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THE EPIZOOTIOLOGICAL ROLE OF RODENTS IN THE TERRITORY OF SERBIA

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Summary

Rodents host a variety of parasitic worms that often cause diseases in animals and humans, better known as helminths. A total of 47 helminth species in 10 rodent hosts from 15 sites have been noted in the territory of Serbia: three species of flukes, 13 species of tapeworms, two species of spiny-headed worms and 29 species of roundworms. Of the tapeworms, *Hymenolepis fraterna* infected the most host species (6) at the highest number of sites (5). Among roundworms, the species found in the largest number of host species (5) and sites (13) was *Heligmosomoides polygyrus*. Other widely distributed roundworms were *Syphacia stroma* (four host species, 12 sites) and *S. frederici* (three host species, 10 sites). The sites with the highest diversity of rodent helminths were the Belgrade area, Fruška gora mountain and Zasavica. Eleven parasite species, among them *Hymenolepis nana*, *H. diminuta*, *Calodium hepaticum* and *Hydatigera taeniaeformis*, are potentially zoonotic. Future studies must include more sites and potentially invasive and invasive host species. Parasites such as *Echinococcus multilocularis*, *Alaria alata* and *Trichinella* sp. deserve special attention: they have been reported in Serbia from non-rodent hosts, but their life cycles include rodents. Indicating the presence of a particular zoonotic group or species in rodents and defining their distribution and prevalence builds a foundation for quantitative and qualitative analyses necessary to monitor agents of zoonosis. Information on infection prevalence in natural reservoirs, urban environment contamination and frequency of human infection is integrated under the One Health approach.

Key words: flukes, tapeworms, nematodes, acanthocephalans, zoonoses

Introduction

Over 40% of mammal species are rodents. Members of this order are characterised by high biotic potential and live on all continents except Antarctica in virtually every type of habitat. Many rodent species live close to human populations and directly influence them and their domestic animals. By using large quantities of food and destroying material and cultural goods, rodents cause visible damage. However, special attention must be given to their role in carrying and transmitting pathogens that cause zoonotic diseases, many of them lethal. Zoonoses are diseases of animals and people that are transmitted between animals or from animals to humans either directly, via vector or through contaminated environments. Rodents play an important part as sources and natural reservoirs of these pathogens: they are commonly asymptomatic carriers that contribute to the maintenance of natural disease hotspots. Rodents transmit viruses, rickettsia, bacteria, protozoa and fungi that cause diseases such as haemorrhagic fever, leptospirosis, bubonic plague, typhus, salmonellosis and leishmaniasis. In fact, it is because of rodents that these diseases are still widely distributed and have a high lethality: more lives were lost to rat transmitted typhus and plague than to every war and revolution waged by humanity [1].

In addition to microorganisms, rodents host a variety of helminths parasitising on animals and humans. Helminths may be specific to a single host species, but they can also infect many different species that can be closely or distantly related. They are defined as non-segmented parasitic worms, which includes species of the phyla Platyhelminthes (flatworms: flukes and tapeworms), Nematoda (roundworms) and Acanthocephala (spiny-headed worms or acanthocephalans). While some helminths do not make their presence known in the host, many cause diseases in animals and humans. Some of the most important diseases in the Palearctic region are caused by *Echinococcus multilocularis*, *Calodium hepaticum*, *Hymenolepis nana*, *H. diminuta*, *Taenia taeniaeformis* and *Trichinella spiralis* [2], parasites that use rodents as intermediate, paratenic or definitive hosts. Over 1.5 billion people and various wild mammal species are estimated to be infected with at least one intestinal helminth species. The high prevalence of these parasites is possibly related to their longevity in the intestinal tract (chronic infection) and the host's inability to prevent re-infection [3]. Coevolution of host and parasite has led to the development of mechanisms that reduce the negative effect of helminths on the host, generally termed disease tolerance [4].

Forest cover in Serbia is 29.1%, around 80% of which constitutes beech and oak woodland with a well-developed herbaceous cover (primarily in the mountains south of the Danube and Sava rivers); such forests are ideal habitats for many rodent species. The remaining 25% of Serbia's territory in the north is occupied by the Pannonian basin containing alluvial plains, loess plateaus and island mountains (Fruška gora – 538 m and Vršac mountains – 639 m). The landscape of this region, also known as Vojvodina, is made up of fragmented forests, flooded meadows, pastures and agricultural land. Additionally, Serbia has abundant water resources including rivers, natural and artificial lakes and wetlands, which altogether makes the country an important hotspot of rodent diversity. These conditions are also beneficial for helminths, creating an environment where they can complete their life cycles.

