Ground-dwelling small mammals in Bogd Khan Mountain: Insights from a Biosphere Reserve in Mongolia

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Abstract:
Anthropogenic activities and rapid urbanisation strongly influence natural ecosystems and their biodiversity. Natural areas on the border of expanding cities are particularly affected by anthropogenic pressures, possibly leading to a decrease or local extinction of animal species. The capital of Mongolia, Ulaanbaatar, is now hosting half of the entire country's population and is rapidly expanding, impacting one of the oldest protected areas in the world, the adjacent Bogd Khan Mountain. Considering small mammals' key role in the ecosystems, and the scarce knowledge of Mongolian rodent ecology, we investigated the ground-dwelling small mammals on Bogd Khan Mountain, and assessed species assemblage and occurrence, essential for planning future conservation actions. We live-trapped rodents in two valleys (4 sites) between May and July 2023. We recorded five ground-dwelling rodents: *Apodemus peninsulae, Craseomys rufocanus, Clethrionomys rutilus, Cricetulus barabensis*, and *Eutamias sibiricus*. Historical records, however, showed a much higher species richness than the one recorded in this study. We discussed our findings in light of species ecology and potential threats to these populations. Our findings highlight the gaps in the understanding of small mammal ecology in Mongolia, emphasizing the need of further studies to ensure the conservation and protection of Bogd Khan Mountain and its wildlife.

Keywords: rodents, live trapping, Siberian chipmunk, anthropogenic disturbance, UNESCO, vole.

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Short title
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Anthropogenic activities and rapid urbanisation strongly influence natural ecosystems and their biodiversity. Natural areas on the border of expanding cities are particularly affected by anthropogenic pressures, possibly leading to a decrease or local extinction of animal species. The capital of Mongolia, Ulaanbaatar, is now hosting half of the entire country's population and is rapidly expanding, impacting one of the oldest protected areas in the world, the adjacent Bogd Khan Mountain. Considering small mammals' key role in the ecosystems, and the scarce knowledge of Mongolian rodent ecology, we investigated the ground-dwelling small mammals on Bogd Khan Mountain, and assessed species assemblage and occurrence, essential for planning future conservation actions. We live-trapped rodents in two valleys (4 sites) between May and July 2023. We recorded five ground-dwelling rodents: *Apodemus peninsulae*, *Craseomys rufocanus*, *Clethrionomys rutilus*, *Cricetulus barabensis,* and *Eutamias sibiricus*. Historical records, however, showed a much higher species richness than the one recorded in this study. We discussed our findings in light of species ecology and potential threats to these populations. Our findings highlight the gaps in the understanding of small mammal ecology in Mongolia, emphasizing the need of further studies to ensure the conservation and protection of Bogd Khan Mountain and its wildlife.

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Emerging economies are leading to increased urbanisation, loss of traditional ways of life, and overexploitation of natural resources, posing a threat to natural resources for future generations. In some regions of the world, traditional herding practices have coexisted with natural ecosystems since early human settlements (Regdel et al., 2012). A representative case is Mongolia, with a small human population and a tradition of nomadic pastoralism, which has helped maintain the pristine landscapes of Central and Northern Asia. However, in recent years, the increase in livestock numbers, decline of nomadic traditions, rapid urbanisation, mineral extraction, and agricultural growth have negatively impacted its environment and biodiversity (Munkhzul et al., 2021; Regdel et al., 2012).

The oldest protected area in Eurasia and perhaps the world, Bogd Khan Mountain, protected since the 12th century, is a sky island lying at the south gates of the city of Ulaanbaatar, the capital of Mongolia, which is now hosting half of the entire country's population. Despite the mountain becoming a nationally recognised Strictly Protected Area in 1995 and a UNESCO Biosphere Reserve in 1996, its isolated forest system is now potentially threatened by the rapid expansion of the city, outdoor recreation, human-induced forest fire, insect outbreaks, air pollution, illegal grazing of livestock and large-scale commercial collection of pine seeds (Bazarragchaa et al., 2022; World Bank Report, 2010). However, there have not been systematic studies in the mountain examining the resident wildlife communities and the potential impacts of recent contemporary threats. Small mammals play a crucial role in the ecosystems as they are responsible for strong bottom-up processes functioning as seed dispersers (Hunter et al., 2022; Zwolak, 2018) and as prey for several mammalian and avian predators (Hussain et al., 2016; Ross et al., 2010; Korpimäki et al., 2004). Additionally, small mammals serve as indicators of forest sustainability (Lozano et al., 2006; Bontzorlos et al., 2005), highlighting their ecological importance and the need for further study. Despite this, 45% of rodent species in Mongolia are classified as Data Deficient (Clark et al., 2006), underscoring a significant gap in knowledge. This study aimed to compile a comprehensive list of ground-dwelling granivorous rodent species inhabiting Bogd Khan Mountain, marking the first effort to systematically

