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Article

Eastward range expansion of yellow-necked mouse *Apodemus flavicollis* Melchior, 1834

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Abstract. Yellow-necked mouse *Apodemus flavicollis* Melchior, 1834 is a typical representative of nemoral plant communities. Until recently, the Iremel Ridge (N 54°32'00" E 58°50'00"; Chelyabinsk Oblast, Russia) was considered the eastern margin of the species range. Since 2014, yellow-necked mouse specimens are being captured 80–120 km east of its accepted range margin in uncharacteristic habitats with unusual feeding conditions. Mastering new territories by yellow-necked mouse is likely related to climate change in recent decades.

Keywords: Southern Urals, Ilmeny State Nature Reserve, Chelyabinsk Oblast, climate change, range shift

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Научная статья

Экспансия желтогорлой мыши *Apodemus flavicollis* Melchior, 1834 на восток

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Аннотация. Желтогорлая мышь *Apodemus flavicollis* Melchior, 1834 – типичный представитель неморальных растительных сообществ. До недавнего времени восточной границей распространения желтогорлой мыши являлся горный массив Ирмель (N 54°32'00" E 58°50'20") в Челябинской области. Начиная с 2014 г. желтогорлая мышь начала отлавливаться на 80–120 км восточней границы ее прежнего ареала в нехарактерных для нее станциях с нетипичными кормовыми условиями. Освоение желтогорлой мышью новых территорий, вероятно, связано с изменением климата в последние годы.

Ключевые слова: Южный Урал, Ильменский заповедник, Челябинская область, изменение климата, сдвиг ареала

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Introduction

Mice of the genus *Apodemus* Kaup, 1829 (Rodentia: Muridae) are common representatives of the genus Muridae. Yellow-necked mouse *Apodemus (sylvaemus) flavicollis* Melchior, 1834 and Ural field mouse *A. (sylvaemus) uralensis* Pallas, 1811 are sympatric (sometimes, syntopic) species, widespread in the western Palearctic. In the southern part of their range, these species are often difficult to distinguish morphologically (Jojic et al., 2014), but in Central and Northern Europe, these species are easily recognized by the presence of a yellow spot on the neck in *A. flavicollis*.

In the northern areas, yellow-necked mouse is found as far as the southern Republic of Karelia, to the east, at the southwestern slopes of the Ural Mountains, where its distribution coincides with the range of fir, larch and cedar, encompassing Republic of Bashkortostan and Orenburg Oblast (Bolshakov, 1977; Kirikov, 1952; Marvin, 1969; Popov, 1960; Snigirevskaya, 1947; Vinogradov and Gromov, 1952). The optimum species range belongs to the broadleaf forests of Europe.

In the Southern Urals, yellow-necked mouse lives in broad-leaved and dark coniferous forests at the western foothills of the Urals; these forests are characterized by the undergrowth of linden; understory and the second canopy layer are formed by single oaks, maples, and elms. This rodent species is more numerous in mountain broadleaf forests comparing to the floodplain mountain forests (Bolshakov et al., 1986; Gromov and Erbaeva, 1995). In the mountain forest belt, the species is found in mixed forests up to 900 m above sea level, in rocky placers overgrown with various shrubs. The species share in these biotopes ranges from 2 to 21% (Bolshakov et al., 1986).

Until recently, the Iremel Ridge (N 54°32'00" E 58°50'20") was the eastern range margin of yellow-necked mouse (Bolshakov et al., 1986). In September 2014, yellow-necked mouse specimen was caught by us in the upper reaches of the Atlan River, 76 km northeast of its accepted range (Fig. 1). This area is located on the boundary between the forest and forest-steppe zones (Kiseleva, 2015). In 2020, yellow-necked mouse was found in the samples obtained in the northern part of the Ilmeny State Nature Reserve, in the coastal biotopes of Lake Bolshoy Ishkul (N 55°17'04.6" E 60°14'45.1") (Fig. 1), i.e., at 121-km distance northeast of the Iremel Ridge (Olenev et al., 2022).

