *Rana temporaria* Linnaeus, 1758, *Bufo bufo* (Linnaeus, 1758), *Lissotriton vulgaris* (Linnaeus, 1758), *Triturus cristatus* (Laurenti, 1768). The amphibians were caught in 2018-2020 in three localities within National Park “Smolny” (Republic of Mordovia, Russia).

Locality I (N 54.760174, E 45.406634): beaver pond on the Kuznal stream. Previously, it was a lowland peatbog, its development was carried out in 1948-1958. In 2016, beavers flooded it. The pond is surrounded by rare dry birch, and in some places, by black alder. Along the banks there are a broad-leaved cattail, sedge, marsh whitefly, willow-leaved turf, dioecious nettle. The surface of the pond has several fallen birches and is covered with duckweed. It is a habitat of *P. lessonae*; spawning sites for *R. arvalis*, *R. temporaria*, *B. bufo*, *L. vulgaris* and *T. cristatus*. A dirt road runs along the Southern bank; a power line runs along the Northern bank. On the Eastern side of the pond there is a spring and a recreation area “Silver spring”. The territory is experiencing transport and recreational anthropogenic impact – spring water is actively taken by the local population all year round. The pond belongs to the category of perennial (more than 3 years) and it is water-abundant.

Locality II (N 54.879431, E 45.493171): percolating pond in the vicinity of the Lesnoy village. It is surrounded by a deciduous forest of oak, linden, birch, aspen, elm; the banks are overgrown with alder and willow. Water vegetation is represented by duckweed and marigold. The pond is divided by sedge dams into several parts with different water levels. It is a habitat of *P. lessonae*; spawning place for *R. arvalis*, *R. temporaria*, *B. bufo*, *L. vulgaris* and *T. cristatus*. It is one of the oldest beaver ponds in the National Park “Smolny”. In 2007, as a result of a dam break, the pond was lowered, but soon restored by beavers. After the 2020 drought, it was partially shallowed.

Locality III (N 54.770564, E 45.373286): young channel beaver pond on the Kuzoleika river. In the western part, it is surrounded by thickets of willow and alder; in the East, there are floodplain meadows. The water is covered with duckweed in several places; inside the pond, there are pieces of dried birch. Broad-leaved cattail, sedge, willow-leaved turf, marsh whitefly and dioecious nettle grow along the banks. The green frogs do not inhabit this place; it is the spawning site for *R. arvalis* and *B. bufo*. The surrounding meadows are mowed down. In 2020, the pond was abandoned by beavers. The reason for that is the drought, that led to a drop in the water level on the Kuzoleika river and transformed it into a chain of smaller standing waters.

*Research method.* Amphibians were examined by complete helminthological autopsy (Skrjabin 1928). The material was collected, recorded, and processed in the laboratory using standard methods (Byhovskaya-Pavlovskaya 1985). The species of helminths was determined from the reports of Ryzhikov et al (1980) and Sudarikov et al (2002). In the analysis of amphibian infestation, the values of the prevalense (P, %) and intensity (R, specimens) of infestation, and the abundance index (A, specimens) are given. Statistical data processing was performed using the programs Statistica 7 and Microsoft Office Excel 2007.

*Results*

*Identification of parasite types.* Nineteen species of helminthes from 16 genera, 12 families, 6 orders, and 3 classes were found in amphibians in beaver ponds: Trematoda (13), Chromadorea (5), and Dorylaimea (1) (Tables 1 and 2).
### Life cycles of amphibian helminths from beaver ponds

