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RESEARCH ARTICLE

Faunal structure of small mammals (Erinaceomorpha, Soricomorpha, Chiroptera and Rodentia) in two protected areas of the Middle Volga region (European Russia)

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Abstract

Most existing data on the distribution of living organisms are usually contained in various taxonomic publications, checklists and natural history collections. As a result, these data tend to be often difficult to generalize. Biodiversity databases are an effective tool for integrating and assessing this type of information. Our dataset, recently published in GBIF as the Darwin Core Archive, contains up-to-date information on the occurrence of small mammals (hedgehogs, shrews, bats and rodents) in two protected areas of European Russia: the Mordovia Nature Reserve and National Park "Smolny". The dataset summarizes animal occurrences from our field studies of small mammals using snap traps, mist nets and nature observations during 2018–2023. This database consists of 7950 records of occurrence of small mammals, including 5672 records in the Mordovia Nature Reserve and 2278 records

in the National park "Smolny". Our dataset lists 35 species of small mammals from 21 genera and 9 families. Each occurrence record contains the name of the species, the basis of the record, the age and sex of animal individual, the reproductive state of the females, the location, the date and the authors of the record. All records are georeferenced and published in GBIF for the first time. The species richness of small mammals noted in the protected areas of Mordovia is similar for other regions of European Russia.

Keywords
Biodiversity, GBIF, micromammals, Mordovia Nature Reserve, national park "Smolny", occurrence dataset

Introduction

One of the important purposes of nature conservation is the all-taxa biodiversity inventory (ATBI), which involves identifying all species of living organisms in a specific geographic area (Cutko 2009; Deharveng et al. 2015). Unfortunately, much of the existing data on the distribution of living organisms is scattered across multiple sources, such as taxonomic papers, checklists and natural history collections. As a result, these data are often difficult to assess as a whole. The GBIF project allows researchers to combine and integrate this type of data in a unified form. The study of biodiversity, as well as its conservation and sustainable use, cannot be realized unless data is stored, discovered and made available for public use (Data's 2009; Chavan and Penev 2011). A scientific paper, that aims to discover and publish biodiversity data resources avoids this problem and makes biodiversity inventories more accessible for the scientific community.

Protected areas are convenient sites for studying the biodiversity of mammals, since they carry out systematic monitoring of the fauna and abundance of animals. On the territory of European Russia there are more than 300 protected areas, where such projects are being implemented, since one of the main tasks of nature reserves and national parks is the inventory of fauna and flora (Didorchuk et al. 2005; Ivanchev 2005; Potapova et al. 2006; Sikkilya 2014; Dmitriev et al. 2016; Lyubimov et al. 2018; Rutovskaya et al. 2020; Bazhenov 2021; Yakimova and Gaidysh 2021; Vasilyev et al. 2023).

Small mammals play a key role in regulatory processes that ensure the sustainability of natural ecosystems (Dickman 1999; Strann et al. 2002; Elkinton et al. 2004; Davidson et al. 2012; Kollberg et al. 2014). Various species of small mammals are part of complex food webs and chains, that contribute to increasing biodiversity in their habitats (Hornfeldt et al. 2005). Abundant and widespread, small mammals are important as a food resource necessary for the existence of many vertebrates at higher trophic levels (Cheveau et al. 2004; Bobretsov 2016; Krebs et al. 2014). Diversity assessment of small mammals can not only contribute to natural resource management, but also form the basis of environmental bioindication (Pearce and

Venier 2005; Leis et al. 2008; Bobretsov 2016; Hope et al. 2017). In addition, many species of small mammals are reservoirs and vectors of natural focal diseases of humans and domestic animals (Bordes et al. 2015; Krucken et al. 2017; Meerburg et al. 2009; Ahissa et al. 2020). Therefore, it is necessary to conduct monitoring studies on the species composition and distribution of small mammals, as well as the structure and dynamics of their populations. Such studies contribute to the forecast of the epidemiological and epizootological situation in a certain territory.

In recent years, a number of studies have been devoted to the fauna and distribution of small mammals in the Middle Volga region (Bakka and Bakka 1999; Gelashvili et al. 1999; Smirnov and Vekhnik 2012; Artaev and Smirnov 2016; Kirillova et al. 2019, 2021a, 2021b; Andreychev, 2020a, 2020b; Andreychev and Kuznetsov 2020; Smirnov et al. 2022; Kirillova and Kirillov 2023). Unfortunately, these works concerned only representatives of one or two taxonomic groups. Comprehensive faunistic studies of small mammals in the Middle Volga region are still missing.

Our dataset "Occurrence of small mammals in Mordovia State Nature Reserve and National Park "Smolny" (European Russia)" makes a significant contribution to data on small mammals in the territory of European Russia (Kirillova et al. 2024), and is based on the research of the staff of the Institute of Ecology of the Volga River basin of RAS and the Joint Directorate of the Mordovia Nature Reserve and National Park "Smolny".

The dataset contains up-to-date information on occurrences of soricomorphs, hedgehogs, bats and myomorph rodents in the territory of the Federal State Budgetary Institution "Zapovednaya Mordovia" (Reserved Mordovia), which includes the Mordovia Nature Reserve and the National Park "Smolny". These data can become the basis for the further study of the distribution and abundance of small mammals in the Middle Volga region.

Here we present a "data paper" (Chavan and Penev 2011; Penev et al. 2017) that aims to describe our dataset on the occurrence of small mammals (Erinaceomorpha, Soricomorpha, Chiroptera and Rodentia) in the Mordovia Nature Reserve and National Park "Smolny", which was recently published in GBIF as the Darwin Core Archive (Kirillova et al. 2024).

Materials and methods

Study area

Both studied protected areas are located on the territory of the Republic of Mordovia in the east of the Russian Plain (European Russia) (Figure 1).

The Mordovia Nature Reserve is located in the northwestern part of the Republic of Mordovia and occupies a territory approximately within 54°42,0′–54°56,0′ north latitude and 43°04,0′–43°36,0′ east longitude. The area of the reserve is 321.62 km^2 (Artaev et al 2012; Khapugin et al. 2016; Ruchin et al. 2016). The National Park "Smolny" is located in the northeastern part of the Republic of Mordo-