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capture and document these species in this region. To reach this scope we investigated the species assemblage in two areas on the south slope of the mountain through live trapping from May 2023 to July 2023 (Fig. 1). Manzushir (47.75836 N, 106.99562 E) and Baruundelger (47.77067 N, 106.96588 E) valleys are dominated by Siberian pine (*Pinus sibirica*), Siberian spruce (*Picea obovata*), and Siberian larch (*Larix sibirica*), with a continental climate characterised by very cold winters and a short growing season (Adyasuren et al., 1998). The forested area is characterised by tall trees, high canopy cover, and low understory cover, while the riparian area of the valley is dominated by shrubs and grass, with a patchy canopy cover supported by water from the ephemeral streams. In May 2023, we also conducted one trapping session at the entrance of Baruundelger Valley. This area was an expansive steppe dominated by drought-tolerant grasses and herbaceous plants. During that season the area was characterised by very low grasses that did not provide any vegetation cover for small mammals. No small mammals were captured during the entire session and, as a result, we decided to discontinue trapping at this location and focus our efforts and resources on the other areas. Using Sherman live traps (7.5 × 9 × 23 cm; HB 110 Sherman Traps Inc. Tallahassee, Florida USA) baited with millet, sunflower seeds, and oat seeds, all mixed with peanut butter, we trapped small mammals during four trapping sessions in both areas, each session lasting three consecutive days/nights for a total of 26 trapping nights (13 in Manzushir Valley and 13 in Baruundelger Valley). In each valley, both a grid and a transect design were set. We used 40 traps spaced 10 m apart, laid in a grid design (90 x 30 m) in the forest and 40 traps in a transect design (390 m) down in the valley (distance grid-transect Manzushir: 1020 m, Baruundelger: 600 m). We checked the traps every day at dawn and dusk, and for a third time halfway through the day if the temperatures were warm. Polyester batting was added to the traps if expected temperatures were below 18°C overnight. We identified animals to the species or genus level (details below) based on the morphological characteristics and measurements described in Batsaikhan et al. (2022). When an animal was captured, sex was determined by measuring the distance between the anus and the urogenital opening and observing the presence of testes in males and nipples in females. Additionally, various morphological measurements

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were recorded, such as body length, tail length, and hind foot length using a ruler (± 1 mm), and the individual's body mass using a 100 g (±1 g) or 300 g (±2 g) Pesola spring balance. We sampled hairs from the back of each animal, which were preserved in 90% ethanol for possible genetic confirmation of the trapped specimens. Moreover, we marked individuals during the first capture event by clipping the fur on their back and colouring their belly with an animal marker (nontoxic and devoid of any hazardous materials Marking Pen, Fine Tip, Fine Science Tools, Heidelberg, Germany) or marking them with a metal numbered ear tag (Monel 1005 1L1 National Band and Tag Co, Newport, Kentucky, USA), based on the species size. Finally, we released all individuals at the capture location.

Trapping, marking, and handling were carried out in accordance with the Guidelines for the treatment of animals in behavioural research and teaching (Animal Behaviour Society, 2020) and the Institutional Animal Care and Use Committee of the University of Wyoming (permit #_20221101JK00573-01).

Over 34 days, a total of 26 trap nights were employed to capture small mammals across all sites; trapping effort was relatively equivalent between all areas (Trap nights grid: BV = 13; MV = 13; Trap nights transect: BV = 10; MV = 13).