<table>
<thead>
<tr>
<th>Helminthes</th>
<th>Life cycle</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Oxysomatium brevicaudatum</em></td>
<td>Bivalvia(^1) – Odonata(^2) – Ranidae(^5)</td>
<td>Pigulevsky (1952)</td>
</tr>
<tr>
<td><em>Gorgodera microovata</em></td>
<td>Bivalvia(^1) – Odonata(^3) – Ranidae(^4)</td>
<td>Pigulevsky (1952)</td>
</tr>
<tr>
<td><em>Pneumonoeces variagatus</em> (Rudolphi, 1819)</td>
<td>Planorbidae(^1) – Culicidae, Libellulidae, Calopterygidae(^3) – Anura(^8)</td>
<td>Skrabin &amp; Antipin (1962)</td>
</tr>
<tr>
<td><em>Opisthioglyphe ranae</em> (Frölich, 1791)</td>
<td>Lymnaeidae(^1) – Lymnaeidae, tadpoles of Anura(^3) – Anura(^5)</td>
<td>Dobrowolsky (1965); Grabda-Kazubsk (1969)</td>
</tr>
<tr>
<td><em>Prostotocus confusus</em> (Looss, 1894)</td>
<td>Bithyniidae(^1) – Odonata, Coleoptera, Trichoptera, Megaloptera, Gammaridae(^4) – anurans (Anura)(^9)</td>
<td>Shevchenko &amp; Vergun (1961); Khotenovsky (1970)</td>
</tr>
<tr>
<td><em>Pleurogenes claviger</em> (Rudolphi, 1819)</td>
<td>Bithyniidae(^1) – Odonata, Coleoptera, Trichoptera, Ephemeroptera, Megaloptera, Gammaridae, Asellidae(^3) – anurans (Anura)(^3)</td>
<td>Khotenovsky (1970); Grabda-Kazubsk (1971)</td>
</tr>
<tr>
<td><em>Pleurogenoides medians</em> (Olsson, 1876)</td>
<td>Bithyniidae(^1) – Odonata, Coleoptera, Ephemeroptera, Trichoptera, Megaloptera, Culicidae, Gammaridae, Asellidae(^3) – anurans (Anura)(^3)</td>
<td>Khotenovsky (1970)</td>
</tr>
<tr>
<td><em>Diplodiscus subclavatus</em> (Pallas, 1760)</td>
<td>Planorbidae(^1) – Amphibia(^2) – Planorbidae(^1) – Anura(^2) – Colubridae(^6)</td>
<td>Skrabin (1949)</td>
</tr>
<tr>
<td><em>Paralepoderma cloacicola</em> (Lühe, 1909), mtc.</td>
<td>Planorbidae(^1) – Anura(^1) – Colubridae(^3)</td>
<td>Dobrowolsky (1969); Grabda-Kazubsk (1975)</td>
</tr>
<tr>
<td><em>Strigea strigis</em> (Schrank, 1788), mtc.</td>
<td>Planorbidae(^1) – tadpoles of Anura(^2) – Anura(^3), 4 – Colubridae, Eulipotyphla, Mustelidae, Canidae(^4) – Strigiformes(^5)</td>
<td>Sudarikov (1959a, 1960)</td>
</tr>
<tr>
<td><em>Strigea sphaerula</em> (Rudolphi, 1803), mtc.</td>
<td>Planorbidae(^1) – tadpoles of Anura(^2) – Anura(^3), 4 – Colubridae(^4) – Corvidae(^5)</td>
<td>Sudarikov (1959a, 1960)</td>
</tr>
<tr>
<td><em>Strigea falconis</em> Szidat, 1928, mtc.</td>
<td>Planorbidae(^1) – tadpoles of Anura(^2) – Anura(^3), 4 – Colubridae, Eulipotyphla, Mustelidae, Canidae(^4) – Accipitriformes, Falconiformes(^5)</td>
<td>Sudarikov (1959a)</td>
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<tr>
<td><em>Alaria alata</em> (Goeze, 1782), msc.</td>
<td>Planorbidae(^1) – Anura(^2) – frogs, snakes, crows, seagulls, ducks, owls, birds of prey, rodents, insectivorous and predatory mammals(^4) – Canidae(^5)</td>
<td>Potekhina (1950); Sudarikov (1959b)</td>
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<td><em>Rhabdias bufonis</em> (Schrank, 1788)</td>
<td>soil – oligochaetes, gastropods(^4) – Anura(^5)</td>
<td>Savinov (1963); Hartwich (1975)</td>
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<td><em>Oswaldocruzia filiformis</em> (Goeze, 1782)</td>
<td>soil – Amphibia(^3)</td>
<td>Hendrix (1983); Moravec &amp; Vojtkova (1975)</td>
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<td><em>Oxysoematium brevicaudatum</em> (Zeder, 1800)</td>
<td>soil – Anura(^5)</td>
<td>Skrabin et al (1961); Moravec &amp; Vojtkova (1975)</td>
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<tr>
<td><em>Cosmocerca ornata</em> (Duiardin, 1845)</td>
<td>water – Anura(^5)</td>
<td>Kirillov &amp; Kirillova (2016); Kirillova &amp; Kirillov (2017)</td>
</tr>
<tr>
<td><em>Icosiella neglecta</em> (Diesing, 1851)</td>
<td>Ceratopogonidae(^1) – Ranidae(^5)</td>
<td>Desportes (1942); Sonin (1968)</td>
</tr>
<tr>
<td><em>Thominx filiformis</em> (Linstow, 1885)</td>
<td>oligochaetes(^1) – <em>Triturus cristatus</em>(^5)</td>
<td>Skrabin et al (1957)</td>
</tr>
</tbody>
</table>

