

Original Research Paper

Comparative Characterization of Small Mammal Communities in Forest-Steppe and Steppe Landscapes of the South of Western and Central Siberia

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Abstract: This study analyzes the fauna, population, and distribution patterns of small mammals of forest-steppe and steppe landscapes of the south of Western and Central Siberia for the period between 1998 and 2021 on the basis of literature data and authors' own materials. Most of these studies were local in nature, while our work is characterized by a generalizing and comparative approach. Seven key research sites were analyzed. Four sites are located in the south of Western Siberia: Ishim forest-steppe (Russian Federation, Tyumen Region), Pre-Irtysh Plain (Kazakhstan, Pavlodar Region), North-Kulunda Plain (Russian Federation, Novosibirsk Region) and Prealtai Foothill Plain (Russian Federation, Altai region). Three sites are localized within the south of central Siberia: Central Tuva Basin (Russian Federation, Republic of Tyva), Shirin and Koibal steppes (Russian Federation, Republic of Khakassia), tazheran steppe of Baikal region (Russian Federation, Irkutsk region). A brief description is given for each site, indicating geographical location, biotopes surveyed, timeline of work, and authors. Population counts and captures of small mammals were carried out according to generally accepted zoological methods. Pitfall trap methods as well as snap traps were used in capturing animals. The dominance structure of each community was assessed using a dominance index representing the proportion of species in the community. To characterize community structure, the first five species were identified by abundance. The dominant species were considered to be those whose proportion in the community was 10% or more. The identification of faunistic complexes was based on faunogenetic and landscape-zonal approaches. Determination of the similarity degree between small mammal communities from different areas was carried out using the method of cluster analysis based on qualitative and quantitative indicators of Jaccard and Sorensen-Chekanov coefficients, with subsequent analysis of dendrograms. GIS mapping methods were used to create the map. The species composition of small mammals includes 37 species belonging to three orders: Eulipotyphla, lagomorpha, and rodentia. The highest species diversity was observed in the steppes of Khakassia (24 species), the prealtay and north-kulunda plains (20-23 species), and the Ishim forest steppe (19 species). In more arid regions, such as the Pre-Irtysh Plain, the Tuva Basin, and the Tazheran steppes of the Baikal region, the number of species decreases (14-16 species). The fauna of small mammals of the studied area is a mixture of species typical of steppes and semideserts of Asia, taiga regions of Siberia, and coniferous-broadleaved forests of Europe. Eight faunistic complexes have been recorded throughout the entire study area, three of which occur everywhere (Boreal, Kazakh-European, European). Of these, the Boreal faunal complex is the most diverse, with a proportion of 38-57% at different sites. The Kazakh-European faunistic complex with the

highest proportion is represented in Northern Kazakhstan (31%) and the highest participation of species of the European faunistic complex is found in the Ishim forest-steppe (16%) and North-Kulunda plain (15%). The dominant structure of small mammal communities in the south of Western and Central Siberia is characterized as disturbed, with a sharp predominance of one or two species over other dominants. The dominant species at all studied sites include the narrow-headed Vole with a share of 16-43% and the striped field mouse, which is distributed unevenly among the leading species, with a share of 11-47%. More sporadically, as leaders in abundance, the tundra Shrew, southern birch mouse, steppe lemming, common Vole, striped field mouse, and harvest mouse are distributed. Only in central Siberia, the striped hamster was identified as the dominant species (19%), and in western Siberia on the territory of the pre-Irtysh plain the Siberian (striped) desert hamster (10%). The highest level of similarity in species composition was revealed between the small mammal communities of the Tuva Basin and the Tazheran steppes of the Baikal region, located in central Siberia, as well as between the north-kulunda and pre-Irtysh plains, localized in western Siberia. The small mammal community of the steppes of Khakassia is characterized by the least similarity with all other studied sites.