Studies of helminth fauna in Serbia intensified in the 1970s and 80s, only to be put on hold and then continued in the second decade of the 21st century. A legal document (Policy on monitoring of zoonoses and causative agents of zoonoses – Official Gazette of the Republic of Serbia 76/2017) supports inter-sectoral cooperation in the surveillance of zoonoses, as part of the One Health approach. This chapter offers a review of the known helminths of rodents in Serbia, organised by hosts and sites, aiming to contribute to both biological research and interdisciplinary cooperation in line with the Policy and One Health approach.

Review of rodent helminth fauna in the territory of Serbia

In the following section, we present a review of helminths of 10 rodent species in Serbia, including hosts identified only to genus level (*Apodemus*).

In Vojvodina, hosts were sampled from nine sites: Zasavica, Fruška gora mountain, Kamarište, Čelarevo, Obedska bara pond, the vicinities of Zrenjanin, Sombor and Kikinda, as well as agricultural areas. South of the Sava and Danube rivers, hosts were sampled in the Belgrade area and Avala, Cer and Liškovac mountains. One of the papers used for this review lists only "mountainous region of Serbia" as the sampling site, whereas European ground squirrel data lists only Serbia.

A total of 47 helminth species from three phyla are listed. The flatworms include three species of flukes and 13 species of tapeworms, four of which were present as larvae. The roundworms were the most numerous group with 29 species, whereas spiny-headed worms were represented by two species (Table 1).

Small mammal helminth fauna was analysed on 11 sites from three typical habitats near the Tisza river. The host sample included 8 rodent species, with *Apodemus agrarius*, *A. sylvaticus* and *Microtus arvalis* being most numerous. While parasites were not identified to species level, average infection prevalence was 66%. Three groups of helminths were registered – flukes, tapeworms and roundworms, the latter being the dominant group [5].

Flukes

Plagiorchis elegans is a parasite of insectivores and rodents [21]. Snails and mosquito larvae serve as the first and second intermediate host respectively. In Serbia, it was reported from Zasavica and Kamarište. There is interesting research on the ability of the fluke to reduce fecundity and survival of an atypical snail host and stimulate immunity and resistance to a different parasite [22]. Because of its effect on intermediate hosts, *P. elegans* is proposed as a biological control agent for disease vectors such as snails and mosquitoes [23].

Flukes of the genus ***Brachylaima*** were found in the striped field mouse on the Zasavica site. The genus itself is distributed worldwide. The species *B. cribbi*, described from Australia, is highly euryxenous, parasitising on rodents, lizards, birds and humans [24]. High infection rate of snails (*Cornu aspersum*) which host fluke metacercariae was reported from Spain [25] and France [26]. Humans are infected by consuming improperly cooked snails, but also vegetables covered with mucus left by snails with viable metacercariae. The flukes mature in the digestive tract of the human host and cause brachylaimiasis. Rodents, which act as definitive hosts of *Brachylaima* species, can be considered as natural reservoirs of the parasite. By passing the fluke's eggs into the environment via faeces, they begin the chain of contamination that leads to snails and humans.

Fasciola hepatica was reported from European ground squirrels in Serbia [8]. This fluke causes fasciolosis, a widespread disease of domestic animals, particularly sheep, goats, cattle and, to a lesser extent, pigs. Mortality is high, especially in sheep. Wild herbivores are also susceptible: in Vojvodina, deer were found to be infected in many hunting areas [27]. Globally, human fasciolosis is on the rise, with two case studies published in Serbia [28, 29]. Although rodents do not play a large role in the epidemiology of this disease, *F. hepatica* was found in black rats and house mice on Corsica [30, 31], whereas the nutria acts as a reservoir in other parts of France [32]. Considering the increase of nutria populations in Serbia (pers. comm.), this rodent species and its parasites warrant further attention.