Note: 1 – intermediate host; 2 – intercalary host; 3 – additional host; 4 – paratenic host; 5 – definitive host.
Helminths of amphibians from beaver ponds of the «Smolny» National Park

<table>
<thead>
<tr>
<th>Helminths</th>
<th>Pond an Kuznal stream (I)</th>
<th>Pond in vicinity of the village Lesnoy (II)</th>
<th>Pond an Kuzoleika River (III)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pelophylax lessonae</td>
<td>Pelophylax lessonae</td>
<td>Pelophylax lessonae</td>
</tr>
<tr>
<td></td>
<td>Rana arvalis</td>
<td>Rana temporaria</td>
<td>Rana arvalis</td>
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<td></td>
<td>Rana temporaria</td>
<td>Rana temporaria</td>
<td>Rana temporaria</td>
</tr>
<tr>
<td></td>
<td>Triturus cristatus</td>
<td>Bufo bufo</td>
<td>Rana arvalis</td>
</tr>
<tr>
<td>G. asiatica</td>
<td>2.70(1)0.03</td>
<td>7.69(1-3)0.15</td>
<td></td>
</tr>
<tr>
<td>G. microovata</td>
<td>2.70(2)0.05</td>
<td>11.54(1-2)0.19</td>
<td></td>
</tr>
<tr>
<td>P. variegatus</td>
<td>16.22(1-4)0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. confusus</td>
<td>13.51(1-4)0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P. claviger</td>
<td>2.70(1)0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O. ranar</td>
<td>5.41(1-2)0.08</td>
<td>3.85(1)0.04</td>
<td></td>
</tr>
<tr>
<td>P. medians</td>
<td>8.11(1-27)0.78</td>
<td></td>
<td></td>
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<tr>
<td>D. subclavatus</td>
<td>2.70(1)0.03</td>
<td>6.25(1)0.06</td>
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<td>P. cloaciloca, mtc.</td>
<td>6.25(2)0.13</td>
<td>1(1)</td>
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<td>S. strigis, mtc.</td>
<td>2.70(5)0.14</td>
<td>7.69(1-3)0.15</td>
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<tr>
<td>S. spheurula, mtc.</td>
<td>2.70(1)0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. falconis, mtc.</td>
<td>2.70(1)0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. alata, msc.</td>
<td>8.11(1-35)1.05</td>
<td>12.50(1-22)1.44</td>
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<tr>
<td>Rh. bufonis</td>
<td>18.75(1-1)0.19</td>
<td>1(1)</td>
<td></td>
</tr>
<tr>
<td>O. filiformis</td>
<td>5.41(1-1)0.05</td>
<td>1(1)</td>
<td></td>
</tr>
<tr>
<td>O. breviceautatum</td>
<td>8.11(1-7)0.24</td>
<td>12.50(1-2)0.19</td>
<td></td>
</tr>
<tr>
<td>C. ornata</td>
<td>12.50(1-1)0.13</td>
<td>7.69(1-1)0.08</td>
<td></td>
</tr>
<tr>
<td>I. neglecta</td>
<td>37.84(1-18)1.89</td>
<td>12.50(2-7)0.56</td>
<td></td>
</tr>
<tr>
<td>Th. filiformis</td>
<td></td>
<td>30.77(1-7)0.62</td>
<td></td>
</tr>
</tbody>
</table>

| Chromadorea | 3 | 5 | 3 | 3 | 1 | 2 | 3 | 3 | 1 |
| Dorylaimea | 37 | 16 | 11 | 27 | 1 | 2 | 1 | 16 | 2 |

