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SMALL MAMMALS AS RESERVOIRS OF TULAREMIA AND HFRS IN THE FOREST ZONE OF SARANSK

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Abstract

Small mammals are important reservoirs for zoonotic pathogens that cause significant morbidity in humans. Of these, tularemia and hemorrhagic fever with renal syndrome (HFRS) are among of the most widespread zoonotic diseases worldwide. Despite the fact that both pathogens have great epidemiological significance in Russia, epizootological data for urbanized areas are still scarce. This study was conducted to investigate the occurrence and prevalence of tularemia and hantaviruses in small mammals living in close proximity to humans. Altogether, 425 small mammals (278 from urban environment and 147 from natural environment) representing nine species (*Myodes glareolus, Microtus arvalis, Cricetus cricetus, Apodemus flavicollis, Apodemus agrarius, Apodemus uralensis*, *Mus musculus, Sorex araneus* and *Neomys fodiens*) were captured in the Russian Republic of Mordovia and screened for pathogens using different serological and bacteriological methods. Red bank vole (*M. glareolus*) and yellow-necked wood mouse (*A. flavicollis*) are among species in the forest zone of the city of Saransk and are the source of a number of zoonotic diseases. In the non-urban environment, the main role as carriers of zoonotic diseases was played by house (*M. musculus*) and striped field (*A. agrarius*) mice. A total of 23 % of the small mammals sampled in Saransk were positive for tularemia, whereas 9.7 % were positive for HFRS. Furthermore, dual infections with both tularemia and hantaviruses were shown in 1.4 % of animals, suggesting that the same small mammal host can be infected with several pathogens at the same time, therefore representing a serious threat to public health. Small mammal ecology is a primary determinant of zoonotic pathogens dynamics in rodent populations and the risk of pathogen transmission to people.

Key words: epidemiology, hantavirus, Mordovia, rodents, urbanization.

Introduction

It is known that epidemics coincide with urbanization, geographic expansion, and migrant movement over time (Taylor et al. 2008, Kang et al. 2012, Halliday et al. 2015, Houéménou et al. 2019). Research results in China revealed the interrelatedness of urbanization, migration, and hantavirus epidemiology, potentially explaining why urbanizing cities with high economic growth exhibit extended epidemics (Tian et al. 2018). However, different types of animals can act as carriers in different cities. For example, Urban Norway (*Rattus norvegicus* (Berkenhout, 1769)) and black (*Rattus rattus*) rats are reservoirs for a variety of zoonotic pathogens (Himsworth et al. 2015).

Republic of Mordovia in Russia is a historical focus for HFRS, tularemia and rabies (Boyarova et al. 2020). Among the small rodents in the wild natural environment, the red bank vole *Myodes glareolus* (Schreber, 1780), the common vole *Microtus arvalis* (Pallas, 1779) and the house mouse *Mus musculus* Linnaeus, 1758 play an important role as carriers of zoonotic diseases (Andreychev et al. 2019). One of our latest studies concluded that the forest dormouse *Dryomys nitedulla* (Pallas, 1779) in Mordovia was identified as a pathogen reservoir causing infectious diseases in humans (Andreychev and Boyarova 2020). However, this type of small mammal is found only in wild natural environment (Andreychev and Kiyaykina 2020, Andreychev and Kuznetsov 2020).

Most researchers of zoonotic diseases choose rats (Himsworth et al. 2013, 2014, 2015; Firth et al. 2014; Wang et al. 2017; Murray et al. 2020; Su et al. 2020; Yashina et al. 2021). This is of course logical, as there are quite a lot of rats. This is not the case in Saransk, so we assumed that the main vectors may be other small mammals (mice, voles, shrews). We set out to study these to determine their possible role in the transfer of zoonotic diseases in Saransk.