Keywords: Small Mammals, Forest-Steppe, Steppe, Composition of Dominants, Faunistic Complex, Western Siberia, Central Siberia

Introduction

Forest-steppe and steppe landscapes, as a result of natural and anthropogenic factors, are the most vulnerable in terms of biodiversity reduction, which requires continuous and long-term monitoring of terrestrial ecosystems. The fauna of these regions faces a number of challenges caused by anthropogenic impacts and climate change. Habitat loss and habitat fragmentation due to agricultural and industrial activities, as well as changing climatic conditions, are leading to the decline and extinction of some species. This requires urgent measures to protect and restore natural ecosystems, as well as the development of strategies for the sustainable use of natural resources to preserve the biodiversity of steppes and forest steppes.

As a result of the mass plowing of virgin steppes, haying, excessive grazing, mining, and other negative factors of human economic activity, active degradation of animal habitats is observed in forest-steppe and steppe territories, communities of small mammals react especially acutely to these changes. They represent a unique and diverse group of animals adapted to life under conditions of variable climate and relief. These species play a key role in maintaining the ecological balance and biodiversity of their habitats. At present, forest-steppe and steppe territories of Western and Central Siberia are undergoing a number of significant anthropogenic transformations, which ultimately lead to a reduction in species abundance and numbers and a radical restructuring of the dominance structure of small mammal populations. Therefore, constant monitoring of steppe

ecosystems in these territories is currently relevant and necessary to identify qualitative and quantitative changes in the communities.

The purpose of this research was to analyze and summarize the available data on the current state of the fauna and population of small mammals of forest-steppe and steppe landscapes in the south of Western and Central Siberia. Such studies on small mammal communities are presented in relatively large numbers, but all of them, as a rule, concern small areas, and their generalization in one source is rare. Recently, such generalizations have been made for the mountains of southern Central and Eastern Siberia (Litvinov *et al.*, 2021), the northern taiga of Western Siberia (Starikov and Vartapetov, 2021), as well as in the south of the Baltic region (Balčiauskas and Balčiauskienė, 2022). Our work allows us to summarize all scattered data on the small mammal populations of this vast region and to form stable concepts on their forest-steppe and steppe communities. In the long term, this may significantly contribute to a better understanding of ecosystem functioning, which will minimize the risks of biodiversity decline in the future. Thus, this publication may become an important contribution to science and contribute to the sustainable management of Siberia's natural resources.

Materials and Methods

The basis for this article was the results of research conducted within the forest-steppe and steppe territories of the south of Western and Central Siberia. The authors of this study conducted research in the south of Western

Siberia in the territory of the Pre-Irtysh (Kazakhstan, Pavlodar region) and Prealtai plains (Russian Federation, Altai region) and in the south of Central Siberia in the Tuva Basin (Russian Federation, Republic of Tyva). In addition, materials of other authors performed on forest-steppe and steppe territories of the Tyumen Region (Gashev and Sazonova, 2000; Sazonova, 2004), Northern Kulunda (Dupal, 2008; 2010), Khakassia (Litvinov *et al.*, 2006; Senotrusova, 2017) and Baikal region (Litvinov and Demidovich, 2006; Litvinov *et al.*, 2015) were involved in the analysis. Thus, the fauna and populations of small mammals were analyzed for seven key sites Fig. (1), a brief description of which, with an indication of geographical location, biotopes examined, periods of work, and authors, is given in Table (1).

The counting and trapping of small mammals were carried out using generally accepted zoological methods. The method of trapping with hero traps allows revealing the species composition of Voles and mice and their relative abundance in the study area. It consists of the use of metal and wooden universal break-back traps. To count small mammals, a line of 50 traps was set up within each habitat at a distance of 5 m from each other. Bread slices soaked in unrefined sunflower oil were used as bait (Karaseva *et al.*, 2008). In addition to traps, small mammals were also captured using the method of pitfall traps, 50 m long (Naumov, 1955). For this purpose, five cones were dug into the bottom of the groove at a distance of 10 m between them, and each cone was filled with 4% formalin solution to a quarter of its height. Animal captures per 100 cone/day or trap/day were taken as the unit of record. The dominance structure of each community was assessed using a dominance index representing the proportion of species in the community. To characterize community structure, the first five species were identified by abundance. Dominant species were considered to be those whose proportion in the community was 10% or more (Kuzyakin, 1962). Allocation of faunistic complexes is based on faunogenetic and landscape-zonal approaches (Kucheruk, 1959; Mekaev, 1987; Shvarts, 1989). In the first approach, the criteria of the place of origin or center of species dispersal are used to delineate these complexes and in the second approach, the criteria of confinedness of species ranges to a certain natural zone or altitudinal belt are used. The belonging of species to one or another faunistic complex is given according to Vinogradov (2012). The degree of similarity between small mammal communities from different areas was determined using the method of cluster analysis based on qualitative and quantitative indicators of Jaccard and Sorenson-Chekanov coefficients (Pesenko *et al.*, 1984) with the following analysis of dendrograms. Species names are given according to the summary by A. Lisovsky *et al.* (2019).