via and occupies a territory approximately within 54°43,0′–54°53,0′ north latitude and 45°04,0′–45°37,0′ east longitude. The area of the national park is 363.85 km^2 (Yamashkin et al. 2000; Grishutkin et al. 2013). Despite the fact that the territory of Mordovia as a whole is characterized by a highly dissected relief, both protected areas are characterized by flat terrain. In the National park "Smolny", the highest elevations are in its northern part – 214–217 m above sea level, and the lowest on the southern border of the park – 97–107 m above sea level. In the Mordovia Nature Reserve, the highest elevation is located in the southeastern part – 187.7 m; the lowest in the west – 110–120 m above sea level (Artaev et al 2012; Yamashkin et al. 2000). The distance between the two protected areas is about 130 km. Both protected areas lie on the boundary of the taiga and forest-steppe zones (Artaev et al 2012; Khapugin et al. 2016; Grishutkin et al. 2013), and most of their territory is occupied by forest communities. The diversity of natural environment conditions determines the richness of the flora and fauna of the Mordovia Nature Reserve and the National Park "Smolny". Currently, the Mordovia Nature Reserve is inhabited by 63 species of mammals from seven orders and 19 families including two species of hedgehogs, 10 species of soricomorphs, 9 species of bats and 22 species of rodents (Artaev et al 2012; Ruchin et al. 2016). The mammal fauna of the National Park "Smolny" consists of 54 species from seven orders and 19 families, including two species of hedgehogs, 7 species of soricomorphs, 8 species of bats and 18 species of rodents (Grishutkin et al. 2013). We have recently recorded the presence of additional mammal species in these protected areas: *Microtus subterraneus* (de Selys-Longchamps, 1836), *Myotis nattereri* (Kuhl, 1817) and *Nyctalus leisleri* (Kuhl, 1817) (Kirillova et al. 2019; Smirnov et al. 2022; Kirillova and Kirillov 2023). More detailed descriptions of these protected areas are given in our earlier works (Kirillova et al. 2021c, 2023).

Data on small mammals

The presented dataset contains the results of our field studies of small mammals in the Mordovia Nature Reserve and the National Park "Smolny" conducted in 2018–2023. This dataset is based on helminthological studies on soricomorphs and myomorph rodents, as well as the survey of chiropterans. The capture of small mammals was conducted in accordance with agreements on scientific cooperation with the Federal State Budgetary Institution "Zapovednaya Mordovia" as part of the survey of small mammals, which is carried out annually in both protected areas.

Myomorph rodents and shrews were captured using spring metal snap traps (120×55 mm). Trap lines with 20 snap traps at 10 m intervals were installed in forests, along the forest edges, the banks of small rivers and streams, and in meadows. Pieces of rye bread fried in sunflower oil were placed in the traps. Small rodents and shrews were captured over five days at each site.

Chiropterans were caught at nights using mist nets. Capture was carried out in the first half of the night, during the period of greatest activity of these animals. We

used the common method of stretching a mist net between two sticks (Jones et al. 1996). Telescopic fishing rods 6 m long, tied to metal pegs dug into the ground, were used as poles. As a rule, we caught bats at each research site for 2–3 nights. After examination, we released the bats at the capture site.

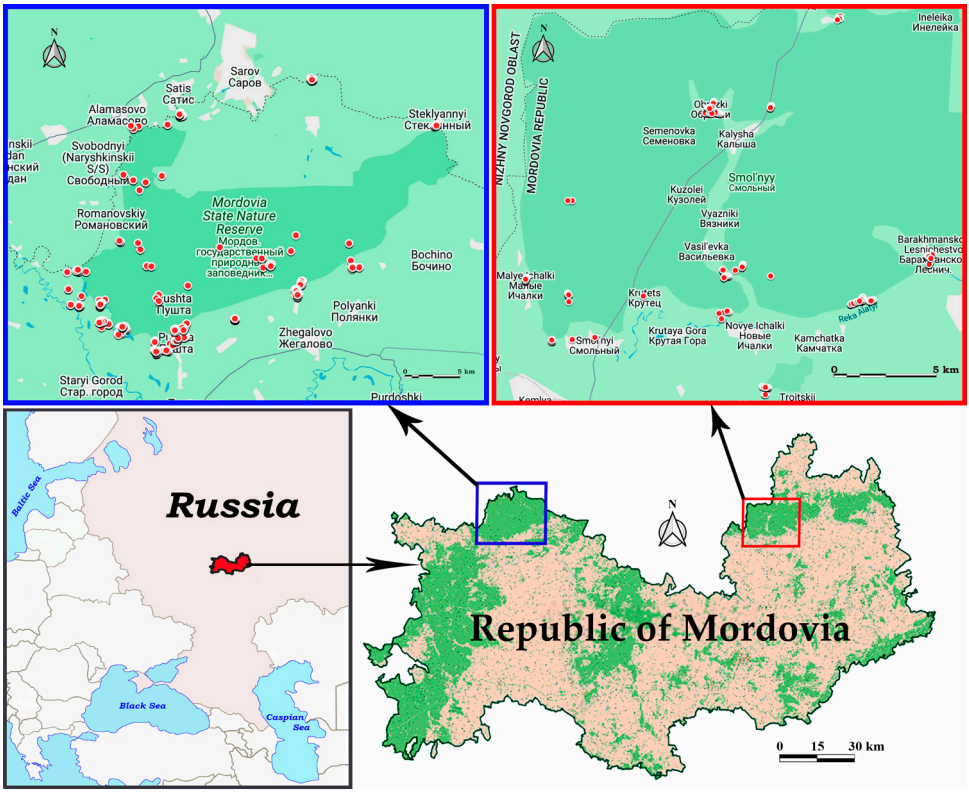

Figure 1. Schematic map of the occurrences of small mammals in the Mordovia Nature Reserve (blue frame) and National Park "Smolny" (red frame). Red circles on the map mark locations where animals were observed.

Part of the material on small mammals (mainly shrews) was obtained during the study of insects in the Mordovia Nature Reserve using pitfall traps (0.5-L plastic cups with 200 ml of a 4% formaldehyde) (Golub et al. 2012). Data on *E. roumanicus*, *T. europaea* and *S. vulgaris* were obtained by searching for road-kill animals and/or direct natural observations.

The sex of small mammals was determined both visually and by helminthological necropsy of small rodents and shrews. We determined the age of small mammals by the degree of development of their thymus and genitalia (Bashenina 1981). In bats, age was determined visually by the degree of mineralization of cartilage tissue in the joints of the forelimbs (Smirnov and Vekhnik 2014; Swartz and Middleton

2008). Small mammals were divided into three age groups: juveniles (young animals), subadults (immature) and adults (mature).

In addition, we obtained information about the reproductive state of females noted pregnancy and the number of embryos in female small rodents and shrews. In female bats, the presence of pregnancy was detected visually, and the lactating or post-lactation state was also noted.

Taxonomic identification of small mammals was carried out according to Macdonald and Barett (2001), Pavlinov et al. (2002), Bystrakova et al. (2008), Zaitsev (2014), Dietz and Kiefer (2016). The taxonomy of small mammals was given according to the GBIF database (https://www.gbif.org/, accessed on 14 January 2024).

The geographic coordinates of each record are provided for the first time. We made all geographical references by recording the coordinates of research sites, using a GPS device or Google maps (https://www.google.ru/maps/). The accuracy of coordinate measurements is 10 m. The accuracy of determining coordinates is up to the fourth digit. All records use the WGS-84 coordinate system.