We captured the following species: the Korean field mouse (*Apodemus peninsulae*), Northern red-backed vole (*Clethrionomys rutilus*), Grey red-backed vole (*Craseomys rufocanus*), Siberian chipmunk (*Eutamias sibiricus*) and Striped dwarf hamster (*Cricetulus barabensis*) (Table 1, Fig. 2). The hamster was the only species captured exclusively in one area, Baruundelger Valley, and only along the transect. Additionally, one non-target species, the Eurasian red squirrel (*Sciurus vulgaris*), was captured twice. Initially, in the field, vole individuals were all identified as Grey red-backed voles based on apparent morphology, totalling 289 trapping events (98 different individuals) (Table 1). However, due to extensive overlap in fur colour variation and body measurements between Grey red-backed and Northern red-backed voles, we performed further genetic analysis using the mitochondrial D-loop region on five samples. We extracted total genomic DNA from a minimum of five hairs using

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the Qiagen Blood and Tissue kit (©Qiagen). We amplified a portion (1100 bp c.ca) of the D-loop with primer pair L15933–H637 (Oshida et al., 2001) using the thermal conditions described in Oshida et al., (2006). PCR reactions, thermal conditions and Sanger sequencing were conducted as in Mazzamuto et al., (2016). The obtained consensus nucleotide sequences were assigned to the species taxonomic level using the BLASTn tool in NCBI-GenBank (https://blast.ncbi.nlm.nih.gov/Blast.cgi). This genetic analysis revealed the presence of Northern red-backed vole among the captured individuals. Future funding will enable genetic analysis of all sampled hairs and a better investigation of phylogeographic and genetic diversity of the sampled taxa.

The catch per unit effort (cpue) was calculated (number of individuals captured/number of occasions) for each species except for *C. barabensis*, while *C. rufocanus* was considered together with *C. rutilus*. In Baruundelger Valley we captured 18 individuals of Korean field mice (11 males, 7 females, total captures 45, cpue 0.021), 15 Siberian chipmunks (9 males, 6 females, total captures 57, cpue 0.027) and 52 individual voles (26 males, 26 females, total captures 121, cpue 0.057). In Manzushir Valley we captured 23 Korean field mice (16 males, 7 females, total captures 80, cpue 0.038), 19 Siberian chipmunks (8 males, 11 females, total captures 54, cpue 0.026) and 46 voles (26 males, 20 females, total captures 164, cpue 0.078).

This research is a pioneering effort to investigate ground-dwelling small mammals in the strictly protected area of Bogd Khan Mountain, where small mammal trapping was conducted for the first time. Given the current and anticipated increase in human disturbance, this study is a foundation for future long-term research on these species to ensure the conservation and protection of the mountain and its wildlife. In the past, a species list of the area was compiled based on species distribution at the global level. However, this record is not included in the international bibliography and is only available in the Mongolian language (Shar et al., 2008). Shar and colleagues (2008) reported the presence of 12 ground-dwelling rodent species in the forest-steppe of the mountain that could have been captured during the survey: six voles (*Microtus gregalis*, *M. maximoviczii*, *Lasiopodomys brandtii*, *Craseomys rufocanus*, *Clethrionomys rutilus*, *Alticola semicanus*), two mice (*Apodemus*

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peninsulae, *Mus musculus*), two hamsters (*Phodopus campbelli*, *Cricetulus barabensis*), one jerboa (*Allactaga sibirica*) and one chipmunk (*Eutamias sibiricus*). As the mountain is a transitional zone where boreal forests give way to steppe, both forest species (e.g., *Apodemus* sp.) and steppe species (e.g., *Allactaga* sp.) are likely to be found. However, despite our trapping effort, we recorded a much lower species richness (n = 5). Moreover, we only captured two individuals of the striped dwarf hamster, which raises questions about the presence of a stable population and its conservation status. We recorded this species only in Baruundelger Valley, whose entrance is delimited by a fence and a gate that limit access to people, guaranteeing a lower human disturbance. On the other hand, Manzushir Valley attracts many visitors due to its renowned monastery and numerous hiking trails that lead to the mountain summit, and its status as a sacred mountain. This human-disturbed area is a popular destination for hikers and tourists that might directly disturb small mammal populations or indirectly disturb them through habitat degradation.

The two vole species we captured, *C. rufocanus* and *C. rutilus*, have a wide distribution. Both species range from Norway to Chukotka in Russia but, additionally, *C. rutilus* also occurs in the northern regions of North America, including Alaska, Yukon, and Nunavut (Linzey et al., 2020; Sheftel and Henttonen, 2016). In comparison, the other vole species listed in the previous species list (Shar et al., 2008) which were not captured during this survey, have smaller and more irregular distribution ranges (IUCN, 2016). Moreover, the habitat types where each species occurs are not clearly identified, indeed information about their habitat use tends to be general and/or not concordant (e.g., Batsaikhan et al., 2022; IUCN, 2016;). Therefore, we can hypothesise that in our study areas we captured the two more ubiquitous vole species, but, due to the lack of knowledge of the exact habitat preferences of each species, it is difficult to draw definitive conclusions. As far as the two hamster species are concerned, also in this case, habitat preferences are not clear, they seem to prefer arid and desert habitats, however, they can be more generalist (Batsaikhan et al., 2022; Poplavskaya et al., 2019). Therefore, further investigations on the occurrence of hamster species in diverse habitat types within the mountain range are necessary to shed light on their conservation status in Bogd Khan Mountain.