Range shifts can occur throughout the historical biogeographical changes in many species, representing an adaptation to a changing climate. The introduction of a new species, coupled with changing weather conditions, can lead to a decline in resident species' abundance, altering the diversity of existing communities. Understanding range dynamics is crucial for predicting and managing biodiversity considering global environmental change (Garnier and Lewis, 2016; Weiskopf et al., 2020).

The study aims to determine the abundance of local rodent species at monitoring sites of the Ilmeny State Nature Reserve and to assess the distribution patterns of yellow-necked mouse in this area.

Materials and methods

The Ilmeny State Nature Reserve is located in Chelyabinsk Oblast, Russia, on the eastern macroslope of the Southern Urals, at its eastern foothills (N 55°00'55" E 60°09'33"). Average altitudes are 400–500 m above sea level, maximum height, 754 m a.s.l. The relief of the region is ridge-rolling, represented by a system of meridionally oriented ridges.

The eastern slope of the Southern Urals is characterized by coniferous forests with an admixture of birch and aspen; in most cases, these are secondary forests that emerged after logging and fires. Almost no broadleaf tree species, except linden (*Tilia cordata* Mill, 1768), extends to the eastern slope of the Ural Mountains. Here, pine forests prevail, represented mainly by mixed grasses and cereals, broad-grass (forbs), green mosses, green moss-lingonberry, and steppe-like forest types (Kulikov, 2005). In pine forests, larch is often found. Under the main canopy of pine and larch-pine sparse forests, steppe shrubs and meadow-steppe herbaceous plants are found quite often, giving steppe-like character to these forests. At waterlogged habitats (in the river valleys, along streams, at lake shores, and swamp edges), native birch groves exist (in particular, downy birch *Betula pubescens* Ehrh.). Common (black) alder (*Alnus glutinosa* (L.) Gaertn) and grey alder (*Alnus incana* (L.) Moench) are quite common. Small areas of linden groves and dark coniferous-broadleaf forests are found very rarely.

The abundance and species composition of rodents has been monitored in the Ilmensky State Nature Reserve over 90 years. N.M. Dukelskaya (1928) was the first who has described the rodent fauna and its abundance. According to the studies performed in the first half of the 20th century, bank vole (*Clethrionomys glareolus* Schreber, 1780) and Ural field mouse (*Apodemus uralensis* Pallas, 1811) have always been widespread in the reserve; bank vole outnumbered Ural field mouse (Danini et al., 1940).

Currently, bank vole dominates in forest biotopes, accounting for up to 98% of catches, with Ural field mouse being second in abundance. Occasionally, there are single specimens of northern red-backed vole (*Clethrionomys rutilus* Pallas, 1779), gray red-backed vole (*Clethrionomys rufocanus* Sundevall, 1846), and meadow voles of genus *Microtus* in the catches (Kiseleva, 2021). The distribution of forest rodents across the reserve is uneven: it is preconditioned by the macro- and microrelief features, including the tree stand density, amount of undergrowth and herbaceous vegetation, amount of forest debris, and moisture.

The rodent population has been surveyed annually since 1991 in the spring (May) and autumn (September) using the series of 50 snap-traps placed at a distance of 10–12 m from each other. This allowed to achieve significant coverage of the study area and to obtain representative results. Surveys were conducted in the southern part of the reserve in two types of biotopes: “wet” (river valley) and “dry” (mixed forests at the mountain slopes). Each snap-trap series was set for 4 days. Within this period, almost all sedentary rodents in the study area were captured (Nurtdinova and Pyastolova, 2006; Baumgardt et al., 2019).

Results

In 1991–2024, approximately 12200 trap-days were performed, and 4100 individuals of five rodent species were sampled. In spring, the numbers of forest rodents are usually very low in the reserve. Over the entire observation period, the average spring numbers of bank voles ranged from 0.44 ± 0.2 to 6.5 ± 1.6 ind./trap-days, of Ural field mouse, 2.7 ± 0.6 ind./trap-days. In autumn, these numbers were 4.6 ± 1.8 to 18.9 ± 2.6 ind./trap-days and 2.1 ± 1.9 to 18.9 ± 2.6 ind./trap-days, respectively (Kiseleva, 2020a, b). Yellow-necked mouse was not present in the catches until 2023.