Tapeworms

Tapeworms of the family **Hymenolepididae** (Cyclophyllidea) are widespread parasites of birds and mammals in the Palearctic, Nearctic, Ethiopian and Oriental regions [33]. In Serbia, they have been reported from five sites and seven host species (Table 1). Certain rodent hymenolepidids are zoonotic and can cause serious diseases in immunocompromised people [34]. In medical terms, the most important species are *Hymenolepis diminuta* (rat tapeworm) and *H. nana* (=*H. fraterna*, dwarf tapeworm) which have various rodents (most often rats and mice) as definitive hosts, and beetles (*Tenebrio*, *Tribolium*), flies and other insects as intermediate hosts [35, 36]. *Hymenolepis* (*Rodentolepis*) *straminea* and *H. asymmetrica* are characteristic of rodents [7, 10, 11, 35, 37].

Species of the genus ***Paranoplocephala*** (Anoplocephalidae) are wide-ranging intestinal parasites of voles in the Holarctic. They are practically exclusive parasites of the genus *Microtus* [38, 39]. Aside from voles, *P. omphalodes* was found in the European hamster (*C. cricetus*) in Hungary [40]. In Serbia, this tapeworm infected two host species in Vojvodina (Table 1).

The genus ***Catenotaenia*** strictly includes intestinal parasites of myomorph, sciurimorph and castorimorph rodents. *Catenotaenia pussila* is a common and specific intestinal parasite of the house mouse (*M. musculus*) [41], although it occurs in other rodents [42]. *Catenotaenia henttoneni* is a wide ranging and relatively common parasite of the bank vole (*M. glareous*) in Europe [41].

Skrjabinotaenia lobata most frequently parasitises in the wood mouse *A. sylvaticus* [43], from which it was recorded at Zasavica. It infects other rodent species such as the striped (*A. agrarius*), yellow-necked (*A. flavicollis*) [35] and house mouse (*M. musculus*) [44]. This tapeworm can absorb heavy metals such as lead and is a potential bioindicator of environmental heavy metal pollution [43].

The cosmopolitan species ***Hydatigera taeniaeformis* (syn. *Taenia taeniaeformis*)** uses rodents as its intermediate hosts, which are infected by consuming eggs from the environment. A cyst (strobilocercus) containing a tapeworm larva (*Strobilocercus fasciolaris*) is then formed on the rodent's liver. Wild and domestic cats and other carnivores are infected after eating an infected rodent [45, 46]. Humans act as accidental hosts [47]. This tapeworm parasitises on a range of rodent species worldwide [48]. In Serbia, its cysts were found in the house and yellow-necked mouse.

Adult tapeworms of the genus ***Mesocestoides*** are intestinal parasites of carnivores (dogs, cats, mustelids) and less commonly predatory birds. *Mesocestoides* species are important in human and veterinary medicine. Aside from carnivores, these tapeworms often infect primates, with sporadic human infections [49]. Two cases of *M. lineatus* infection in humans were described in Korea [50]. The larva (tetrathyridium) occupies the body cavity of the intermediate host – a rodent, reptile or bird [51]. *Mesocestoides lineatus* larvae were found in rodents all over Europe, except for the Italian peninsula [52]. In Serbia, larvae were reported from the bank vole and European hamster in Vojvodina.

The definitive hosts of ***Taenia martis*** are martens, particularly the beech marten (*Martes foina*), whereas rodents are intermediate hosts (voles, mice, squirrels, muskrat). This tapeworm is widely distributed in central Europe [53]. In Serbia, its larvae were registered in the bank vole at Fruška gora. The zoonotic potential of *T. martis* is now considered to be significant, due to the higher number of human cases and fatal infections in other primates [54]. Equally zoonotically significant is ***T. crassiceps***, which causes cysticercosis in humans and has a wide range in the northern hemisphere. Foxes, jackals, wolves, dogs, cats and mustelids are its definitive hosts, and muskrats, voles, mice and moles serve as intermediate hosts [53]. It was found in European ground squirrels in Serbia. The most common definitive hosts of ***T. polyacantha*** are foxes and other canids, whereas its most common intermediate hosts are voles, especially the bank vole [55] in which it was found in Fruška gora. The listed *Taenia* species are sympatric with *E. multilocularis* in the greater part of its range, which spans throughout northern Eurasia, south of the tundra belt [56].

Roundworms

Trichuris muris infects a wide range of host species, including those from the genera *Apodemus*, *Mus*, *Rattus*, *Microtus*, *Myodes* and *Arvicola* [21]. This roundworm causes a strong immune response in its host and is often eliminated before maturation. Its presence in various hosts suggests that there is an infection threshold, below which an immune response is absent. Species of the genus *Trichuris* are frequently used in immunological research aimed at treating autoimmune diseases.