The purpose of this article is to highlight the role of small mammals as carriers or reservoirs of zoonotic diseases in the city forest zone. In addition to the main carriers in the natural environment, there is a high probability that other small mammals account for the circulation of zoonotic disease pathogens in urban environments.

Material and Methods

The work was carried out in the forest zone of Saransk and some districts of Mordovia (Fig. 1). The Republic of Mordovia is located in the centre of the European part of Russia. Its extreme points are defined by geographical coordinates 42º11' – 46º45' E and 53º38' – 55º11' N. The maximum distance from west to east is 298 km and the distance from north to south is 57 to 140 km. The area of the republic is 26,200 km^2. Features of the geological structure are determined by its location in the central part of Russian Platform and north-western slopes of Volga Upland. In the western part, Volga Upland reaches Oka-Don Lowlands (Yamashkin 1998, Andreychev 2017).

The work is based on the materials of our own surveys of rodents and insectivorous mammals conducted in the urban environments and natural environments of Mordovia, using traditional methods of trap lines and trap grooves (Karaseva and Telicina 1996). Field work was carried out during the snow-free period (May to November). The snap traps were set in the typical habitats of the small mammals for several days and then transferred to the next site. Their number in each line was 25. Traps were checked for material every morning. Bread soaked in sunflower oil was used as bait.

During the research period of 2020, a total of 425 specimens (278 from urban environments and 147 from natural environments) of the following rodents were trapped: red bank vole *M. glareolus* – 55.2 %, common vole *M. arvalis* – 6.4 %, common hamster *Cricetus cricetus* (Linnaeus, 1758) – 0.5 %, yellow-necked mouse *Apodemus flavicollis* (Melchior, 1834) – 9.9 %, Ural field mouse *Apodemus uralensis* (Pallas, 1811) – 3.8 %,