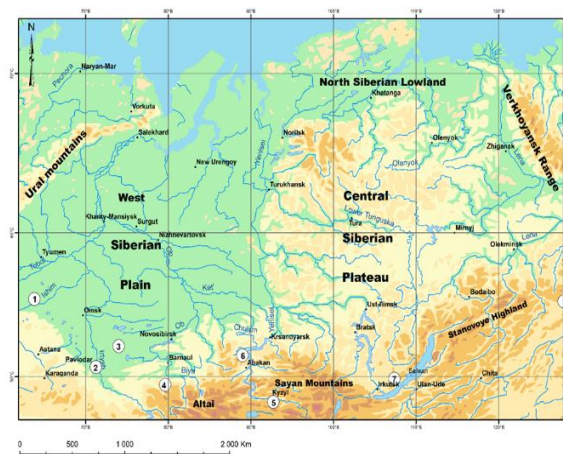


Fig. 1: Research areas and small mammal capture sites. Key areas: 1–, 2–Pre-Irtysh, 3–Kulunda, 4–Prealtai, 5–Tuva, 6–Khakassia, 7–Baikal region

Table 1: Work execution plots

№	Geographical location	Habitats	Years of work	Authors
1	Russian Federation, Tyumen region, Ishim forest-steppe	Fields of spring grain crops Young fallow fields (1-5 years) Old fallow fields (6-12 years) Virgin steppe areas	1998–1999, 2001–2003	Gashev and Sazonova, 2000; Sazonova, 2004
2	Kazakhstan, Pavlodar region, Pre-Irtysh plain	Steppes: Mixed grass-wormwood, mixed grass-feather grass-wormwood, mixed grass-fescue grass, fescue grass-wormwood, wormwood-feather grass, wormwood	2016–2019	Sergazinova <i>et al.</i> , 2018; Sergazinova, 2023; Zhapar and Sergazinova, 2021
3	Russian Federation, Novosibirsk region, North-Kulunda plain	Steppes: Wormwood-cereals, feather grass-fescue grass along forest belts Fields Cereals-mixed grass meadows along lakeshores	2001, 2003–2009	Dupal, 2008; 2010
4	Russian Federation, Altai region,	Meadows with copses Pasture meadows	2009–2012, 2014–2016	Makarov, 2017;

	Prealtaifoothill plain	Fields: Buckwheat, rye, sunflower, corn, fodder grasses, fallow fields Mixed grass-meadow steppes Mixed grass-feather grass steppes Steppes: Wormwood-caragan, wormwood-mixed grass-cereals, mixed grass-cereals-wormwood with forest belts, mixed grass-cereals-wormwood with forest belts and plantings of small-leaved elm trees Steppes: Mixed grass-cereals, wild rye-alkaline Field protection forest belts of Siberian larch, black poplar, balsamic poplar, squat elm, and berry apple tree		Makarov and Sergazino va, 2018, Makarov and Sergazino va 2022
5	Russian Federation, Republic of Tyva, Central Tuva Basin		2021	Makarov <i>et al.</i> , 2023
6	Russian Federation, Republic of Khakassia, Shirin and Koibal steppes		2000–2006	Litvinov <i>et al.</i> , 2006; Senotrusova, 2017
7	Russian Federation, Irkutsk region, Baikal region, Tazheran steppe and forest-steppe areas of Olkhon Island	Larch copses Steppes Stony areas among steppes Marshy meadows Ecotone areas between larch copses and steppes	2000–2004	Litvinov and Demidovich, 2006; Litvinov <i>et al.</i> , 2015