Capillaria (Aonchotheca) murissylvatici is a widely distributed species in Europe. It is a typical parasite of voles but has also been recorded in *Apodemus* mice and rats [21, 57-59]. The species ***Aonchotheca annulosa*** is a common intestinal parasite of numerous European rodents, but it has been found in certain insectivorous mammals as well as captive monkeys, which is a potential threat to endangered species. The possibility of transmission to zoo employees cannot be excluded [60].

Within the genus *Eucoleus* there are no adequate morphological criteria for discriminating between the two species that commonly infect rodents, ***E. gastricus*** and ***E. bacillatus***, making identification difficult; indeed, it is possible that they represent a single species [61]. *Eucoleus gastricus* is generally reported as a parasite of *Rattus* species [62]. Certain authors claim that *Eucoleus* roundworms are specific parasites of murine rodents [63], while others report them from arvicoline rodents as well [58].

Calodium hepaticum (syn. *Capillaria hepatica*) causes the zoonotic disease capillariasis. The parasite has been found in more than 60 countries throughout Europe, North, Central and South America, Asia, Africa and Oceania, and its main hosts are rodents of the superfamily Muroidea. *Calodium hepaticum* infects the liver of the host and can be found in numerous mammals, including humans, rabbits, dogs, cats and cattle [64]. Humans are accidental hosts, with less than 50 cases reported per year [65]. Poor hygiene, bad living conditions and cohabitation of domestic animals and rodents act together to create predisposition for capillariasis [66]. While the disease is spread worldwide, it is most common in tropical and temperate areas [67].

Boreostrongylus minutus is a widespread roundworm and a frequent parasite of rodents in humid lowland or alpine areas. Its low host specificity means it is categorised as a polyxenous parasite [21].

Gastrointestinal roundworms of the genus ***Heligmosomoides***, which includes four species found in Serbia, are rodent parasites that can be considered as founders of helminth communities in hosts due to their strong immunosuppressive effect [68]. *Heligmosomoides polygyrus* is a very common parasite of mice and voles in Europe and North America [69], while *H. travasossi* is a typical parasite of European hamsters (*C. cricetus*) [70]. *Heligmosomoides glareoli* is a specific parasite of voles, particularly *M. glareolus,* which was its host in Serbia; the species is widespread in Europe [21]. *Heligmosomoides laevis* is, based on available data, a parasite of voles which acted as its hosts in Serbia.

The genus ***Heligmosomum*** is represented by two species in Serbia. *Heligmosomum mixtum* is the most common helminth of *M. glareolus* [68, 71]; both host and parasite have a large range in the western Palearctic, excluding the Mediterranean biome [72]. In Serbia, *H. mixtum* was found in Fruška gora. The species *H. costellatum* is a common intestinal parasite of *M. arvalis* in central Europe [73], and generally infects Holarctic and Neotropical rodents [74]. It can be found in other vole species throughout Europe [75].

Nippostrongylus brasiliensis is a cosmopolitan species frequently found in rats (*R. rattus*, *R. norvegicus*), as well as mice (*M. musculus*) [76]. It is often used in laboratory studies due to its simple life cycle and the fact that it is related to *Ancylostoma duodenale,* which infects humans.

Species of the genus ***Syphacia*** (Oxyuridae, more than 39 species) are widespread intestinal parasites of rodents. As a result of coevolution with their rodent hosts, they display high host specificity. Commonly known as pinworms, they are perhaps the best studied parasites of laboratory rodents. *Syphacia stroma* and *S. frederici* are the best-known parasites of the wood and yellow-necked mouse in Europe [77]. Eight *Syphacia* species are known from Serbia; most of them were found in their typical hosts, with *S. stroma* and *S. frederici* being most common and infecting the most host species.

Aspiculuris tetraptera is a frequent intestinal parasite of the house mouse (*M. musculus*), but has been detected in other rodent species such as *M. glareolus* and *A. sylvaticus*. It is commonly found in laboratory mice and is regularly used in laboratory studies [78], with a high biomedical importance [79].

Heterakis spumosa is a parasite of *Apodemus* mice; it has also been found in *R. rattus* [80] and *R. norvegicus* [12, 58, 80].

In literature, ***Rictularia proni*** is almost exclusively listed as a parasite of *Apodemus* species [15, 21, 58, 81]. However, it has been reported in the bank vole in Serbia (Table 1).