Data were visualized using "R" programming language (2024) with "treemapify" (Wilkins 2024) and "ggplot2" (Wickham 2016) packages. The degree of similarity of two protected areas in the species composition of small mammals was determined using the Jaccard index (C_J). To determine species diversity, the Shannon index (H') was calculated. The significance of differences between the values of the Shannon index was assessed using Student's t-test (Magurran 1992).

All data is additionally available as a MySQL database for local use at: https://figshare.com/articles/dataset/mammals_db/25285288 (Figshare 2024). Accession options are provided in the attached "readme.txt" file.

This study was approved by the Bioethics Committee of the Institute of Ecology of Volga River Basin of RAS (Registration number: 1/24; 26 March 2024). Our research was conducted in compliance with the ethical standards of humane treatment of animals in accordance with the recommended standards described by the Directive of the European Parliament and of the Council of the European Union of 22 September 2010, "On the protection of animals used for scientific purposes" (EU Directive 2010/63/EU).

Results and discussion

Structure of dataset

The dataset contains 7950 records of small mammals (Erinaceomorpha, Soricomorpha, Chiroptera and Rodentia) including 5672 records in the Mordovia Nature Reserve and 2278 records in the National Park "Smolny".

We chose standard terms from the Darwin Core (https://dwc.tdwg.org/list/#2-use-of-terms) to describe our database (Darwin Core 2024). Each record includes

basic information about location (latitude/longitude), date, age and sex of the specimen, reproductive state of females, names of the observer and identifier (Table 1).

Table 1. Description of the dataset

Column Label	Column Description
occurrenceID	An identifier for the occurrence (as opposed to a particular digital record of the occurrence)
basisOfRecord	The specific nature of the data record: LivingSpecimen, PreservedSpecimen or HumanObservation
scientificName	The full scientific name, including the genus name and the lowest level of taxonomic rank with the authority
kingdom	The full scientific name of the kingdom in which the taxon is classified
phylum	The full scientific name of the phylum or division in which the taxon is classified
class	The full scientific name of the class in which the taxon is classified
order	The full scientific name of the order in which the taxon is classified
family	The full scientific name of the family in which the taxon is classified
lifeStage	The age class or life stage of the Organism(s) at the time the Occurrence was recorded
sex	The sex of the biological individual(s) represented in the Occurrence
reproductiveCondition	The reproductive condition of the biological individual(s) represented in the Occurrence
decimalLatitude	The geographic latitude of location in decimal degree
decimalLongitude	The geographic longitude of location in decimal degrees
geodeticDatum	The ellipsoid, geodetic datum or spatial reference system (SRS) upon which the geographic coordinates given in decimalLatitude and decimalLongitude are based
locality	A spatial region or named place
eventDate	The date when the Event occurred
recordedBy	A person responsible for recording the original Occurrence
identifiedBy	A list of names of people who assigned the Taxon to the subject

Dataset description

The dataset lists 35 species of small mammals from 21 genera and 9 families that we found in the Mordovia Nature Reserve and National Park "Smolny" and documented simultaneously with geographic coordinates (Table 2).

For the dataset, we identified all small mammals to the species level. The East European vole, *Microtus levis* Miller, 1908 and the common vole, *M. arvalis* are sibling species. In a significant part of Eurasia, including the Middle Volga region, these two rodent species are sympatric (Baranovskiy et al. 1994; Okulova et al. 2008; Yalkovskaya et al. 2012; Stakheev et al. 2023). Molecular-genetic studies of these

similar rodent species have not been conducted in the study area. Therefore, occurrences of *M. arvalis* may include those of *M. levis*.

In our dataset the largest families in terms of species richness are Vespertilionidae (10 species), Soricidae (7), Cricetidae (6) and Muridae (6) (Figure 2). This is 82.8% of all small mammal species found in the two protected areas of Mordovia. The family Gliridae is represented here by only two species. In the Mordovia Nature Reserve and National Park "Smolny" there is only one species each from the families Erinaceidae, Sciuridae, Sminthidae and Talpidae.

Table 2. Taxa included in our database

Rank	Scientific Name	Common Name
kingdom	Animalia	animals
phylum	Chordata	chordates
class	Mammalia	mammals
order	Chiroptera	bats
order	Erinaceomorpha	erinaceomorphs
order	Rodentia	rodents
order	Soricomorpha	soricomorphs
family	Cricetidae	hamsters
family	Erinaceidae	hedgehogs
family	Gliridae	dormice
family	Muridae	murids
family	Sciuridae	squirrels
family	Sminthidae	birch mice
family	Soricidae	shrews
family	Talpidae	moles
family	Vespertilionidae	vesper bats
species	*Myotis brandtii* Eversmann, 1845	Brandt's bat
species	*Myotis dasycneme* (Boie, 1825)	pond bat
species	*Myotis daubentonii* (Kuhl, 1817)	Daubenton's bat
species	*Myotis nattereri* (Kuhl, 1817)	Natterer's bat
species	*Nyctalus leisleri* (Kuhl, 1817)	Leisler's bat
species	*Nyctalus noctula* (Schreber, 1774)	Noctule bat
species	*Pipistrellus nathusii* Keyserling & Blasius, 1839	Nathusius' pipistrelle
species	*Pipistrellus pygmaeus* Leach, 1825	Soprano pipistrelle
species	*Plecotus auritus* (Linnaeus, 1758)	brown long-eared bat
species	*Vespertilio murinus* Linnaeus, 1758	parti-coloured bat
species	*Erinaceus roumanicus* Barrett-Hamilton, 1900	northern white-breasted hedgehog

Rank	Scientific Name	Common Name
species	*Crocidura suaveolens* (Pallas, 1811)	lesser white-toothed shrew
species	*Neomys milleri* Mottaz, 1907	Mediterranean water shrew
species	*Neomys fodiens* Pennant, 1771	Eurasian water shrew
species	*Sorex araneus* Linnaeus, 1758	Eurasian common shrew
species	*Sorex caecutiens* Laxmann, 1788	Laxmann's shrew
species	*Sorex isodon* Turov, 1924	Taiga shrew
species	*Sorex minutus* Linnaeus, 1766	Eurasian pygmy shrew
species	*Talpa europaea* Linnaeus, 1758	European mole
species	*Apodemus agrarius* (Pallas, 1771)	striped field mouse
species	*Apodemus flavicollis* (Melchior, 1834)	yellow-necked wood mouse
species	*Apodemus uralensis* (Pallas, 1811)	pygmy wood mouse
species	*Micromys minutus* (Pallas, 1771)	harvest mouse
species	*Mus musculus* Linnaeus, 1758	house mouse
species	*Rattus norvegicus* (Berkenhout, 1769)	Norway rat
species	*Sicista betulina* Pallas, 1779	Northern birch mouse
species	*Sciurus vulgaris* Linnaeus, 1758	red squirrel
species	*Glis glis* (Linnaeus, 1766)	edible dormouse
species	*Dryomys nitedula* (Pallas, 1778)	forest dormouse
species	*Arvicola amphibius* (Linnaeus, 1758)	European water vole
species	*Myodes glareolus* (Schreber, 1780)	bank vole
species	*Microtus agrestis* (Linnaeus, 1761)	short-tailed field vole
species	*Microtus cf arvalis* (Pallas, 1778)	common vole / east European vole
species	*Microtus oeconomus* (Pallas, 1776)	root vole
species	*Microtus subterraneus* (de Selys-Longchamps, 1836)	European pine vole

In terms of the number of species, four genera of small mammals predominate: *Microtus*, *Myotis*, and *Sorex* (4 species each), and *Apodemus* (3 species), constituting 48.6% of all animal species in the dataset. The remaining genera of small mammals are represented by one or two species.