In October 2023, adult male and female of yellow-necked mouse were captured in the southern part of the Ilmeny State Nature Reserve, on the territory of the European mink nursery (N 55°01'38.46" E 60°10'18.69") (Fig. 1). In 2024, spring and autumn rodent censuses did not reveal the presence of yellow-necked mice at the monitoring sites. However, in the autumn, one adult male and one adult breeding female of this species were captured in the southern part of the reserve, once again on the territory of the European mink nursery (Fig. 1), and in the northern part of the reserve near Lake Bolshoy Ishkul (G.V. Olenev, pers. comm.). Therefore, *A. flavicollis* continues to colonize the territory of reserve.

Discussion

Monitoring of the rodent population carried out in the Ilmeny State Nature Reserve allows for detailed tracking of changes in their numbers and species composition.

Forest rodents prefer to inhabit river valleys, lakeshores with dense thickets of bird cherry, rowan, and viburnum in the second canopy layer, as well as lowlands with abundant undergrowth and deadwood. Rodents persist in such areas during unfavorable years, leading to their dispersal to adjacent territories (Kiseleva, 2020a). However, narrow valleys of mountain rivers and streams are confined to mountain slopes. Their total area is small, and their biotopic capacity varies greatly depending on the specific landscape. Pine forests on the mountain slopes are less favorable for rodents, as these areas are usually dry and are characterized by poorly developed undergrowth, sparse canopy density, and little deadwood or natural shelters. Rodent populations in such areas are often extremely small or even absent. These features of the landscape and vegetation in the reserve precondition low overall abundance of forest rodents and its significant seasonal and interannual fluctuations.

Vegetation cover largely determines the species composition, abundance, and spatial distribution of small mammals. Yellow-necked mouse is considered a typical representative of nemoral plant communities, since in all seasons the predominant part of its food consists of seeds, especially that