Gongylonema longispiculum is a parasite of European ground squirrels (*S. citellus*) [82], as well as other rodents [83] and marsupials [84].

Mastophorus muris is a cosmopolitan parasite characterised by a high morphological variability, likely due to its wide range and low host specificity. Aside from domestic and wild rodents, it infects carnivores, marsupials, and even lemurs in Madagascar [85].

Streptopharagus kutassi is listed as a parasite of *Citellus fulvus* and *Meriones persicus* in Iran, and, more generally, as a common parasite of Gerbillinae and Sciuridae species from eastern Europe to central Asia [86]. It has also been found in the black rat (*R. rattus*) in Spain [87].

Spiny-headed worms

Spiny-headed worms or acanthocephalans are obligate parasites found in all vertebrate classes, especially fish and birds. ***Moniliformis moniliformis*** has been found in European ground squirrels and yellow-necked mice in Serbia (Table 1) and is potentially zoonotic. Humans are accidental hosts and are infected by eating insects which contain larvae. Inside the body, the larva does not mature or, if it does, does not produce eggs [20]. There is evidence that humans can be infected with at least nine spiny-headed worm species, most commonly with *M. moniliformis,* but also ***Macracanthorhynchus hirudinaceus*** [88] which has been reported from ground squirrels in Serbia.

Prospects of rodent helminth fauna research

In Serbia, various studies reported on the presence of medically important parasites whose life cycles include rodents. While none of these species have been found in Serbian rodents at the time of writing, they deserve attention in future studies of rodent helminth fauna.

Foxes in Vojvodina have been confirmed to be infected with ***Echinococcus multilocularis*** [89, 90], which implies that rodents, particularly voles, are also infected in this area. This also means that the environment is contaminated with fox faeces which contain tapeworm eggs. The range of *E. multilocularis* is spreading and human infections are on the rise. Since the parasite causes a dangerous disease – multilocular echinococcosis – studies of wild animals (intermediate and definitive hosts) are necessary to ascertain the situation in the field, forecast further spread of the disease and deploy preventive measures.

Rodents in Serbia are sporadically infected with ***Trichinella*** roundworms in the domestic and sylvatic cycles [91, 92]. Although rats are primarily infected, there is still debate whether they are reservoirs or victims of the disease; even if the latter is the case, they can still be infective if their corpses are eaten by pigs. Infected rats occur on farms where pigs are infected as well, and where dead animals are improperly disposed of so that rats can consume their remains [93, 94]. Rodents in general are vagile organisms that easily move from natural into urban environments and vice versa, emphasising the need to monitor *Trichinella* infection (especially near farms). Additionally, the example stresses the significance of proper disposal of dead animals and environmental protection, as the environment itself becomes a source of disease through human activity.

Alaria alata is a fluke that ranges throughout Europe. Its definitive hosts are foxes, jackals and other carnivores that release the eggs of the parasite through faeces. In Serbia (Vojvodina), the parasite has been found in foxes [89]. Its first and second intermediate hosts are snails and tadpoles or frogs, respectively. However, this fluke uses many paratenic hosts, including reptiles, birds, wild and domestic pigs, rodents and humans [95]. Mesocercariae of *A. alata* were found in domestic pigs and wild boars in Vojvodina. Alariosis can occur in humans after eating the meat of infected pigs. Studies have shown that mesocercariae can also be found in rodents, who should be monitored for the presence of *A. alata* [97]. Since the life cycle of the parasite is closely tied to aquatic habitats, which are numerous in Vojvodina, there is a clear need to continually monitor the parasite fauna of wild animals including rodents.

Table 1. An overview of helminth species registered in wild rodent populations in Serbia

