

**FIRST RECORD OF *Moniliformis moniliformis* (Bremser, 1811)
(MONILIFORMIDA: MONILIFORMIDAE) IN MICE OF THE GENUS
Apodemus Kaup, 1829 (RODENTIA: MURIDAE) IN SERBIA**

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ABSTRACT. As a part of research activities focused on rodent helminth fauna in Serbia, over the previous decade, we registered the presence of a species with zoonotic potential, *Moniliformis moniliformis*, an acanthocephalan (or spiny-headed worm) intestinal parasite that primarily infects rats, mice, and voles. The adult form of the species *M. moniliformis* was found in the small intestine of a single striped field mouse (*Apodemus agrarius*) from Cer Mountain, and two individuals of the yellow-necked mouse (*Apodemus flavicollis*) from the localities of Donji Milanovac and Senokos. Another species of Acanthocephala, reported in earlier studies of *Spermophilus citellus* in Serbia, is *Macracanthorhynchus hirudinaceus*, which also has zoonotic potential. Data on human infection with the acanthocephalans are scarce worldwide, including Serbia, but they should not be ignored.

Key words: Acanthocephala, zoonoses, helminths, rodents, *Apodemus*.

The Acanthocephala is a diverse group of parasites comprising around 1100 species (MATHISON *et al.*, 2021), 30 of which are present in Serbia (ĐUROVIĆ, 2022). Their hosts are aquatic and terrestrial vertebrates, including humans (RIBAS and CASANOVA, 2006). Most acanthocephalan species are intestinal parasites of marine vertebrates (MATHISON *et al.*, 2016). Several species are of medical and veterinary significance, where heavy infections may cause morbidity and mortality (TEIMOORI *et al.*, 2011). Of the nine species that may cause acanthocephaliasis in humans, *Moniliformis moniliformis* (Bremser, 1811) and *Macracanthorhynchus hirudinaceus* (Pallas, 1781) are the most common and generally parasitize on terrestrial mammals (TEIMOORI *et al.*, 2011; MATHISON *et al.*, 2016; LOTFY, 2020; MATHISON *et al.*, 2021).

Moniliformis moniliformis is a cosmopolitan intestinal parasite of rodents (LYNGGAARD *et al.*, 2021), mostly mice, rats, and voles, with cockroaches and beetles acting as intermediate

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hosts (TEIMOORI *et al.*, 2011; SHIMALOV, 2018). Inside the intermediate host, the parasite goes through several larval stages, including acanthor, acanthella, and the infective cystacanth. LIBERSAT and MOORE (2002) showed that *M. moniliformis* presence affects the ability of cockroaches to successfully evade predators, a phenomenon that benefits the parasite by increasing the chances of the cockroach being eaten by the rodent definitive host, thereby completing the parasite's life cycle (LOTFY, 2020). The definitive hosts, including humans, are infected by ingesting insects carrying the cystacanth larva (MATHISON *et al.*, 2021). Amphibians and reptiles may act as paratenic hosts (LOTFY, 2020).

The aim of this study was to survey and record the occurrence of the zoonotic parasite species *M. moniliformis*, an intestinal acanthocephalan, within the rodent population in Serbia, with a concurrent focus on raising awareness regarding its potential implications for human health. Mice of the genus *Apodemus* Kaup, 1829 were sampled over several years, as part of research of small rodent helminth fauna from various localities in Serbia. The mice were captured with Longworth and snap traps, then taken to the Institute for biological research "Siniša Stanković" in Belgrade for genetic analysis. After the necessary organs were sampled, the mice with intestinal tract intact were transported to the Animal Ecology Laboratory of the Department of Biology and Ecology (University of Novi Sad, Faculty of Sciences). The mice were dissected, and their intestinal tract was removed, followed by the extraction of parasites as described in TOŠIĆ *et al.* (2022). Once helminth extraction was completed, the parasites were stored in 70% ethanol until the preparation of native and permanent slides for identification. The preparation of permanent slides followed the protocol given by TOŠIĆ *et al.* (2022), and identification of acanthocephalans was based on morphological characters and followed the keys by RYZHIKOV *et al.* (1979) and GENOV (1984).