Note: prevalence (P, %) is in front of round brackets; intensity range (R, specimens) is in round brackets; abundance (A, specimens) is behind the round brackets; square brackets show the number of helminth species at the larval stage. Infestation indicators were calculated for a sample of at least 15 amphibian specimens. In another case, the number of infected hosts and the intensity of the infestation are indicated.
Helminth species are distributed according to the degree of host specificity as follows: 15 species are widespread polyhostal parasites of amphibians, 3 species (trematodes Gorgodera asiatica Pigulevsky, 1945, G. microovata Fuhrmann, 1924 and nematode Icosiella neglecta (Diesing, 1851)) are specific, oligohostal parasites for frogs of the family Ranidae. The nematode Thominx filiformis (Linstow, 1885) is the only narrowly specific monohostal parasite of the crested newt.

Amphibians serve as the definitive hosts for 13 species of helminths that parasitize at the adult stage of development. For another 5 species of trematodes at the larval stage (Paralepoderma cloacicola (Lühe, 1909), mtc., Strigea strigis (Schrank, 1788), mtc., S. sphaerula (Rudolphi, 1803), mtc., S. falconis Szidat, 1928, mtc. and Alaria alata (Goeze, 1782), msc.), amphibians are intercalary (mesocercar), additional (metacercar), and/or paratenic (metacercar) hosts. Opisthioglyphe ranae (Frölich, 1791) combines different stage of development in the organism of amphibians, what characterizes them as amphixenic hosts.

There are three ecological groups of helminth species depending on the way of invasion, stage of development and specifics of the life cycle (Table 1).

Group I includes adult stages (maritae) of trematodes (8 species). They settle in the internal organs: the bladder (G. asiatica, G. microovata), lungs (P. variegatus), intestines (O. ranae, P. confusus, P. claviger, P. medians and D. subclavatus). Amphibians are infected with trematode maritae in a trophic way, consuming their additional (metacercar) hosts – aquatic invertebrates (insects, crustaceans, gastropods) and vertebrates (amphibian tadpoles).

The nematode Th. filiformis is very close to the group I. The life cycle of the parasite is not known. But the species of this genus are biohelminth, their development includes the obligatory participation of intermediate hosts – earthworms.

Group II includes larval stages (mesocercariae and metacercariae) of trematodes (5 species). They settle in the body cavity, on the walls of internal organs, mesentery and amphibian musculature. Infection with them occurs in two ways: for some species (Strigea), it is associated with the use of additional and/or paratenic hosts of the underlying trophic level; for others, it is a consequence of oral or percutaneous penetration of cercariae. Findings of trematodes larvae indicate the participation of different amphibian species as an additional and/or paratenic host in the circulation of predator parasites of higher trophic levels.

The nematode I. neglecta is very close to the group II. It belongs to biohelminths, its development goes on with the change of hosts. Invasive larvae after the death of intermediate hosts – woodlice – fall into the water, from where they percutaneously enter the amphibian body, followed by migration and settlement in the tissues of the throat, tongue and fascia of the femoral muscles.

Group III includes adult stages of nematodes of the geohelminth group (4 species). They settle in the internal organs: lungs (Rh. bufonis), intestines (O. brevicaudatum, O. filiformis and C. ornata). Infection with them is random and occurs when the host has oral and/or percutaneous contact with invasive larvae on land or in water.

Pelophylax lessonae had the largest number of helminth species (16 species); R. arvalis and R. temporaria had less helminth species: 8 and 7 respectively; B. bufo and T. cristatus had the smallest number of helminth species: 3 and 1 respectively. No helminths were found in L. vulgaris.

Pelophylax lessonae. Sixty-four specimens were examined from two beaver ponds: on the Kuznal stream (37) and near the Lesnoy village (27). Sixteen species of helminths were found: Trematoda (12) and Chromadorea (4) (Table 2). Fifteen species were found in green frogs on the Kuznal stream and 7 species – in the vicinity of the Lesnoy village. Trematodes both adults and larvae predominate in the composition of helminths. The long relation between of the P. lessonae with habitats creates optimal conditions for infection with trematodes that penetrate through food. Nematodes are mainly represented by adult stages from the group of geohelminths. Infestation of green frogs with helminths is generally low; the extent of infestation does not exceed 40%. The
nematode *I. neglecta* infected frogs the most (30.77-37.84%; 0.62-1.89 specimens). Among trematodes, *P. variegatus* is more common (11.54-16.22%; 0.19-0.24 specimen). Frogs from the population on the Kuznal stream are more infected with most helminth species than those from the population in the vicinity of the Lesnoy village (Table 2).