Parasite species	Host	Site	Source
TREMATODES			
***Brachylaima* sp.**	*Apodemus agrarius*	Zasavica	[6]
Plagiorchis elegans	*A. agrarius* *Apodemus* sp.	Zasavica Kamarište	[6] [7]
Fasciola hepatica	*Spermophilus citellus*	Serbia	[8]
CESTODA			
Paranoplocephala omphalodes	*Arvicola amphibius*	Čelarevo	[9]
	Cricetus cricetus	Vojvodina (agrobiocoenoses)	[10]
Catenotaenia henttoneni	*Myodes glareolus*	Fruška gora	[11]
C. pusilla	*Mus musculus*	Belgrade	[12]
Skrjabinotaenia lobata	*Apodemus sylvaticus*	Zasavica	[6]
Hymenolepis asymmetrica	*M. glareolus*	Fruška gora	[11]
H. diminuta	*C. cricetus*	Vojvodina (agrobiocoenoses)	[10]
	Rattus norvegicus	Belgrade	[13]
	S. citellus	Serbia	[8]
H. fraterna	*A. sylvaticus*	Zasavica	[6]
	Apodemus sp.	Kamarište	[7]
	C. cricetus	Vojvodina (agrobiocoenoses)	[10]
	M. musculus	Belgrade	[12]
	R. norvegicus	Belgrade	[13]
	S. citellus	Serbia	[8]
Rodentolepis straminea	*A. sylvaticus, A. agrarius, Microtus* sp.	Zasavica	[6]
	Apodemus sp.	Kamarište	[7]
	C. cricetus	Vojvodina (agrobiocoenoses)	[10]
Taenia crassiceps	*S. citellus*	Serbia	[8]
***T. martis* (larva)**	*M. glareolus*	Fruška gora	[11]
***Hydatigera taeniaeformis* (*Cysticercus fasciolaris* larva)**	*A. flavicollis*	Avala	u.d.
	M. musculus	Belgrade	[12]

***Tetratirotaenia polyacantha* (larva)**	*M. glareolus*	Fruška gora	[11]
***Mesocestoides lineatus* (*Tetrathyridium baillieti* larva)**	*C. cricetus*	Vojvodina (agrobiocoenoses)	[10]
	M. glareolus	Fruška gora	[11]
NEMATODA			
***Trichuris muris* (*Trichocephalus muris*)**	*A. flavicollis*	Mountainous region of Serbia	[14]
		Fruška gora	[15]
		Obedska bara	[16]
		Avala, Liškovac	[17]
	A. sylvaticus	Sombor	[18]
		Zasavica	[6]
	A. amphibius	Čelarevo	[9]
	M. musculus	Sombor	[18]
		Belgrade	[12]
	M. glareolus	Fruška gora	[19]
	R. norvegicus	Belgrade	[13]
Capillaria* (*Aonchotheca*) *murissylvatici	*A. flavicollis*	Fruška gora	[15]
	A. sylvaticus	Zasavica	[6]
	M. glareolus	Fruška gora	[19][11]
Aonchotheca annulosa	*A. flavicollis*	Avala, Liškovac	[17]
		Obedska bara	[16]
	A. sylvaticus	Zrenjanin	[18]
***Eucoleus gastricus* (*Thominx gastrica*)**	*A. flavicollis*	Fruška gora	[15]
***Calodium hepaticum* (*Capillaria hepatica*)**	*A. flavicollis*	Belgrade	[20]
***Strongylus* sp. (larva)**	*R. norvegicus*	Belgrade	[13]
Boreostrongylus minutus	*A. amphibius*	Čelarevo	[9]
Heligmosomoides glareoli	*M. glareolus*	Fruška gora	[19][11]
H. polygyrus polygyrus	*A. flavicollis*	Mountainous region of Serbia	[14]
		Fruška gora	[15]
		Avala, Liškovac	[17]
		Obedska bara	[16]
	A. sylvaticus	Kikinda, Sombor, Zrenjanin	[18]
	Apodemus sp.	Kamarište	[7]
	M. musculus	Sombor, Zrenjanin	[18]
		Belgrade	[12]
	M. glareolus	Fruška gora	[11]
H. laevis	*A. amphibius*	Čelarevo	[9]
	Microtus arvalis	Kikinda, Sombor, Zrenjanin	[18]
H. travassosi	*C. cricetus*	Sombor, Zrenjanin	[18]
		Vojvodina (agrobiocoenoses)	[10]
Heligmosomum costellatum	*A. amphibius*	Čelarevo	[9]
	Microtus sp.	Zasavica	[6]
H. mixtum	*A. amphibius*	Čelarevo	[9]
	M. glareolus	Fruška gora	[19][11]
Nippostrongylus brasiliensis	*R. norvegicus*	Belgrade	[13]
Syphacia agraria	*A. agrarius*	Sombor, Zrenjanin	[18]
		Kamarište	[7]
S. arvicolae	*A. amphibius*	Čelarevo	[9]
S. frederici	*A. flavicollis*	Mountainous region of Serbia	[14]
		Fruška gora	[15]