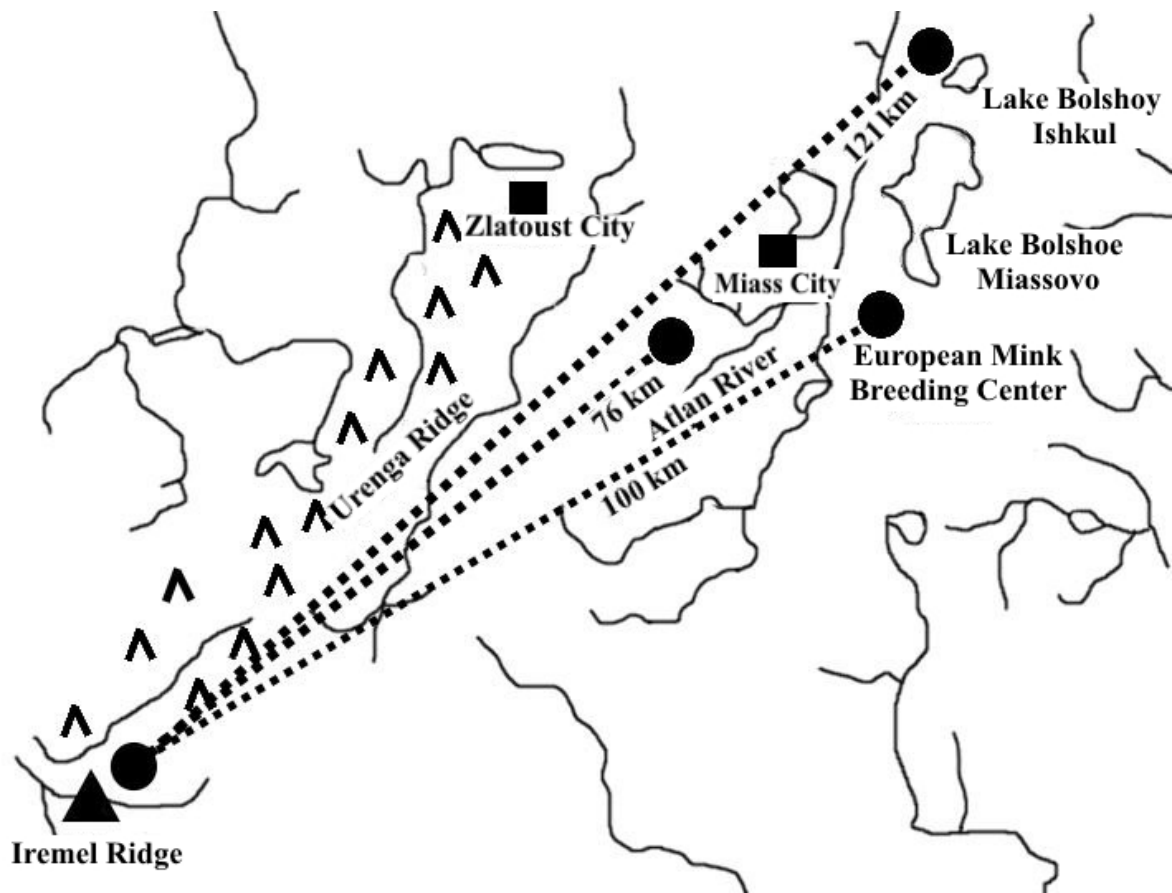


Fig. 1. Sampling site map of yellow-necked mouse (*Apodemus flavicollis*) in 2014–2024 in Chelyabinsk Oblast, Russia. ▲ – the known easternmost habitat of yellow-necked mouse until 2014; ● – sites, where yellow-necked mouse was caught after 2014.

of broad-leaved trees (beech nuts, acorns, hazel nuts, linden and maple seeds) and of some shrubs (spindle tree, rose hips, etc.). The abundance of this rodent species fluctuates depending on the seed harvest of broad-leaved trees (Gromov and Erbaeva, 1995). In addition, yellow-necked mouse feeds on American maple seeds and on a variety of grasses, supplementing its diet with fungi and invertebrates (up to 30%) (Abt and Bock, 1998; Drożdż, 1966).

Broadleaf trees are absent at the eastern foothills of the Ural Mountains and within the Ilmeny State Nature Reserve. Linden trees, which are sometimes found on the mountain slopes, generally do not bear fruit under the forest canopy. Therefore, the Ilmeny State Nature Reserve and adjacent areas lack the typical feeding conditions for yellow-necked mouse.

Analyzing the locations of this species' capture sites within the reserve, we assume that yellow-necked mouse began to colonize mountain slopes in sparse pine-birch forests covered with thickets of steppe shrubs. On the dry rocky slopes of southern and southwestern exposure, where average altitude is 400–500 m a.s.l., widespread communities of mountain shrub steppes comprise scalloped spirea *Spiraea crenata* L., Iberian spirea *S. hypericifolia* L., European dwarf cherry *Cerasus fruticosa* Pall. (= *Prunus cerasus* L.), black-fruited cotoneaster *Cotoneaster melanocarpus* J. Jacq. ex Lindl., Russian rose *Rosa glabrifolia* C.A. Mey. ex Rupr., prickly wild rose *R. acicularis* Lindl., Ruthenian broom *Chamaecytisus ruthenicus* (Fisch. ex Wot.) Klásk., there are also single specimens of common barberry *Berberis vulgaris* L. The herbaceous-shrub layer is very dense, tightly closed; its projective cover reaches 80–90%. Here, red clover *Trifolium pratense* L., mountain clover *Amoria montana* (L.) Sojak (= *Trifolium montanum* L.), dropwort *Fillipendula vulgaris* Moench, spike speedwell *Veronica spicata* L., yellow bedstraw *Galium ruthenicum* Willd. (= *Galium veru* L.), wormwood *Artemisia sericea* (Besser) Weber ex Stechm., Siberian bellflower *Campanula siberica* L., yarrow *Achillea millefolium* L.,

yellow clover *Medicago falcata* L., etc., are common (Erokhina, 2007; Kulikov, 2005). The territory of the European mink nursery, where yellow-necked mice have been caught for the last two years, is located at the base of the south-eastern slope, and Lake Bolshoy Ishkul, at the foothills of the Ishkul Ridge.