Among all occurrences of small mammals in two protected areas, the proportion of Rodentia is much higher (63.4%) than those of Chiroptera (27.9%), Soricomorpha (8.6%), and Erinaceomorpha (0.1%). This is typical for both the Mordovia Nature Reserve and the National Park "Smolny" (Figure 3). The occurrence of hedgehogs (Erinaceomorpha) is low (9 records in both protected areas) and is not shown in Figure 3.

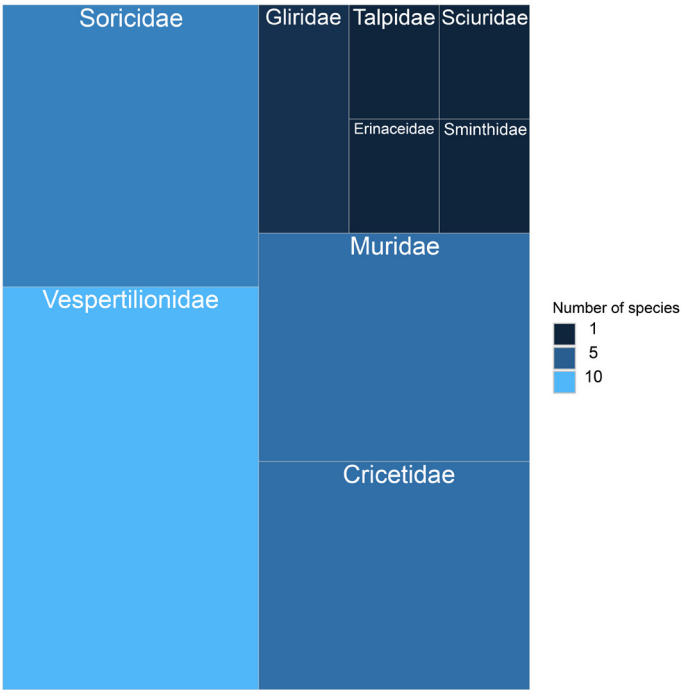

Figure 2. Taxonomic distribution of animal species by family in the dataset.

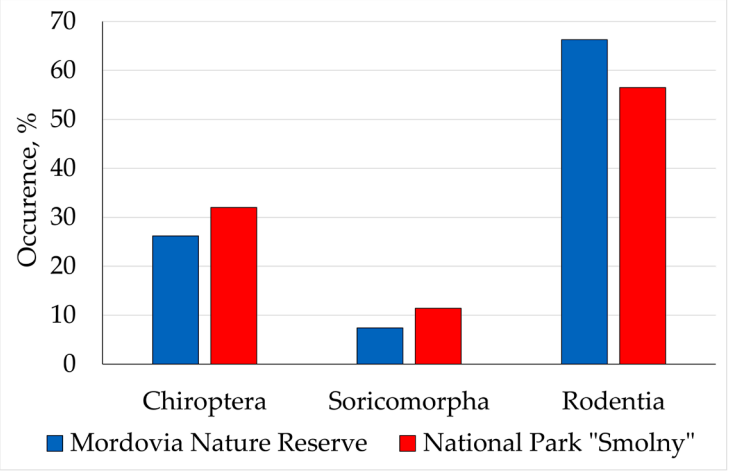

Figure 3. Distribution of small mammals by order in two protected areas.

The number of occurrences of small mammals of different families and genera is shown in Figure 4. The families Muridae (2557 occurrences), Cricetidae (2457), and Vespertilionidae (2217) also predominate here, accounting for 91.0% of all occurrences in the dataset (Figure 4). Moreover, 91.5% of them belong to four genera from these families: *Apodemus* (2546), *Myodes* (2275), *Nyctalus* (1102) and *Pipistrellus* (697), as well as the genus *Sorex* (661) from the family Soricidae (Figure 4).

In our dataset, *M. glareolus* (28.6%), *A. uralensis* (16.6%), *N. noctula* (13.4%) and *A. flavicollis* (12.0%) predominate in occurrence in both protected areas. In the Mordovia Nature Reserve, the same species of micromammals dominate: *M. glareolus* (32.6%), *A. uralensis* (18.0%), *N. noctula* (15.8%), *A. flavicollis* (12.1%). In the NP "Smolny" the composition of dominants is somewhat different: *M. glareolus* (18.7%), *A. uralensis* (13.1%), *P. nathusii* (14.1%), *A. flavicollis* (11.6%), *S. araneus* (10,8%).

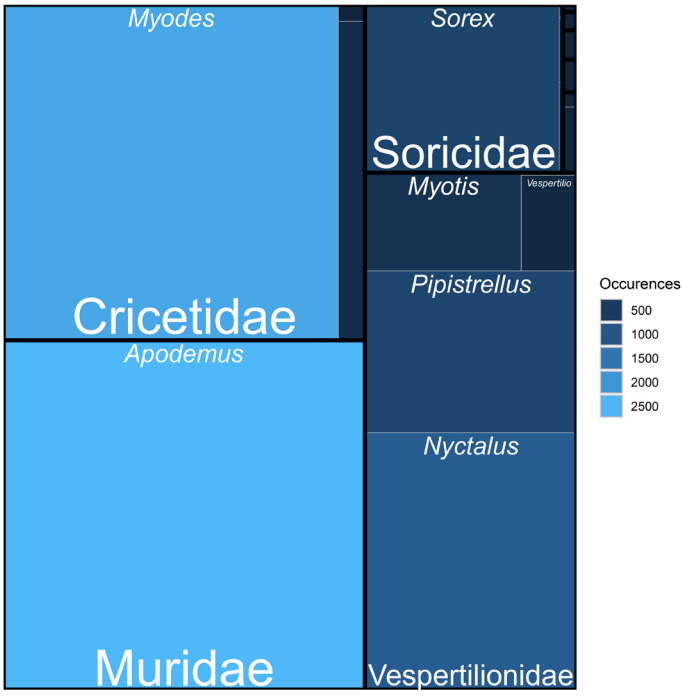

Figure 4. Distribution of occurrences among families in the dataset.

Our dataset contains age and sex data for mammals of the orders Soricomorpha, Chiroptera and Rodentia. These data can serve as a basis for analyzing the population structure of various species of small mammals. For example, Figure 5 shows the age and gender structure of the most abundant bat species in our dataset, *N. noctula*.