was recorded in the territories of the Prealtaifoothill and North-Kulunda plains (20-23), in the Ishim forest-steppe (19), and in the steppes of Khakassia (24) Table (2). This is explained by relatively favorable climatic conditions and the mosaic of landscape units represented there (meadows, and steppes alternating with copse forests and island forests). A much smaller number of small mammal species is typical of the driest arid territories localized in Northern Kazakhstan within the Pre-Irtysh plain, in the Tuva Basin, and in the tazheran steppes of the Baikal region (14-16).

Table 2: Species composition of small mammals in key areas of forest-steppe and steppe landscapes of the South of Western and Central Siberia

Species	Key areas*						
	1	2	3	4	5	6	7
Talpa altaica Nikolsky, 1883	-	-	-	-	-	+	-
Sorex araneus Linnaeus, 1758	+	+	+	+	-	+	+
Sorex tundrensis Merriam, 1900	+	+	+	+	+	+	+
Sorex daphaenodon Thomas, 1907	+	-	-	-	-	-	-
Sorex caecutiens Laxmann, 1788	+	-	+	+	+	+	+
Sorex isodon Turov, 1924	+	-	+	+	-	-	-
Sorex roboratus Hollister, 1913	-	-	-	-	-	+	-
Sorex minutus Linnaeus, 1766	+	+	+	+	+	+	+
Sorex minutissimus Zimmermann, 1780	-	+	+	+	+	+	+
Neomys fodiens Pennant, 1771	-	-	+	-	-	+	+
Crocidura <i>suaveolens</i> Pallas, 1811	-	+	-	-	-	-	-
Crocidura sibirica Dukelsky, 1930	-	-	-	+	-	+	-
Ochotona dauurica Pallas, 1776	-	-	-	-	+	-	-
Ochotona pusilla Pallas, 1768	-	+	-	-	-	-	-
Sicista betulina Pallas, 1779	-	-	-	+	-	+	-
Sicista subtilis Pallas, 1773	-	+	+	+	+	+	-
Sicista napaea Hollister, 1912	-	-	-	+	-	-	-
Phodopus sungorus Pallas, 1773	-	+	+	-	-	+	-
Cricetulus <i>barabensis</i> Pallas, 1773	-	-	+	+	+	-	+

Results

During the work in the forest-steppe and steppe landscapes of the south of Western and Central Siberia, 37 species of small mammals belonging to three orders (Eulipotyphla, Lagomorpha, Rodentia), 6 families, and 24 genera were identified. The greatest number of species

<i>Cricetus cricetus</i> Linnaeus, 1758	+	-	-	-	-	+	-
<i>Myodes glareolus</i> Schreber, 1780	+	-	-	-	-	-	-
<i>Myodes rutilus</i> Pallas, 1779	+	+	+	+	-	+	+
<i>Craseomys rufocanus</i> Sundevall, 1846	+	-	-	+	+	+	+
<i>Ellobius talpinus</i> Pallas, 1770	-	+	-	+	-	-	-
<i>Lagurus lagurus</i> Pallas, 1773	-	+	+	+	-	+	-
<i>Arvicola amphibius</i> Linnaeus, 1758	-	-	+	-	-	+	+
<i>Lasiopodomys gregalis</i> Pallas, 1779	+	+	+	+	+	+	+
<i>Agricola agrestis</i> Linnaeus, 1761	+	-	-	+	+	+	-
<i>Alexandromys oeconomus</i> Pallas, 1776	+	+	+	+	+	+	+
<i>Microtus arvalis</i> Pallas, 1778	+	+	+	+	-	+	-
<i>Meriones meridianus</i> Pallas, 1773	-	-	-	-	+	-	-
<i>Micromys minutus</i> Pallas, 1771	+	+	+	+	+	+	+
<i>Apodemus agrarius</i> Pallas, 1771	+	-	+	+	-	+	-
<i>Apodemus peninsulae</i> Thomas, 1907	-	-	-	+	+	+	+
<i>Sylvaemus uralensis</i> Pallas, 1811	+	+	+	+	-	-	-
<i>Mus musculus</i> Linnaeus, 1758	+	-	+	-	-	-	-
<i>Rattus norvegicus</i> Berkenhout, 1769	+	-	-	-	-	-	-
Species in total	19	16	20	23	14	24	14