A southwest-facing mountain slope extends from the northern boundary of the reserve, where the Ishkul Ridge and Lake Bolshoy Ishkul are located, to the southern part of the reserve, along which the reserve's boundary runs. Numerous orchards locate at the slope base, they can serve as a refuge for yellow-necked mouse (Gryz and Krauze-Gryz, 2019).

The colonizing rate for yellow-necked mouse will obviously depend on the landscape features. According to field data on 78 animal species, the colonization rate was higher in almost 75% of cases, when animal faced with living environment of poor quality. Therefore, there is a compromise between faster spread in the low-quality habitats and quick population increase in a high-quality environment (Lyons et al., 2005).

Analyzing the distribution and habitat use of bank voles, Ural field mice, and yellow-necked mice, J. Gurnell (1985) concluded that there is no competition between these species, although it may occasionally arise at high population densities. Therefore, if yellow-necked mice reproduce actively within the reserve, the competition between these rodent species may occur.

According to direct visual observations of encounters between bank voles and yellow-necked mice in the field, the latter behave aggressively, while bank voles tend to retreat (Andrzejewski and Olszewski, 1963). As a result, the habitat range for bank voles decreases. Yellow-necked mice are more competitive than bank voles; they may influence either population dynamics or the spatial distribution and/or demographic variables of bank voles (Bujalska and Grúm, 2008; Fasola and Canova, 2000). However, no competition between these species has been found in other studies (Grúm and Bujalska, 2000). At the Alpine foothills, the location of finding of both *A. flavicollis* and *Cl. glareolus* depends on the presence and height of tree and shrub cover, i.e., these species have spatial partitioning according to microhabitat structure (Hille and Mortelliti, 2010). It is believed that ecological differences and dispersal across different microhabitats contribute to their stable coexistence (Montgomery, 1980).

According to our previous studies, the dominance of Ural field mouse over bank vole causes significant behavioral changes in the latter (Kiseleva, 1990). Furthermore, the normal reproductive cycle of bank vole population is disrupted (Kolcheva and Olenyev, 1991). Therefore, we believe that abundant introduction of yellow-necked mouse may impact negatively the existing rodent community.

In our opinion, yellow-necked mouse may master new territories due to climate change in recent years. In the Southern Urals, the average annual temperature has increased by approximately 18 °C in less than 100 years. Moreover, the rate of increase in mean annual temperatures has accelerated markedly since the 1970s, rising on average by a factor of two. The temperature has increased to a greater extent in the winter months, to a lesser extent in the spring and autumn, and has remained virtually unchanged in the summer. Spring and autumn have become warmer, with spring begins earlier, but autumn, later¹. The frost-free period has changed most dramatically compared to the beginning of the 20th century, increasing by 86 days and averaging currently 205 days. These changes altered the population dynamics of forest rodents. In particular, the frequency of population peak events has increased, and the rodent abundance at these peaks has increased by 1.4–2.1 times. Population peaks of bank vole and Ural field mouse now recur every 2–3 years (Kiseleva, 2020a, b). Therefore, the introduction of yellow-necked mouse may lead to changes in the fecundity, size, and survival of these species.

Despite the lack of typical conditions and food for yellow-necked mouse within the reserve, the presence of a wide variety of forest vegetation allows this species to select habitats according to its biological and ecological requirements. Climate change also facilitates the colonization of new territories. It is still unclear whether the range margin of yellow-necked mouse will shift in the study area, or whether the appearance of single specimens with active exploratory behavior at new territories is merely the individual attempts to disperse, taking advantage of emerging climatic opportunities.

¹ Weather forecast and data archive. Web page. URL: <https://chelpogoda.ru> (accessed: 30.10.2024).

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