Based on the results of our bat survey in 2018–2023, we found that females of *N. noctula* significantly outnumbered males in both protected areas. Moreover,

subadult individuals of both sexes predominate in the bat population (Figure 5). As with other species of migratory bats, mainly females of *N. noctula* fly to the Middle Volga region to breed their offspring. Only solitary males fly with females. Thus, during our study, only 6 occurrences of adult males were recorded.

In addition, our dataset provides information on the reproductive status of females of small mammals. Thus, out of 157 adult females of *N. noctula* encountered in the Mordovia Nature Reserve, 153 individuals were in the post-lactation period. Four recorded adult females were infertile. Six pregnant, two lactating and 36 post-lactation females were registered in the National Park "Smolny" (Kirillova et al. 2024). Findings of such females indicate the presence of bat brood colonies in the study area.

Our data includes specimens of small mammals whose sex and age were not determined. This is due to the fact that their carcasses in traps were eaten by forest carnivores (mainly mustelids) and shrews. In such cases the animal's head was usually left in the traps, from which only the species could be identified.

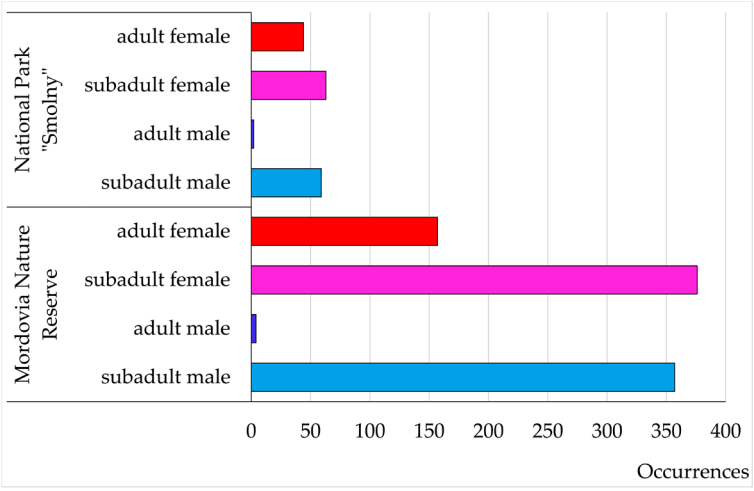

Figure 5. Distribution of *Nyctalus noctula* individuals by age and sex in the dataset.

Various ecological groups of small mammals live in the protected areas of Mordovia. Most of them are mesophilic species (29 out of 35), preferring moist habitats (deciduous and mixed forests, thickets, tall-grass meadows and hayfields). Of these, 24 species are members of the forest faunal complex (all bat species, *E. roumanicus*, *S. araneus*, *S. caecutiens*, *S. isodon*, *S. minutus*, *T. europaea*, *A. agrarius*, *A. flavicollis*, *A. uralensis*, *S. vulgaris*, *G. glis*, *D. nitedula*, *M. glareolus*, and *S. betulina*). The meadow faunal complex includes *C. suaveolens*, *M. minutus*, *M. agrestis*, *M. cf arvalis*, and *M. subterraneus*.

Arvicola amphibius, *M. oeconomus*, *N. milleri*, and *N. fodiens* belongs to the floodplain faunal complex. Occurrences of these hydrophilic species were recorded in wetlands, along the banks of small rivers, streams and lakes.

Synanthropic rodents are *M. musculus* and *R. norvegicus*, which usually live near humans. However, the occurrence of a single individual of *M. musculus* was recorded in the National Park "Smolny" far from human habitation.

According to the lifestyle of small mammals encountered, they can be divided into flying (all bat species), tree-dwelling (*S. vulgaris*, *G. glis*, *D. nitedula*), semi-aquatic (*A. amphibious*, *N. milleri*, *N. fodiens*), terrestrial (*E. roumanicus*, *C. suaveolens*, *S. araneus*, *S. caecutiens*, *S. isodon*, *S. minutus*, *A. agrarius*, *A. flavicollis*, *A. uralensis*, *M. minutus*, *M. musculus*, *R. norvegicus*, *M. agrestis*, *M. cf arvalis*, *M. oeconomus*, *M. subterraneus*, *M. glareolus*, *S. betulina*) and underground (*T. europaea*) species.

We found 30 species of small mammals in the Mordovia Nature Reserve, and 27 species in the National Park "Smolny". In both protected areas 21 species of micromammals are common. For small mammals from two protected areas, an average degree of similarity in species composition was noted according to the Jaccard index (0.58).

This is due to the fact that 8 species of small mammals were found only in the Mordovia Nature Reserve (*C. suaveolens*, *N. milleri*, *S. caecutiens*, *S. isodon*, *P. auritus*, *R. norvegicus*, *D. nitedula*, and *M. oeconomus*), and 5 rodent species were found only in the National Park "Smolny" (*M. musculus*, *S. vulgaris*, *G. glis*, *A. amphibious*, and *M. subterraneus*). A comparison of the small mammal fauna of two protected areas according to the Shannon species diversity index (H') showed that the species diversity of small mammals in the National Park "Smolny" is higher than in the Mordovia Nature Reserve – 2.387 and 2.087, respectively. The value of the Shannon diversity index for small mammals of the Mordovia Nature Reserve is lower, which is associated with the high abundance of two species of small mammals in this protected area (*A. uralensis* and *M. glareolus*). For the fauna of small mammals in both protected areas, the differences in Shannon index values are statistically significant ($P < 0.001$).

The diversity of small mammals noted in the protected areas of Mordovia is typical for European Russia (Table 3).

The species richness of 9 families of small mammals that we recorded in Mordovia varies in different regions of European Russia. This is due to the varying degrees of knowledge of the fauna of small mammals. As a rule, in certain regions of Russia only one group or order of small mammals has been well studied. There are no comprehensive studies including representatives of all families and orders. Therefore, the prospect of further study of small mammals requires complex faunistic approaches, including the use of molecular genetic methods. On the territory of European Russia, this will make it possible to clarify the distribution of mammals, the species identity of which still remains problematic.

Table 3. Comparison of biodiversity of some regions of European Russia at the family level

Family	Mordovia (this study)	Samarskaya Luka (Smirnov and Vekhnik 2012; Kirillova et al. 2021a, 2021b)	Karelia (Sikkilya 2014; Yakimova and Gaidysh 2021; Medvedev and Pozdnyakov 2003; Belkin et al. 2015)	Ryazan Oblast (Didorchuk et al. 2005; Ivanchev 2005)	Saratov Oblast (Novichkova and Zavyalov 2009; Tsvetkova and Oparin 2016; Chekashov et al. 2020)	Nizhny Novgorod Oblast (Bakka and Bakka 1999; Gelashvili et al. 1999; Boryakova et al. 2010; Dmitriev et al. 2016)	Voronezh Oblast (Klimov 2013; Vyshegorodskikh 2015; Smirnov et al. 2023)
Vespertilionidae	10[1]	15	7	11	12	12	15
Erinaceidae	1	1	0	1	0	0	0
Soricidae	7	4	6	7	3	4	4
Talpidae	1	1	1	1	0	0	0
Cricetidae	6	6	8	5	6	7	4
Muridae	6	6	3	4	5	6	5
Gliridae	2	2	0	0	0	2	1
Sciuridae	1	2	0	0	0	0	4
Sminthidae	1	–	1	1	1	1	1
Total	35	37	26	30	27	32	34

Note: [1] Number of species.