Key areas: 1-Tyumen, 2-Pre-irtysh, 3-Kulunda, 4-Prealtai, 5-Tuva, 6-Khakassia, 7-Baikal area

Faunistic complexes are marked in color according to Vinogradov (2012):

■ Boreal	■ European
■ Mongolian	■ Saharan-Gobi
■ Kazach-European	■ Euro-Manchurian
■ East Asian	■ Pryaltaysky

The fauna of small mammals of the study region consists of species that are typical to open steppe and semi-desert areas of Asia, taiga regions of Siberia, and coniferous-broadleaved forests of Europe. The most diverse group of the boreal faunal complex is represented, with the proportion of species varying from 38-57% in the sites under consideration. The greatest number of forest species was found in the westernmost key site within the Ishim forest-steppe, on the territory of the Prealtai plain and in Khakassia (10 each) and the least number was found in the steppes of Northern Kazakhstan and the Tuva Basin (6 each). The second are representatives of the Kazakh-European faunistic complex. The lowest proportion of this faunistic group is characteristic of the Baikal key area, where only the Narrow-headed Vole was recorded, 4 species from this group were found in the territories of the Prealtai plain and Khakassia and, finally, the highest representation of the Kazakh-European complex was established in Northern Kazakhstan (5 species). The representation of the European faunistic complex is usually small everywhere and includes from one to three species, but its highest percentage was recorded for the Ishim forest-steppe and North-Kulunda plain (15-16 %) and the lowest for the steppe territories of Tuva and Baikal region (7% each). The same number of species and approximately the same proportion (from 7-15%) are common to the Euro-Manchurian faunistic complex. Most of all Mongolian species were found in the small mammal communities of the Central Tuva Basin, where they are represented by the Daurian pika and striped hamster, as well as on the territory of the North-Kulunda Plain, where Siberian (Striped) Desert and striped hamsters are present. In addition, the absence of Mongolian species in the Ishim forest-steppe of the Tyumen section was also established. The presence of species of the Pryaltaysky faunistic complex, expressed by the Siberian white-toothed Shrew and the Altai birch mouse, was registered on the Prealtai plain, as well as in the steppes of Khakassia, where they include the Altai mole and the Siberian white-toothed Shrew. In addition, only in central Tuva Basin, the Middy Jird, a faunal element of the Saharan-gobi species complex, was recorded in Fig. (2).

Population of Small Mammals of the Tyumen Key Site

This site is located in the western part of the West Siberian Plain within the Ishim forest-steppe. Natural conditions are characterized by the flatness of the territory, abundance of bogs and lakes, continental climate, and high salinity of waters. Forests are represented by intrazonal pine forests growing on sandy terraces of the Tobol Valley and small scattered forests on watersheds. A vast area is occupied by steppe meadows and meadow steppes, which are currently plowed everywhere.

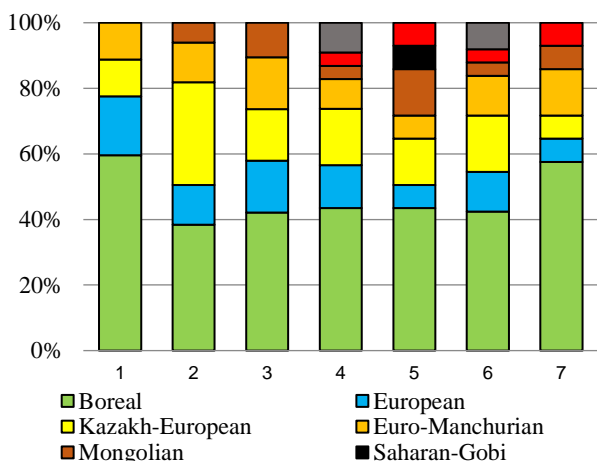


Fig. 2: The proportion of representatives of Eurasian faunal complexes in the population of small mammals in forest-steppe and steppe landscapes of the south of Western and Central Siberia. Key areas: 1-Tyumen, 2-Pre-Irtysh, 3-Kulunda, 4-Prealtai, 5-Tuva, 6-Khakassia, 7-Baikal area

Research on small mammal communities was conducted here in 1998 and 1999 and from 2001-2003. A total of 43 sample plots belonging to 4 habitats were examined: Fields of spring grain crops, young fallow lands, old fallow lands, and virgin steppe areas.