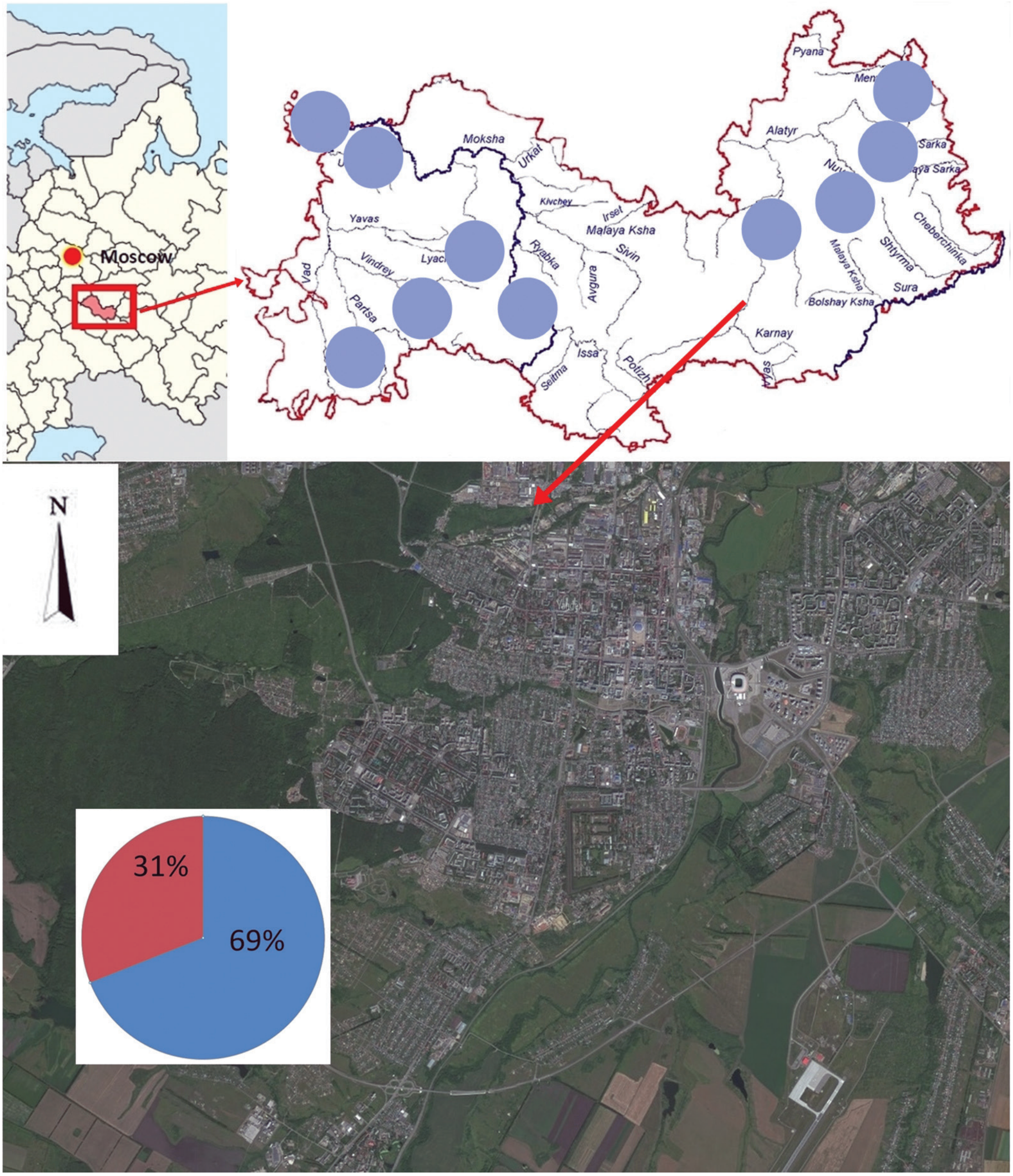

Fig. 1. Geographical position of Saransk.

Note: for the region, blue circles – collection points of the material, for the satellite image of city the red sector is the percentage of all infected (tularemia + HFRS) small mammals, the blue sector is the percentage of uninfected small mammals.

striped field mouse *Apodemus agrarius* (Pallas, 1771) – 11.8 %, house mouse *M. musculus* – 7.5 %, Eurasian common shrew *Sorex araneus* Linnaeus, 1758 – 4.7 %, and Eurasian water shrew *Neomys fodiens* (Pennant, 1771) – 0.2 %. The captured mammals were transported to the laboratory of the Center for Hygiene and Epidemiology of Republic of Mordovia. ELISA, using 'Huntagnost' test system for pathogen presence, was the main method used to detect HFRS antibodies in homogenized rodent organs (lung). Tests for tularemia were performed using a serological method.

Results and Discussion

A total of 23 % of small mammal samples in Saransk were positive for tularemia while a total of 9.7 % were positive for HFRS. Furthermore, dual infections with both tularemia and hantaviruses were detected in 1.4 % of animals, suggesting that the same small mammal host can be infected with several pathogens at the same time, therefore representing a serious threat to public health. In the natural (non-urban) habitat, only house mouse and striped field mouse were infected with HFRS (Table 1).

Comparing the range of mouse rodent species infected with tularemia in urban environments with data obtained for natural environments in previous years (Andreychev and Boyarova 2020), a similar pattern was noted insofar as red bank vole played a primary role as carrier of this disease (75 % in urban environments compared to 42 % in natural ones). Yellow-necked mouse, ranked second in urban environment for presence of tularemia bacteria (25 %). In natural environment of Mordovia, Ural field mouse was found positive for the same bacteria (25 %).

Comparing results obtained in urban environments for mouse rodent species infected with HFRS (Table 1) with data obtained for natural environments in previous years (Andreychev and Boyarova 2020), it should be noted that while red bank vole was primary in urban environments – 85 %, house mouse was primary in natural environment – 41 %. *A. flavicollis* ranked second in urban environments for presence of HFRS (15 %); and red bank vole (23 %) and common vole (23 %), were found positive for HFRS in natural environment.