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References

Ahissa L, Akpatou BK, Bohoussou HK, Kadjo B, Kone I (2020) Species composition and community structure of terrestrial small mammals in Tanoé--Ehy Swamp Forest (South-East Ivory Coast): Implication for conservation. Nature Conservation Research 5: 53–63. https://dx.doi.org/10.24189/ncr.2020.005

Andreychev A (2020a) Ecological and faunal complexes of insectivorous mammals of the Republic of Mordovia, Russia. Biodiversitas 21: 3344–3349. https://doi.org/10.13057/biodiv/d210758

Andreychev A (2020b) Short Communication: Proportion faunal assemblage of rodents in geoecological districts of Mordovia, Russia. Biodiversitas 21(9): 3961–3968. https://doi.org/10.13057/biodiv/d210906

Andreychev AV, Kuznetsov VA (2020) Checklist of rodents and insectivores of the Mordovia, Russia. ZooKeys 1004: 129–139. https://doi.org/10.3897/zookeys.1004.57359

Artaev ON, Smirnov DG (2016) Bats (Chiroptera; Mammalia) of Mordovia: specific structure and features of distribution. Nature Conservation Research 1(1): 38–51. https://doi.org/10.24189/ncr.2016.004

Artaev ON, Ruchin AB, Bugaev KE, Grishutkin GF, Potapov SK, Spiridonov SN (2012) Vertebrates of the Mordovia State Nature Reserve. Flora and Fauna of Reserves 120. Committee of RAS for the conservation of biological diversity, Moscow, 64 pp. [In Russian]

Bakka AI, Bakka SV (1999) Bats of the Nizhny Novgorod. Plecotus et al. 2: 44–59. [In Russian with English summary]

Baranovskiy PM, Bogomolov PL, Karaseva EV, Demidova TN (1994) Distribution of East European and common voles. In: Sokolov VE, Karaseva EV (Eds) Synanthropy of rodents. Russian Academy of Sciences, Ivanovo-Moscow, 77–87. [In Russian]

Bashenina NB (1981) Ontogenesis. In: Bashenina NB (Ed.) European bank vole. Nauka, Moscow, 211–227. [In Russian]

Bazhenov YuA (2021) Ecology of bat species in the arid region of the Daurian steppe at the peak of drought. Nature Conservation Research 6(1): 42–49. https://dx.doi.org/10.24189/ncr.2021.007

Belkin VV, Panchenko DV, Tirronen KF, Yakimova AE, Fedorov FV (2015) Ecological status of bats (Chiroptera) in winter roosts in Eastern Fennoscandia. Russian Journal of Ecology 46(5): 374–380. https://doi.org/10.1134/S1067413615050045

Bobretsov AV (2016) Population ecology of small mammals in plain and mountain landscapes of the North-East of the European part of Russia. KMK, Moscow, 381 pp. [In Russian]

Bordes F, Blasdell K, Morand S (2015) Transmission ecology of rodent-borne diseases: New frontiers. Integrative Zoology 10: 424–435.

Boryakova EE, Melnik SA, Sizov ON (2010) Plant cover and distribution of small mammals in the Nizhny Novgorod Predvolzhie. Bulletin of Nizhny Novgorod University 2(2): 376–382. [In Russian]

Bystrakova NV, Ermakov OA, Titov SV (2008) Keys to small mammals (Orders Insectivora, Rodentia) of the Middle Volga region. Penza State Pedagogical University, Penza, 56 pp. [In Russian]

Chavan V, Penev L (2011) The data paper: a mechanism to incentivize data publishing in biodiversity science. BMC Bioinformatics 12 (Suppl 15): S2. https://doi.org/10.1186/1471-2105-12-S15-S2

Chekashov VN, Zakharov KS, Magerramov ShV, Selenina AG, Martsokha KS, Shilov MM, Sludsky AA, Ermakov NM, Korneev MG, Tolokonnikova SI, Tarasov MA, Sonin VK,

Romanov RA, Matrosov AN, Popov NV (2020) Ecological aspects of an outbreak of Hemorrhagic fever with renal syndrome in the territory of the Saratov region. Povolzhskiy Journal of Ecology 3: 353–366. https://doi.org/10.35885/1684-7318-2020-3-353-366 [In Russian]

Cheveau M, Drapeau P, Imbeau L, Bergeron Y (2004) Owl winter irruptions as an indicator of small mammal population cycles in the boreal forest of eastern North America. Oikos 107: 190–198.

Cutko A (2009) Biodiversity Inventory of Natural Lands: A How-To Manual for Foresters and Biologists. NatureServe, Arlington, Virginia, 40 pp.

Darwin Core. https://dwc.tdwg.org/list/#2-use-of-terms (accessed 22 May 2024).

Data's shameful neglect (2009) Nature 461: 145. https://doi.org/10.1038/461145a

Davidson AD, Detling J, Brown JH (2012) Ecological roles and conservation challenges of social, burrowing, herbivorous mammals in the world's grasslands. Frontiers in Ecology and the Environment 10(9): 477–486. https://doi.org/10.1890/110054

Deharveng L, Bedos A, Daugeron C, Villemant C, Judson MI (2015) Organization, usefulness and limitations of an ATBI (All Taxa Biodiversity Inventory): the inventory of terrestrial invertebrates in the Mercantour National Park. Zoosystema 37(1): 9–30. https://doi.org/10.5252/z2015n1a1

Dickman CR (1999) Rodent-ecosystem relationships: a review. In: Singelton G, Leirs L, Zhang Z (Eds) Ecologically based rodent manadgment. Australian Centre for International Agricultural Reseach, Canberra, 113–133.

Didorchuk MV, Panchenko IM, Antonyuk EV (2005) Long-term changes in the species composition and number of amphibians and small mammals in a model area of the above floodland terrace of the Pry River. Proceedings of the Oksky Nature Reserve 24: 135–154. [In Russian]

Dietz C, Kiefer A (2016) Bats of Britain and Europe. Bloomsbury Publishing, London, 400 pp.

Dmitriev AI, Krivonogov DM, Trushkova MA, Zamoreva ZhA (2016) Assessment of existence conditions of small mammal communities after large forest fires of 2010 under a conservation regime. Proceedings of the State Nature Biosphere Reserve "Kerzhensky" 8: 85–95. [In Russian]

Elkinton JS, Liebhold AM, Muzika R-M (2004) Effects of alternative prey on predation by small mammals on gypsy moth pupae. Population Ecology 46(2): 171–178. https://doi.org/10.1007/s10144-004-0175-y

Figshare. MySQL database (2024) https://figshare.com/articles/dataset/mammals_db/25285288 (accessed 5 May 2024).