The population of small mammals consists of 19 species, among which 68 % belong to rodents and only 32% to insectivores. This microterio-complex is characterized by the presence of four dominants. Among them, the striped field mouse (37%) and the narrow-headed Voles (22%) predominate, while the common Shrew (16%) and especially the Northern Red-backed Vole (10%) are more than twice as less abundant. The striped field mouse prefers all four habitat types (plowed fields, fallow fields, and virgin steppes) approximately equally. In contrast, the narrow-headed Vole, Common Shrew, and Northern Red-backed Vole prefer old fallow fields and virgin steppes to a greater extent. In addition to the four dominant species, the common Shrew (4%) is also among the top five leaders in abundance of this community Fig. (3).

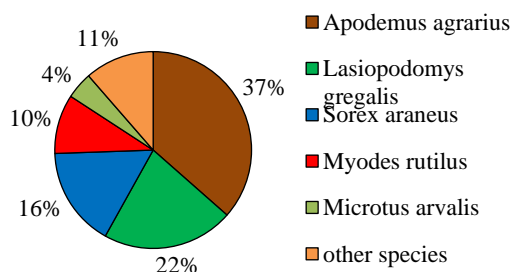


Fig. 3: Leaders by abundance (first five) in small mammal communities of the Tyumen key site, %

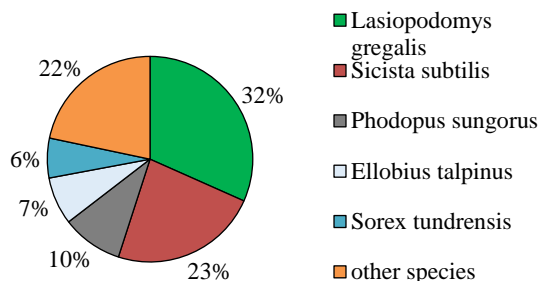


Fig. 4: Leaders by abundance (first five) in small mammal communities of Pre-Irtysh key site, %

Population of Small Mammals in the Pre-Irtysh Key Site

Here the studies were conducted within the Pre-Irtysh physical-geographical area of Northern Kazakhstan, which has the appearance of a typical plain with deep and numerous lakes, gentle hills, and ridges. In the far southeast of the region, ancient Aeolian landforms stand out. Absolute altitudes vary mainly from 100-120-150 m above sea level. Due to the arid climate and the predominance of flat relief, the river network is poorly developed and is represented mainly by temporary watercourses. From 2016-2018, fieldwork was carried out in the neighborhood of Pavlodar on 12 sample plots representing different variants of steppes and in 2019 on the territory of Mayskiy district of Pavlodar region in 4 steppe habitats. During the working period, 16 species of small mammals were recorded here, with a significant predominance of rodents over insectivores (62.5-31%). The dominant structure of this community is characterized by a significant predominance of the narrow-headed Vole and Southern Birch mouse, which together account for 55% of the total population. Among the dominants of the microterio-complex could be included the Siberian (striped) Desert hamster (10%) and subdominants the Northern Mole Vole and the tundra Shrew (6-8%) Fig. (4). In addition to the first five leaders in abundance, the Steppe lemming and the common vole (5-6%) have a significant share in the population of small mammals and the participation of other species is not significant.