Morphological identification confirmed the presence of *M. moniliformis* in one striped field mouse *Apodemus agrarius* (Pallas, 1771) from Cer Mountain and two yellow-necked mice *A. flavicollis* (Melchior, 1834) from Donji Milanovac and Senokos (Figure 1). The single parasite from the Senokos locality was successfully measured and photographed as native (Figure 2) and permanent slide (Figure 3). The individual from the said locality was a male, with a body length of 47.75 mm and a body width of 1.2 mm. The length of the unsegmented anterior end was 3.75 mm, and that of the posterior end was 10.05 mm. The average testicle length and width were 2.8 and 0.65 mm, respectively. The proboscis was destroyed or removed at some point between extraction and examination, preventing its measuring and description.

To the best of our knowledge, this paper represents the first published finding of *M. moniliformis* in *A. agrarius* and *A. flavicollis* in Serbia. The only officially published finding of *M. moniliformis* and *M. hirudinaceus* in Serbia is from the European ground squirrel *Spermophilus citellus* (ŠOTI *et al.*, 1979). According to RYZHIKOV *et al.* (1979), the definitive hosts of *M. moniliformis* are ground squirrels, jerboas, rats, mice (house, field, wood and yellow-necked), hamsters and their relatives, gerbils, and voles (bank and water). GENOV (1984) lists three *Apodemus* species (*A. agrarius*, *A. flavicollis*, *A. sylvaticus*) and the European ground squirrel as parasite hosts. SHIMALOV (2018) reported the presence of *M. moniliformis* in a single-field mouse in Belarus, and KACHAMAKOVA *et al.* (2023) recently found it in Bulgarian ground squirrels. In addition to rodents, cats, and dogs (SALEHABADI *et al.*, 2008), mustelids also act as definitive hosts (SHIMALOV, 2018). Infection with this parasite was found in black rats (*Rattus rattus*) and Norway rats (*R. norvegicus*) in Iran and Brazil (TEIMOORI *et al.*, 2011; GOMES *et al.*, 2020), bats in Brazil (PORTES SANTOS and GIBSON, 2015), as well as various rodent species in Egypt and hedgehogs in Tunisia (WARD and NELSON, 1967).

Acanthocephaliasis in humans is most often diagnosed by confirming the presence of eggs or adults in the stool. Although acanthocephalan eggs are not commonly encountered in practice, they have a specific morphology that should attract attention and point towards more detailed examination (MATHISON *et al.*, 2021).