GBIF (2024) https://www.gbif.org/ (accessed 23 May 2024).

Gelashvili DB, Ushakov VA, Slepov AV, Dmitriev AI, Zamoreva ZhA (1999) Ecological characteristics of small mammals in the Nizhny Novgorod Trans-Volga region. Bulletin of Nizhny Novgorod University. Biological series 1: 51–59. [In Russian]

Google Maps (2024) https://www.google.ru/maps/ (accessed 23 May 2024).

Grishutkin GF, Lapshin AS, Spiridonov SN, Artaev ON, Ruchin AB, Kuznetsov VA, Andreychev AV (2013) Vertebrates of the National Park "Smolny". Flora and Fauna of National

Parks 124. Committee of RAS for the conservation of biological diversity, Moscow, 56 pp. [In Russian]

Golub VB, Tsurikov MN, Prokin AA (2012) Insect Collections: Collection, Processing and Storage of Material. KMK, Moscow, 339 pp. [In Russian]

Hope AG, Waltari E, Morse NR, Flamme M, Cook JA, Talbot S (2017) Small mammals as indicators of climate, biodiversity, and ecosystem change. Alaska Park Science 16: 72–78.

Hornfeldt B, Hipkiss T, Eklund U (2005) Fading out of vole and predator cycles? Proceedings of the Royal Society B 272(1576): 2045–2049. https://dx.doi.org/10.1098/rspb.2005.3141

Ivanchev VP (2005) Dynamics of the vertebrate animal fauna of the Oksky Nature Reserve (1935–2004). Proceedings of the Oksky Nature Reserve 24: 273–305. [In Russian]

Jones C, McShea WJ, Conroy J, Kunz JH (1996) Capturing mammals. In: Wilson DE, Cole FR, Nichils JD, Rudran R, Foster MS (Eds) Measuring and monitoring biological diversity: standard methods for mammals. Smithsonian Institution Press, Washington, DC, 115–155.

Khapugin AA, Vargot EV, Chugunov G, Shugaev NI (2016) Invasion of alien plants in fire-damaged forests at southern boundary of the taiga zone. Forest Systems 25(3): 2171–9845. http://dx.doi.org/10.5424/fs/2016253-09461

Kirillova NYu, Kirillov AA (2023) The first record of *Nyctalus leisleri* (Kuhl, 1817) (Chiroptera, Vespertilionidae) in the Mordovia Nature Reserve (European Russia). Proceedings of Samara Scientific Center of RAS 5: 31–37. [In Russian]

Kirillova NYu, Kryštufek B, Kirillov AA, Ruchin AB, Grishutkin GF (2019) The first record of *Microtus subterraneus* (de Sélys-Longchamps, 1836) (Rodentia, Cricetidae) for Mordovia, Russia. Acta Biologica Sibirica 5(4): 145–149. https://doi.org/10.14258/abs.v5.i4.7149

Kirillova N, Kirillov A, Vekhnik V, Klenina A (2021a) Occurrence of the insectivores and rodents of the Samarskaya Luka (Russia). Occurrence dataset. Version 1.6. Institute of Ecology of the Volga river basin of Russian Academie of Science, https://www.gbif.org/dataset/126ccf3a-0c99-466d-8aea-95d3e6d30acc

Kirillova N, Kirillov A, Vekhnik V, Klenina A (2021b) Occurrence of the insectivores and rodents in the Samarskaya Luka (European Russia). Biodiversity Data Journal 9: e68315. https://doi.org/10.3897/BDJ.9.e68315

Kirillova N, Ruchin A, Kirillov A (2021c) Helminths in myomorph rodents (Rodentia, Myomorpha) from the National Park “Smolny” and its surroundings (European Russia). Forests 12: 1510. https://doi.org/10.3390/f12111510

Kirillova NYu, Ruchin AB, Kirillov AA, Chikhlyaev IV, Alpeev MA (2023) Overview of helminths in land vertebrates from the Mordovia Nature Reserve, European Russia. Nature Environment & Pollution Technology 22(4): 1667–1690. https://doi.org/10.46488/NEPT.2023.v22i04.001

Kirillova NYu, Kirillov AA, Ruchin AB, Alpeev MA, Smirnov DG, Vekhnik VP (2024) Occurrence of small mammals in Mordovia State Nature Reserve and National Park “Smolny” (European Russia). Occurrence dataset. Version 1.1. Joint Directorate of the Mordovia State Nature Reserve and National Park "Smolny", https://doi.org/10.15468/wtucv2

Klimov AS (2013) Perennial abundance dynamics and the modern state of small mammalian species in lowland swamps of the Usmansky pine forest (Voronezh region). Povolzhskiy Journal of Ecology 1: 42–50. [In Russian]

Kollberg I, Bylund H, Huitu O, Björkman Ch (2014) Regulation of forest defoliating insects through small mammal predation: reconsidering the mechanisms. Oecologia 176(4): 975–983. https://doi.org/10.1007/s00442-014-3080-x

Krebs CJ, Boonstra R, Boutin S, Sinclair ARE, Smith JNM, Gilbert BS, Martin K, O'Donoghue M, Turkington R (2014) Trophic dynamics of the boreal forests of the Kluane region. Arctic 67: 71–81.

Krucken J, Blumke J, Maaz D, Demeler J, Ramunke S, Antolova D, Schaper R, von Samson-Himmelstjerna G (2017) Small rodents as paratenic or intermediate hosts of carnivore parasites in Berlin, Germany. PLoS ONE 12: e0172829. https://doi.org/10.1371/journal.pone.0172829

Leis SA, Leslie Jr DM, Engle DM, Fehmi JS (2008) Small mammals as indicators of short-term and long-term disturbance in mixed prairie. Environmental Monitoring and Assessment 137(1-3): 75–84. https://doi.org/10.1007/s10661-007-9730-2

Lyubimov A, Kryuchkov A, Eglit A, Ivanova D, Khumalo N (2018) Improvement of the strictly protected areas nets in Russian Federation. Samarskaya Luka: Problems of Regional and Global Ecology 27: 17–20. https://dx.doi.org/10.24411/2073-1035-2018-10131 [In Russian]

Macdonald DW, Barett P (2001) Mammals of Europe. Princeton University Press, Princeton, 312 p.

Magurran AE (1992) Ecological Diversity and Its Measurement. Mir: Moscow, 182 pp. [In Russian]

Medvedev IV, Pozdnyakov SA (2003) Communities of small mammals in planned protected areas of Karelia. Proceedings of Karelia Scientific Center of RAS 4: 181–186. [In Russian]

Meerburg BG, Singleton GR, Kijlstra A (2009) Rodent-borne diseases and their risks for public health. Critical Reviews in Microbiology 35: 221–270.