We did not find *Mus musculus,* a species known to depend on human activities that tends to live close to anthropogenic areas (Rowe, 1975). In one of our study sites, Manzushir Valley, only temporary facilities such as tourist gers and camping tents were present during the summer season. This habitat is more suitable for the other mouse species we captured, *A. peninsulae*, which lives both in natural environments such as forested areas and touristic sites or campgrounds, that characterised our study sites (Li et al., 2020). Finally, the forests and shrublands that covered our study sites, may not have allowed the detection of *A. sibirica*, which inhabits grassland ecosystems (Liao et al., 2016). A wider survey is needed to expand our knowledge of this species' range.

Although the trapping effort was limited to three months, the standardised methods employed and the systematic arrangement of traps across two macrohabitats provide strong confidence that the majority, if not all, of the small mammal species present in the area were captured. These methods are widely recognised for their effectiveness in sampling small mammal communities and ensuring representative coverage (Harkins et al., 2019). However, extending the trapping period or exploring additional macro- and microhabitats in future studies could serve as a new starting point for refining species inventories and addressing potential gaps. The absence of captures for certain expected species may, however, reflect a lack of ecological information on their habitat preferences, activity patterns, or population dynamics, which poses a challenge to fully understanding their presence or absence in the study area. The low species richness documented in this study might be related to several environmental challenges, one of which is grazing (reviewed by Schieltz and Rubenstein, 2016), known as one of the major causes of habitat degradation in Mongolia (Tuvshintogtokh and Ariungerel, 2013; but see Staalduinen et al., 2007). Cows and horses, which are present in our study sites but whose effects are still to be evaluated in this protected area, graze on similar vegetation to that consumed by many rodents, and their large-scale consumption reduces food availability, creating competition that may lead to a decline in rodent populations, particularly in resource-limited areas (Gankhuyag et al., 2021). Moreover, some plant species may be overgrazed while others that are less palatable to grazers may become more dominant, thus altering the species composition of plant

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communities (Schieltz and Rubenstein, 2016). This change in vegetation can impact the availability of preferred food sources for rodents, leading to changes in rodent diets and potentially affecting their health and reproduction (Schieltz and Rubenstein, 2016). However, Staalduinen and colleagues (2007) reported that reduced grazing leads to a lower abundance of rhizomatous species, favoured by many rodent species, and an increase in tussock species. Grazing can also lead to a reduction in ground cover which for rodents, especially those that rely on dense vegetation for shelter and protection from predators, results in loss of habitat. We recorded several potential predators through a concurrent camera trap study in Bogd Khan Mountain (Davaasuren et al., 2024). Among them, we recorded foxes (*Vulpes vulpes* and *V. corsac*), weasels (*Mustela* sp.), martens (*Martes* sp.) and Pallas's cat (*Otocolobus manul)* (Davaasuren et al., 2024; Murdoc et al., 2010; Ross et al., 2010). Moreover, avian predators (such as different owl species, Strigidae, and black kite, *Milvus migrans*) could predate small mammals (Hussain et al., 2016).

In conclusion, studying ground-dwelling small mammals in Bogd Khan Mountain is a crucial step toward advancing our understanding of the taxonomic and functional diversity of mammal communities. Small mammals play a pivotal role as drivers of bottom-up ecological processes, and changes in their composition and abundance can significantly influence producer-consumer and predator-prey dynamics in forest-steppe ecosystems. Given that nearly half of the small mammal species in Mongolia are classified as Data Deficient, there is a pressing need for further studies to assess their population status and ecological roles. Such research is essential to inform conservation strategies. With the aim of promoting long-term sustainable development in this noteworthy biosphere reserve, understanding ecosystem processes and species' responses to anthropogenic factors becomes essential to provide science-based recommendations.

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322 **Table 1** – Average body weight (g), body length, tail length and foot length measures (mm) ± SD of
323 small mammals in Bogd Khan Mountain, Mongolia. Number of individuals and catch per unit effort
324 (cpue) between brackets. *Craseomys rufocanus* and *Clethrionomys rutilus* are considered together
325 due to the difficulties of their identification (as described in the text).