**Rana arvalis.** Nineteen specimens were examined from three beaver ponds: on the Kuznal stream (16), on the Kuzoleika river (2) and near the village Lesnoy (1). Eight helminth species were found: Trematoda (3) and Chromadorea (5) (Table 2). Nematodes from the group of geohelminths mainly dominate in *R. arvalis*. It is due to the terrestrial way of life of *R. arvalis*. Trematodas are mainly represented by larval stages and are rare parasites of this host. The infestation with marite trematodes is possible only in the spring during the breeding season but is limited to the “mating post”. The rate of infestation with most species of helminths is low. The most common nematode is *O. filiformis* (50.00%; 2.13 specimens); infection with other species does not exceed 20%. Concerning trematodas, mesocercariae *A. alata*, msc. is the most common (12.50%; 1.44 specimens) (Table 2).

**Rana temporaria.** Thirteen specimens were examined from two beaver ponds: on the Kuznal stream (11) and near the Lesnoy village (2). Seven helminth species were found: Trematoda (3) and Chromadorea (4) (Table 2). Composition and community structure of helminth species in *R. temporaria* are similar to those in *R. arvalis*. Nematodes from the group of geohelminths dominate. Trematodes are represented exclusively by larval stages. The “mating post” of the host prevents infection with marite trematodes during the breeding season. The rate of infestation with most species of helminths is low. The nematode *O. brevicaudatum* and mesocercariae trematodes *A. alata*, msc. Are more common than other species (Table 2).

**Bufo bufo.** Sixteen specimens were examined from the beaver pond on the Kuzoleika river. Three nematode species were found: Chromadorea (3) (Table 2). All of them are geohelminths. The presence or absence of nematodes are associated with the land – based way of life of the host. “Mating post” prevents infection with marite trematodes during the breeding season. The density of the frog’s skin and the poisonous secret of the skin glands prevent percutaneous penetration of cercariae. Infection of common toads with nematodes is high. *O. filiformis* occurs the most (100%; 11.69 specimens). *Rh. bufonis* (87.50%; 5.50 specimens) and *O. brevicaudatum* (62.50%; 2.19 specimens) occur less often (Table 2).

**Triturus cristatus.** One specimen was examined from the beaver pond near the Lesnoy village. Only one specimen of *Th. filiformis* from the class Dorylaimea was found (Table 2). This is a biohelminth transmitted through earthworms. Newts are unable to hunt large or fast prey due to their body structure and small mouth size. As a result, their main food in the terrestrial life phase is sedentary earthworms, slugs, and insect larvae.

Only two species of nematodes, *O. filiformis* and *O. brevicaudatum*, are most common for the amphibians of beaver ponds. They have been found in 4 species of tailless amphibians: *P. lessonae*, *R. arvalis*, *R. temporaria*, and *B. bufo*. Two more species of trematodes (*A. alata*, msc.) and nematodes (*C. ornata*) were found in all 3 frog species. Two species (*D. subclavatus, I. neglecta*) of helminths infect the *P. lessonae* and *R. arvalis*. Other two species (*P. cloacicola*, mtc., *Rh. bufonis*) infect the *R. arvalis* and *R. temporaria*. The remaining 11 species of parasitic worms had only one host.

The greatest variety of helminths was found in amphibians in the old and permanent beaver pond on the Kuznal stream (18 species). In the vicinity of the Lesnoy village, there were half as many helminth species in the pond restored by beavers (9 species). The abandoned pond on the Kuzoleika river had the poorest composition of helminths (4 species) (Table 2).

Out of the total number of helminths, only 2 nematode species were found in all localities: *Rh. bufonis* and *O. filiformis*. Another 8 species of trematodes (*G. microovata, P. variegatus, O. ranae, S. strigis*, mtc. and *A. alata*, msc.) and nematodes (*O.
brevicaudatum, C. ornata and I. neglecta) were found in two of the three studied ponds. The findings of the other 9 helminth species were very local.