Population of Small Mammals of the Kulunda Key Site

The working area was located in the southeast of the west Siberian lowland within the southern forest-steppe on the territory of the North-Kulunda plain. Natural conditions are characterized by the presence of birch and birch-aspen forests, between which large areas are occupied by mixed grass-meadow and steppe vegetation, as well as fresh and salt lakes with a variety of reed river floodplains. At present, extensive areas of fescue grass-wormwood and feather grass steppes are plowed for agro-cultures. Records of small mammals were conducted here in 2001 and in the period 2003-2009 in 4

habitats characterizing different steppe and field tracts. The microterio-complex of this community consists of 20 species, most of which belong to rodents (65%). The dominant composition includes the narrow-headed Vole, which occupies almost half of the community (43%), as well as the harvest mouse and Herb Wood mouse (10% each). In addition, the dominant species is also represented by the Root Vole (9.5%), which prefers well-moisturized habitats along the shores of lakes. The steppe lemming (8%) has a comparatively high share in the population of small mammals, along with which the common Vole and the common Shrew (5% each) are subdominants. According to the scale of abundance, the narrow-headed Vole belongs to numerous species, the other listed species to common species, and the remaining species of the community of this site to rare species Fig. (5).

Population of Small Mammals of the Preatai Key Site

Here the studies were conducted within the Preatai foothill plain, which borders the Altai Mountains from the north-west and north with a narrow foothill strip with a total area of about 21,000 km². From the south, the prealtai plain is adjoined by the mountain provinces of north-western, northern, and North-Eastern Altai, and in the east it gradually passes into the foothills of the Salair ring. The prealtai plain is a weakly undulating steeply-sloping region with meadow mixed grass-cereals steppes. Forest areas are represented by pine forests growing on sandy terraces of the lower reaches of the biya (river) and the upper reaches of the Ob River, as well as small sparse birch and birch-aspen forests. Otherwise, the territory is almost treeless and is heavily plowed for grain crops, mainly buckwheat, wheat, and oats. An eastern forest-steppe plot was inspected here between 2009-2012 and in 2014 and in 2015 and 2016 records were conducted in two steppe plots located in the central and western parts of the prealtai plain. During the work, a total of 29 different habitats were examined, from which materials on forest fields, fields, meadows, and steppe tracts were taken for analysis. A total of 23 species of small mammals were recorded in the community of this site, of which rodents accounted for 70%. The site leaders include the harvest mouse, the percentage of which is about half that of the other abundance leaders (33%). On the prealtai plain, the harvest mouse prefers field-protective forest belts on the border with fields of buckwheat, sunflower, corn, rye, and fallow fields, where it inhabits tall grassy areas. In addition to it, the dominants of fields and steppes of the Preatai Plain include the narrow-headed Vole and striped field mice (16-10%), as well as the tundra Shrew, which reaches high abundance in high-grass and moistened areas on the border with birch-aspen forests (11%) Fig. (6).

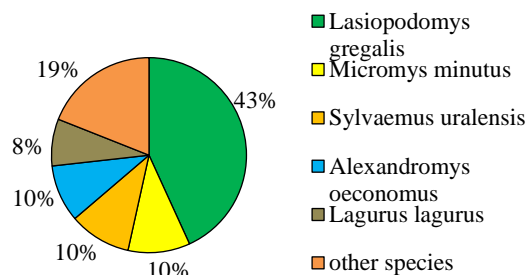


Fig. 5: Leaders by abundance (first five) in small mammal communities of the Kulunda key site, %

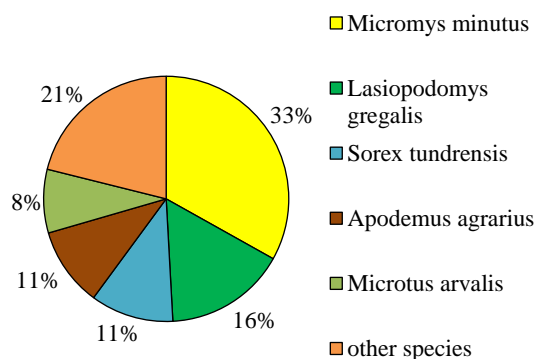


Fig. 6: Leaders by abundance (first five) in small mammal communities of the Preatai key site, %

Along with the dominants, the common Vole is also the leader in the field-protective forest belts and in the mixed grass-meadow steppes near the boggy forests, Eurasian pygmy Shrew prevails (6-8%). Other representatives of small mammals, including the common Shrew, herb wood mouse, southern birch mouse, root vole, etc., belong to secondary species.