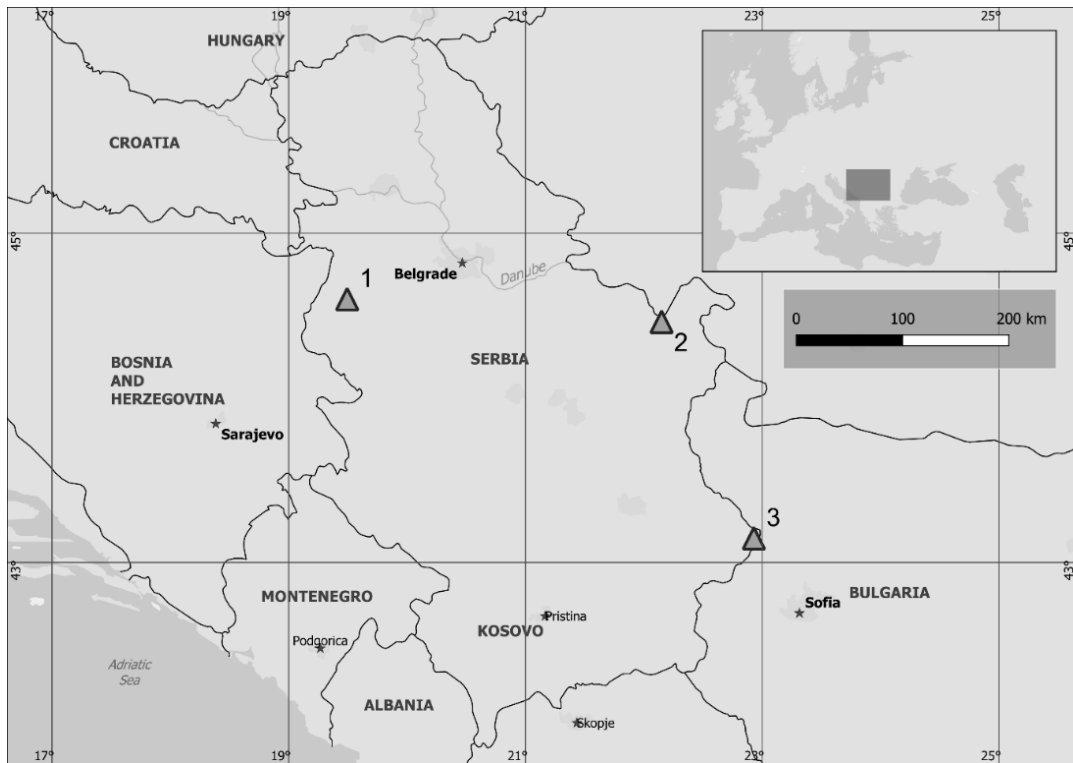


Figure 1. The map of Serbia showing sampling sites of the *Apodemus* mice infected with *M. moniliformis*. The position of the main map area within Europe is highlighted in the inlay map (top right). 1 – Cer Mountain; 2 – Donji Milanovac; 3 – Senokos.