		Cer, Avala, Liškovac	[17]
		Obedska bara	[16]
	A. sylvaticus	Kikinda, Sombor, Zrenjanin	[18]
	Apodemus sp.	Kamarište	[7]
S. muris	*R. norvegicus*	Belgrade	[13]
S. nigeriana	*M. arvalis*	Kikinda, Sombor, Zrenjanin	[18]
S. obvelata	*M. musculus*	Kikinda, Sombor, Zrenjanin	[18]
		Belgrade	[12]
S. petrusewiczi	*A. amphibius*	Čelarevo	[9]
	M. glareolus	Fruška gora	[19][11]
S. stroma	*A. amphibius*	Čelarevo	[9]
	A. flavicollis	Mountainous region of Serbia	[14]
		Fruška gora	[15]
		Kamarište	[7]
		Avala, Liškovac	[17]
		Obedska bara	[16]
	A. sylvaticus	Kikinda, Sombor, Zrenjanin	[18]
		Kamarište	[7]
	M. glareolus	Fruška gora	[19][11]
***Syphacia* sp.**	*A. sylvaticus, Microtus* sp.	Zasavica	[6]
	M. musculus	Belgrade	[12]
Aspiculuris tetraptera	*A. flavicollis*	Fruška gora	[15]
	M. musculus	Kikinda, Sombor, Zrenjanin	[18]
		Belgrade	[12]
	M. glareolus	Fruška gora	[19][11]
Heterakis spumosa	*A. agrarius*	Zasavica	[6]
		Kamarište	[7]
	A. sylvaticus	Zasavica	[6]
	A. amphibius	Čelarevo	[9]
	M. musculus	Belgrade	[12]
		Zasavica	[6]
	R. norvegicus	Belgrade	[13]
Rictularia proni	*A. agrarius*	Zasavica	[6]
	A. flavicollis	Mountainous region of Serbia	[14]
		Fruška gora	[15]
		Cer	[17]
	M. glareolus	Fruška gora	[11]
Gongylonema longispiculum	*S. citellus*	Serbia	[8]
***Gongylonema* sp.**	*M. musculus*	Belgrade	[12]
Mastophorus muris	*M. musculus*	Belgrade	[12]
Streptopharagus kutassi	*S. citellus*	Serbia	[8]
ACANTHOCEPHALA			
Moniliformis moniliformis	*S. citellus* *A. flavicollis*	Serbia	[8] [20]
Macracanthorhynchus hirudinaceus	*S. citellus*	Serbia	[8]

Conclusion

Forty-seven species of helminths from three phyla have so far been reported from Serbia. This total includes three species of flukes, 13 species of tapeworms, two species of spiny-headed worms and 29 species of roundworms. Among tapeworms, *H. fraterna* was present on the highest number of sites and infected six host species. Among roundworms, the species that infected the most host species and occurred on the most sites was *H. polygyrus*. Two more widely occurring roundworms were *S. stroma* (four host species, 12 sites) and *S. frederici* (three host species, 10 sites). Eleven parasite species are of medicinal and veterinary importance as potential sources of zoonoses.

Endoparasites are an integral component of their hosts' ecology and ethology. The significance of parasitological research comes from obtaining information on species ranges, infection intensity and parasite distribution, with special regard to species of medicinal or veterinary importance. Insight into the composition of endoparasite communities also contributes to knowledge on local and regional biodiversity.

Increased contact between domestic and wild animals and man has led to parasite exchange, mostly from animals to humans but also vice versa. Serbian experts on animal and human health have collaborated with the EU, WHO and OIE to define priority zoonotic diseases: brucellosis, echinococcosis, rabies, Q fever, tularemia, avian influenza, West Nile fever and haemorrhagic fever with renal syndrome. Rodents are natural reservoirs for most of these diseases; determining the presence, distribution and prevalence of pathogens in rodents is a necessary step in defining epizootic areas and monitoring zoonoses.

The distribution and prevalence of zoonoses does not simply reflect geographic and ecological circumstances, but also the level of dedication and resource allotment to disease prevention and control, both in infected human populations and their environment. The One Health approach connects information on infection prevalence in natural reservoirs, urban environment infection and human infection frequency with preventive and control measures such as education and diagnosis.

The findings presented in this chapter highlight a need to continue and broaden helminthological research, with emphasis on regular monitoring of rodent parasites. The approach needs to be expanded by including new study sites, introducing methods that detect helminths outside the intestinal tract and considering invasive (*Ondatra zibethicus*) and potentially invasive (*Myocastor coypus*) host species.

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