Table 1. Small mammal population structure involved as reservoirs of tularemia and HFRS in urban and non-urban environments in 2020.

Species	City of Saransk				Other districts			
	n_{urban}	TUL	HFRS	TUL + HFRS	$n_{non\text{-}urban}$	TUL	HFRS	TUL + HFRS
Myodes glareolus	219	48	23	4	16	0	0	0
Microtus arvalis	2	0	0	0	25	0	0	0
Cricetus cricetus	1	0	0	0	1	0	0	0
Apodemus flavicollis	30	16	4	1	12	0	0	0
Apodemus uralensis	2	0	0	0	14	0	0	0
Apodemus agrarius	10	0	0	0	40	0	1	0
Mus musculus	1	0	0	0	31	0	3	0
Sorex araneus	12	0	0	0	8	0	0	0
Neomys fodiens	1	0	0	0	-	-	-	-

Note: n_{urban} – number of specimens from Saransk, $n_{non\text{-}urban}$ – number of specimens from natural environments, TUL – number of positive tests for tularemia, HFRS – the number of positive tests for HFRS, TUL+HFRS – simultaneous detection of positive tests for tularemia and HFRS.

Our study also showed that in 2020, some striped field mice in natural environment were infected with HFRS, which confirmed that this species may be active in the epizootic process in Mordovia (Trankvilevsky et al. 2007, 2011).

Suburban forest zone of Saransk in 2020 was potentially dangerous in relation to zoonotic diseases. It is known that HFRS and tularemia are widespread in many other Russian cities as well. The increase in the incidence of HFRS in Voronezh Region took place in 2007 when 154 people were infected. More than 50 % of cases involved people who were infected in the city (Gaponov 2017).

We also compared our results with the infection rates of small mammals in urban environments of Switzerland (Adler et al. 2002), where there is also a significant proportion of infected small mammals from the genera *Apodemus* and *Myodes*.

The large proportion of yellow-necked mice testing positive for zoonotic diseases in urban environments of Mordovia is understandable, since scientists have previously noted their role as carriers in other countries. Dobrava–Belgrade virus strain (DOBV) which causes HFRS in humans has been found in *A. flavicollis* (Weidmann et al. 2005). A previous study in Greece showed that approximately 10 % of *A. flavicollis* carried DOBV (Papa et al. 2000). In Albania, it was identified as primary reservoir causing HFRS in humans (Rogozi et al. 2013, Papa et al. 2016). In Slovenia, the yellow-necked mouse, the striped field mouse (*A. agrarius*), and the red bank vole (*M. glareolus*) were all found to play an important role in zoonotic circulation of HFRS (Stanko et al. 2004). Positive results for tularemia in the Republic of Moldova were recorded in species *M. glareolus, A. flavicollis* and *A. uralensis* (Chicu et al. 2010). Thus, the yellow-necked mouse may be one of the most important carriers of zoonotic diseases. However, in Mordovia, it is in urban environments that its role has become more pronounced. This may be due to the smaller distribution across the region of other mouse species (*A. uralensis, A. agrarius*) (Andreychev 2020).

Our data on the higher incidence of double infections in small mammals in urban environments of Saransk are consistent with the results from Hungary. Dual infections with both *Leptospira* spp. and hantaviruses were shown in 2.6 % of mammals (Kurucz et al. 2018).

Conclusions

There are clear differences in the role played by different small mammal species as reservoirs for zoonotic pathogens in the forest zones of urban environments versus the non-urban environments of Mordovia. The importance of red bank vole and of yellow-necked mouse in urban environments and of house mouse and striped field mouse in non-urban environments in relation to zoonotic diseases was confirmed. In addition, evidence of dual infection by tularemia and hantavirus was found, suggesting that the same small mammal host can be infected with several pathogens at the same time, therefore representing a serious threat to public health.

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