Potapova NA, Nazyrova RI, Zabelina NM, Isaeva-Petrova LS, Korotkov VN, Ochagov DM (2006) Reference book of protected areas of the Russian Federation. Vol. 2. ARRINP, Moscow, 364 pp. [In Russian]

Novichkova OV, Zavyalov EV (2009) Comparative analysis of the synanthropization degree of bats (Chiroptera, Mammalia) on the territory of the Saratov region. Bulletin of Mordovia State University 19(1): 138–140. [In Russian]

Okulova NM, Sapelnikov SF, Baskevich MI, Vlasova OP, Mayorova AD, Egorov SV, Mironova TA, Sarychev VP (2008) Comparative ecology of three forms of common voles *Microtus arvalis* sensu lato in the Central Black Earth region. Scientific statements 43(3): 128–139. [In Russian]

Pavlinov IYa, Kruskop SV, Varshavsky AA, Borisenko AV (2002) Terrestrial animals of Russia. Reference book-definition. KMK, Moscow, 298 pp. [In Russian]

Pearce J, Venier L (2005) Small mammals as bioindicators of sustainable boreal forest management. Forest Ecology and Management 208: 153–175. https://dx.doi.org/10.1016/J.FORECO.2004.11.024

Penev L, Mietchen D, Chavan V, Hagedorn G, Smith V, Shotton D, O Tuama E, Senderov V, Georgiev T, Stoev P, Groom Q, Remsen D, Edmunds S (2017) Strategies and guidelines for scholarly publishing of biodiversity data. Research Ideas and Outcomes 3: e12431. https://doi.org/10.3897/rio.3.e12431

R Core Team (2024) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. http://www.r-project.org/index.html (accessed 11 May 2024).

Ruchin AB, Kirillov AA, Chikhlyaev IV, Kirillova NYu (2016) Parasitic worms of land vertebrates of the Mordovia Nature Reserve. Flora and Fauna of Reserves 124. Committee of RAS for the Conservation of Biological Diversity, Moscow, 72 pp. [In Russian]

Rutovskaya MV, Aleksandrov AN, Podshivalina VN, Soboleva AS, Glushenkov OV (2020) Habitat conditions of *Desmana moschata* (Talpidae, Eulipotyphla, Mammalia) in the buffer zone of the Prisurskiy State Nature Reserve (Russia). Nature Conservation Research 5: 36–46. https://dx.doi.org/10.24189/ncr.2020.011

Sikkilya NS (2014) Faunal analysis of small mammals in the Kostomuksha Nature Reserve. Bulletin of Petrozavodsk State University 2(139): 33–35. [In Russian]

Smirnov DG, Vekhnik VP (2012) Biotopic structure of bat communities inhabiting flood plain ecosystems of the Samarskaya Luka. Proceedings of Samara Scientific Center of RAS 14: 177–179. [In Russian]

Smirnov DG, Vekhnik VP (2014) Sex ratio and spatial structure of settled bat species populations (Chiroptera: Vespertilionidae) in the Middle Volga River basin. Zoologicheskii Zhurnal 93(9): 1117–1127. https://doi.org/10.7868/S0044513414090104 [In Russian]

Smirnov DG, Kirillova NYu, Kirillov AA, Ruchin AB, Vekhnik VA (2022) New records of *Nyctalus leisleri* (Kuhl, 1817) and *Myotis nattereri* (Kuhl, 1817) (Mammalia: Chiroptera: Vespertilionidae) from National Park "Smolny" and its surroundings, Republic of Mordovia. Journal of Threatened Taxa 14(8): 21553–21560. https://doi.org/10.11609/jot.6919.14.8.21553-21560

Smirnov DG, Klimov AS, Numerov AD, Trufanova EI (2023) Experience in using an echo meter touch ultrasonic module in studies of the species composition, occurrence, and biotopic preferences of bats (Chiroptera, Vespertilionidae) in Voronezh Oblast. Biology Bulletin 50(7): 1511–1524. https://dx.doi.org/10.1134/S1062359023070245 [In Russian]

Stakheev VV, Khlyap LA, Mironova TA, Abramson NI, Malygin VM, Lissovsky AA (2023) Geographic distribution of *Microtus arvalis* and *Microtus rossiaemeridionalis* in Eastern Europe. Russian Journal of Theriology 22(1): 53–61. https://doi.org/10.15298/rusjtheriol.22.1.06

Strann K, Yoccoz N, Ims R (2002) Is the heart of Fennoscandian rodent cycle still beating? A 14-year study of small mammals and Tengmalm's owls in northern Norway. Ecography 25(1): 81–87. https://doi.org/10.1034/J.1600-0587.2002.250109.X

Swartz SM, Middleton KM (2008) Biomechanics of the bat limb skeleton: scaling, material properties and mechanics. Cells Tissues Organs 187: 59–84. https://doi.org/10.1159/000109964

Tsvetkova AA, Oparin ML (2016) Dynamics of the abundance and community structure of small mammals in the Saratov Trans-Volga region. Povolzhskiy Journal of Ecology 4: 493–506. [In Russian]

Vasilyev AG, Lukyanova LE, Gorodilova YuV (2023) Coupled variation of red-backed vole species in biotopes disturbed by windfall and fire in the Visim State Nature Reserve (the Middle Urals). Nature Conservation Research 8(3): 24–46. https://dx.doi.org/10.24189/ncr.2023.020 [In Russian]

Vyshegorodskikh NV (2015) Species diversity of Chiroptera in the northeast of the Voronezh region. Proceedings of Orel State University 4(67): 135–142. [In Russian]

Yakimova AE, Gaidysh IS (2021) The species composition and abundance of terrestrial small mammals in the Finnish-Russian Friendship Nature Reserve. Nature Conservation Research 6 (Suppl. 1): 127–136. https://dx.doi.org/10.24189/ncr.2021.028

Yalkovskaya L, Markova E, Zykov S, Sibiryakov P (2012) New cytogenetic data on the distribution of the common vole (*Microtus arvalis*) of the obscurus karyotypic form (Arvicolinae, Rodentia) in the Vyatka-Kama CIS-Ural region. Zoologicheskii Zhurnal 91(9): 1109–1113. [In Russian]

Yamashkin AA, Silaeva TB, Alba LD, Gagarin YN, Maslyaev VN, Grishutkin GF (2000) Mordovian National Park "Smolny". Mordovia State University, Saransk, 88 pp. [In Russian]

Zaitsev MV, Voyta LL, Sheftel BI (2014) The mammals of Russia and adjacent territories. Lipotyphlans. Zoological Institute Russian Academy of Sciences, Saint Petersburg, 391 pp. [In Russian]

Wickham H (2016) ggplot2: Elegant Graphics for Data Analysis. 3rd edition. Springer, New York. https://ggplot2-book.org/ (accessed 12 May 2024).

Wilkins D (2021) Treemapify: Draw Treemaps in 'ggplot2'. R Package Version 2.5.5. https://CRAN.R-project.org/package=treemapify (accessed 12 May 2024).