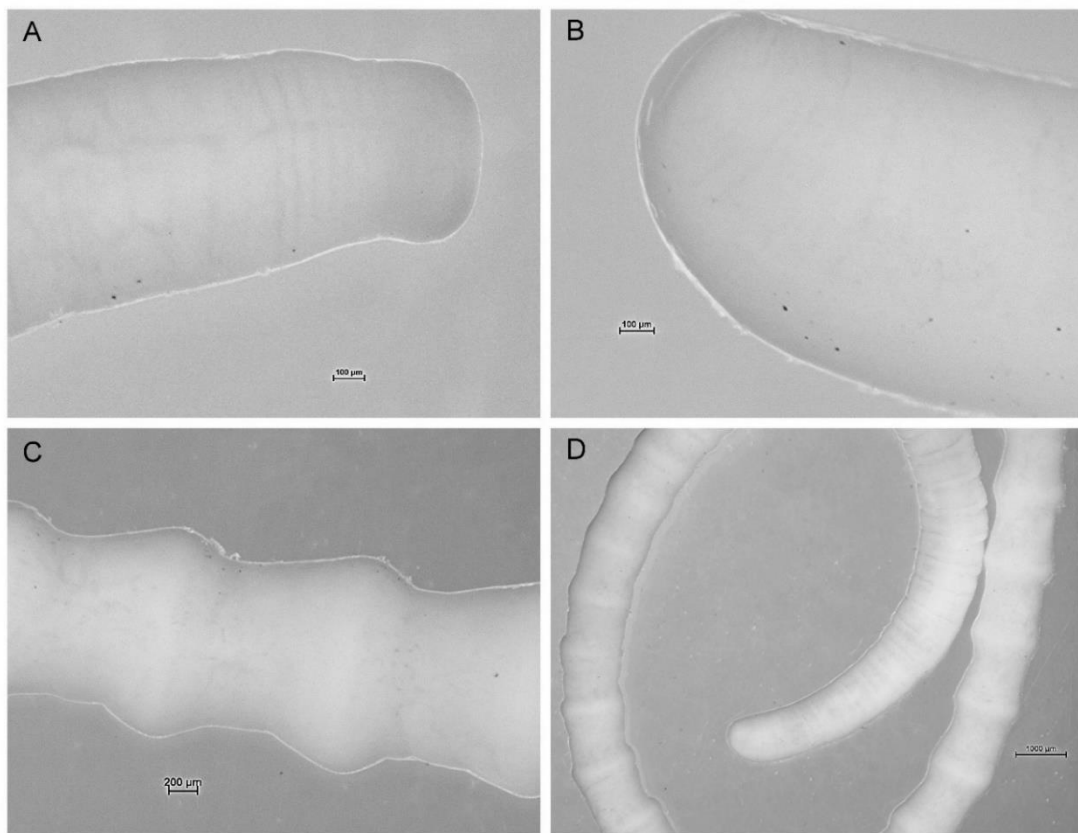


Figure 2. Adult male of *M. moniliformis*. A – anterior body part, B – posterior body part, C – pseudosegmentation, D – posterior body part with superficial pseudosegmentation. Images were taken with a stereomicroscope under magnification 1x (D) and 6x (A, B, C).

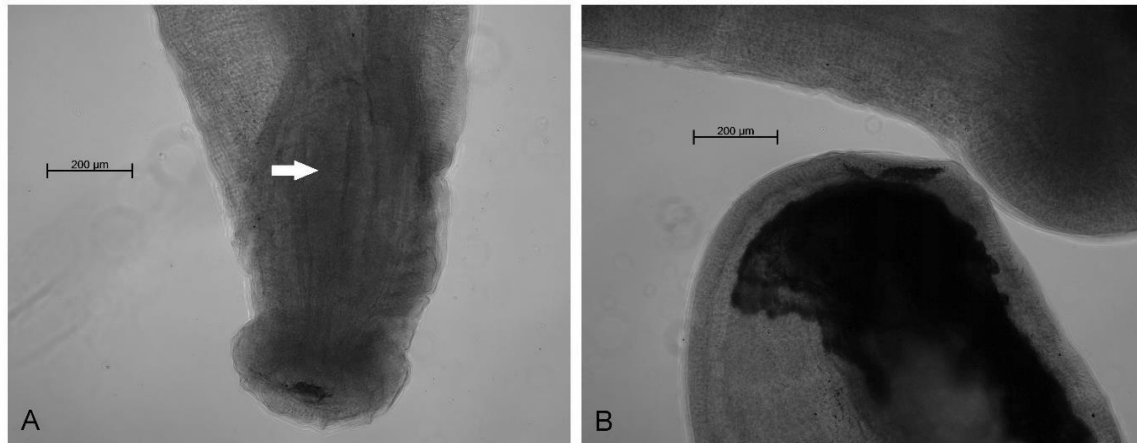


Figure 3. Adult male of *M. moniliformis*. A – anterior body part (white arrow shows proboscis - receptaculum), B – posterior part of the body. Magnification 10x.

Currently, there are no available routine serological or molecular tests for acanthocephaliasis diagnosis in humans (MATHISON *et al.*, 2016). Symptoms of infection with *M. moniliformis*, when they occur, include loss of appetite and body mass, strong abdominal pain, diarrhea, fever, vomiting, irritability, weakness, and cough (BERENJI *et al.*, 2007; LOTFY, 2020).

Several cases of human infection with *M. moniliformis* were reported in Iran (SAHBA *et al.*, 1970; BERENJI *et al.*, 2007; SALEHABADI *et al.*, 2008; MARAGHI *et al.*, 2014), Saudi Arabia (SAHAR *et al.*, 2006), Iraq, Australia, Nigeria, Zimbabwe, USA (Florida), Colombia, Italy, Egypt, Nigeria, Sudan, Russia, Israel, and Bangladesh (MATHISON *et al.*, 2021). There are no recorded cases of human acanthocephaliasis in Serbia, which should not diminish the fact that the parasite is present in rodent populations from several localities in the country. Continuous monitoring of small rodent helminth fauna is necessary, not only for the presence of *M. moniliformis*, but also other zoonotic helminths that have already been reported in the country.

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