Discussion. The helminth fauna of amphibians is formed during the implementation of their biological characteristics (way of life, food spectrum, stage of development, age, and gender) in their habitat (biotope) for a certain period. Each biotope also has its own unique set of biotic (composition of flora and fauna) and abiotic (terrain, microclimate, presence and nature of reservoirs, illumination, type of soil) factors (Rohde 1979; Aho 1990; Ruchin et al 2009; Hamann et al 2013; Chikhlyaev et al 2018a). Some of them change during different seasons (Vanderburgh & Anderson 1987; King et al 2008). These factors influence the formation of the amphibian population of beaver ponds and their helminth fauna.

When beavers start settling the pond, massive land amphibian species – R. arvalis and B. bufo – only appear there during the breeding season. The appearance of aquatic amphibian species at this stage is impossible due to the frequent erosion of dams and the lack of food supply. When beaver ponds become perennial with stable water levels and rich hydrobionts, green frogs and newts settle there (Dalbeck et al 2007; Dalbeck & Weinberg 2009; Bashinsky 2014). These processes are similar for ponds on the Kuznal stream and around the Lesnoy village. When the beavers leave, the dams gradually erode, the pond becomes shallow and may drain, forcing the aquatic amphibians to leave the habitat. Probably something similar happened at the beaver pond on the Kuzoleika river.

The helminth fauna of aquatic amphibian species, in particular green frogs (genera Pelophylax), is known to be the richest (Okulewicz et al 2014; Herczeg et al 2016; Chikhlyaev et al 2018b, 2019a, b; León-Règagnon 2019; Kuzmin et al 2020). Their dominant group of helminths is trematodes, whose life cycle includes a wide variety of species of hydrobionts (bivalves and gastropods, insect larvae and imagos, crustaceans, amphibian tadpoles). Therefore, the existence of trematodes directly depends on the presence and nature of the reservoir. Most nematodes species of amphibians are geohelminths. For them, the presence of land-dwelling hosts, such as brown frogs and toads, is the most important factor (Chikhlyaev & Ruchin 2014; Okulewicz et al 2014; Zhigileva & Kirina 2015; Chikhlyaev et al 2016, 2020; Korzikov & Aleksanov 2018; Kirillova et al 2020). Brown frogs and toads have a short-term connection with ponds only during the breeding season, and therefore they only temporarily depend on their condition. The dependence of nematodes on the state of reservoirs is even less, which explains their wide distribution.

Beavers have a positive effect on amphibians, but, on the contrary, their effect on helminths is negative. This is especially true for biohelminth (trematodes). On the one hand, mainly in green frogs, there is a generally low level of infestation with most helminth species. On the other hand, with the deterioration of beaver ponds, the species composition of helminths is impoverished due to the loss of certain species of trematodes, often at the marita stage. In a lowland and water-abundant pond on the Kuznal stream, 12 species of trematodes were found in the green frogs. In a percolating and went low pond, restored by beavers, only 4 species of trematodes were found near the village Lesnoy. Only 1 species was found in a channel pond, abandoned by beavers on the Kuzoleika river (Table 2), where green frogs were not found at all.

There are several probable reasons for the low infestation of amphibians with helminth in beaver ponds. First, the artificial nature of reservoirs affects since parasitic connections and systems there have not yet formed completely due to the absence of any invertebrates and/or vertebrate hosts of different ranks. Secondly, the special dynamics of the hydrological regime (fluctuation of the water level due to the break/repair of dams) has a negative impact both directly on the free-living invasive stages of helminths, and indirectly through the suppression of the vital activity of hydrobionts (intermediate hosts). Third, climate factors play an important role. For example, insufficient snow cover in winter and low precipitation in the summer 2020 led to shallowing of small rivers in the National Park “Smolny”.
Conclusions. The data obtained show that the composition and structure of the community of amphibian helminths inhabiting beaver ponds is according to the general parasitological rules on the influence of the host's habitat on its parasites. The state of the beaver pond, which determines the species composition of the amphibian population, plays a key role. The helminth fauna varies from the richest in long-term flooded ponds, where beavers regularly repair dams, to the poorest in shallowed and restored ponds. The disappearance of some of the hosts (green frogs) in ponds abandoned by beavers leads to a sharp decrease in the number of trematode species. Thus, the criteria “presence/absence of green frogs” makes it possible to determine the state of the beaver pond and the presence/absence of trematodes. Green frogs can be considered as a biological indicator of the helminth fauna structure in the amphibian population of beaver ponds.

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