326 Species (n; cpue)	Body weight	Body length	Tail length	Foot length
327 *Apodemus peninsulae* (41; 0,030)	24.64 ± 5.31	87.80 ± 9.46	83.55 ± 7.32	22.15 ± 1.40
328 *Craseomys rufocanus* + *Clethrionomys rutilus* (98; 0,068)	27.46 ± 7.91	93.26 ± 11.23	29.06 ± 3.87	17.34 ± 1.38
329 *Cricetulus barabensis* (2; -)	17.00 ± 2.65	74.00 ± 2.52	18.00 ± 1.00	15.00 ± 2.65
330 *Eutamias sibiricus* (34; 0,026)	84.94 ± 10.00	138.61 ± 9.97	-	33.78 ± 1.67

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Figure 1 – Location and images of the study sites (BV: Baruundelger Valley; MV: Manzushir Valley) within Bogd Khan Mountain, Mongolia. Land use map (2019) generated using European Union's Copernicus Land Monitoring Service information (CF = closed forest; OF = open forest).

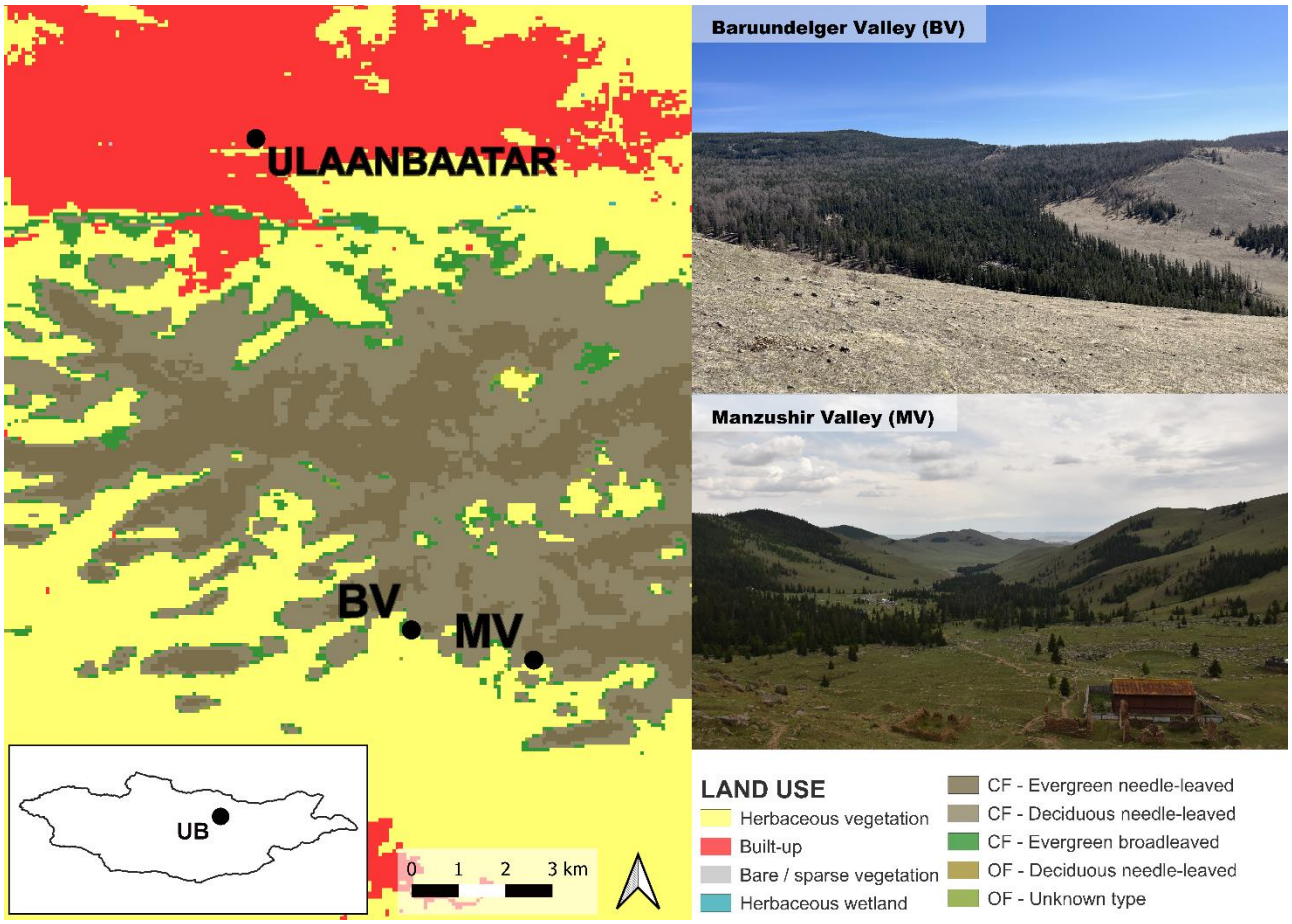

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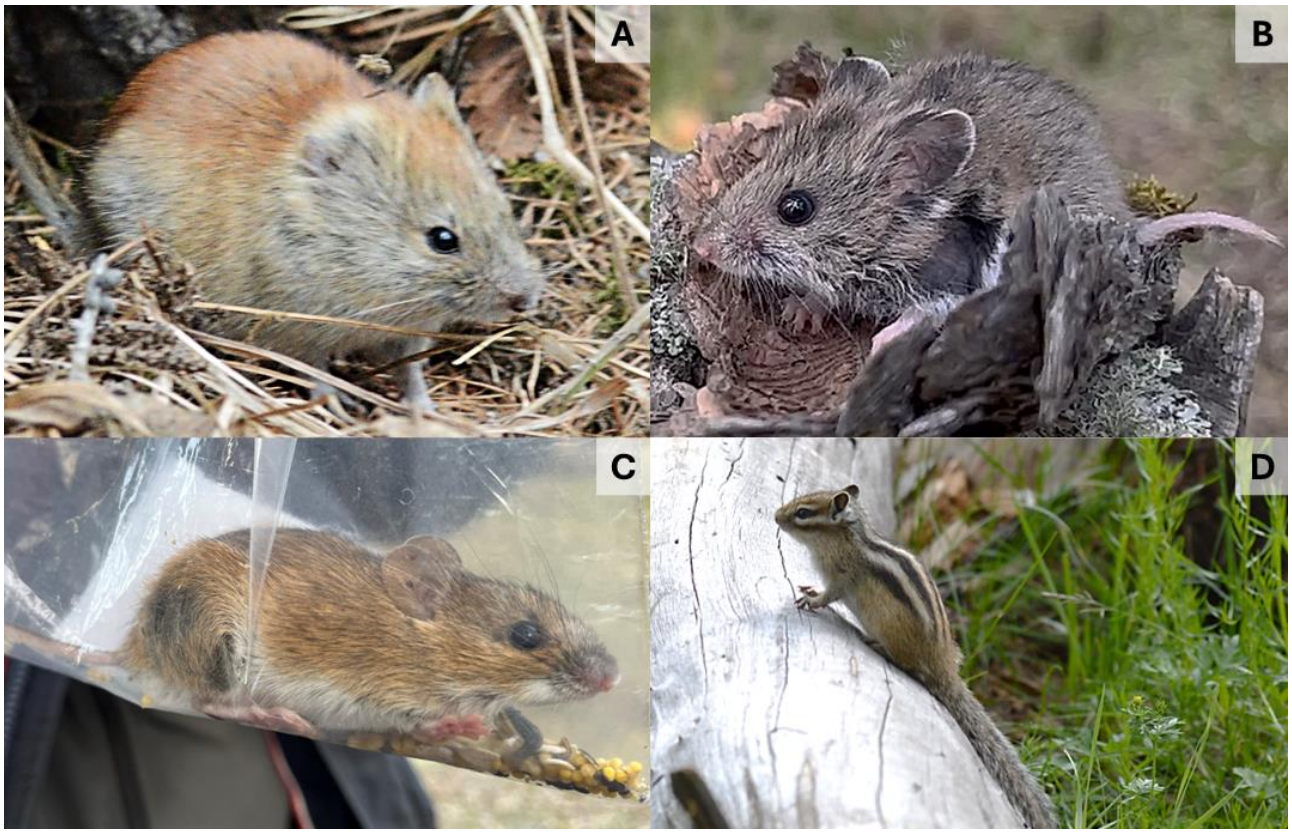
Figure 2 – Species captured during the study period: (A) vole (*Craseomys rufocanus* or *Clethrionomys rutilus*), (B) *Cricetulus barabensis*, (C) *Apodemus peninsulae*, (D) *Eutamias sibiricus*.



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