Population of Small Mammals of the Tuva Key Site

This study area is located in the central part of the Tuva Basin 45 km south of Kyzyl in the neighborhood of Dus-khol' and Khadyn lakes. The central Tuva Basin is located in the very center of Asia and is surrounded by the western Sayan, shapshal, tsagaan-shibetu, tannu-ola ridges, and the mountains of Eastern Tuva. The length of the Basin is about 400 km, width of up to 60-70 km. Absolute heights of relief vary from 600-900 m. The inner parts of the Basin are characterized by steeply sloping plain relief, in the vegetation cover of which different variants of steppes predominate, which are anthropogenic ally-derived xerophytic communities. According to their floristic composition, they can be characterized as true steppes represented by different variants. Small mammals were recorded here in 2021 within 4 biotopes: Wormwood-mixed grass-caravan steppe, wormwood-mixed

grass-cereal steppe, mixed grass-cereal-wormwood steppe with forest belts, and mixed grass-cereal steppe with forest belts and plantings of small-leaved elm. During the period of work here, 14 species of small mammals with absolute predominance in the species composition of rodents (64%) were identified. Among small mammals of the Tuva steppes, the narrow-headed Vole absolutely dominates, with its share twice as high as the abundance of other species (42%). The second place in the dominant species is occupied by the striped hamster (19%) and the third and fourth places are occupied by the Southern birch mouse and tundra Shrew (12-14%). The first five leaders in terms of abundance also include the harvest mouse, but in terms of proportion it corresponds to the secondary species (4%) Fig. (7). Other species account for only 9% of the small mammal population, which indicates a low leveling of this community and a high predominance of some specialized steppe species.

Population of Small Mammals of the Khakass Key Site

This area includes the Shirin Steppe located in the Chulym-Yenisei Basin and the Koibal Steppe lying within the Minusinsk Basin. The relief is hilly and knoll-like, characterized by the alternation of flat areas with groups of hills, low hilly ridges, and small mountain massifs 800-900 m high. The vegetation is represented by various steppe and meadow formations, alternating with protective forest belts. The hydrographic network is characterized by the presence of numerous lakes of various sizes and mineralization, with alkaline-saline meadows spread along their floodplains. Small mammals were counted here from 2000-2006. Thirteen habitats were examined, including three steppe sites and ten forest belts of different rock compositions. The steppe microteriocomplex of Khakassia includes 24 species, of which rodents account for 62%. Due to the high abundance of field-protective forest belts, the striped field mouse (47%) sharply predominates in the territory of the Khakassia section as a whole. In the same forest belts and in the surrounding steppes, the narrow-headed Vole dominates (21%), and together with it the steppe lemming (14%). These three species form the basis of the species composition of small mammals in the steppe landscapes of Khakassia. The top five leaders in terms of abundance also include the common Vole, which occupies a subdominant position in the steppe microteriocomplex (5%), and the harvest mouse, whose share is secondary (3%). Participation of other species in the structure of dominance is quite small and their joint share does not exceed 10%, which indicates the specificity of the natural environment for small mammals in the arid conditions of the steppe Basins of Khakassia Fig. (8).

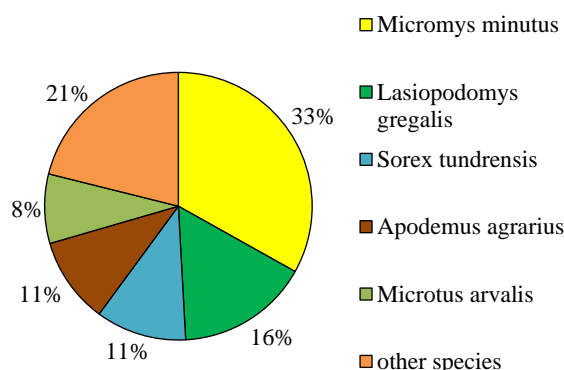


Fig. 7: Leaders by abundance (first five) in small mammal communities of the Tuva key site, %

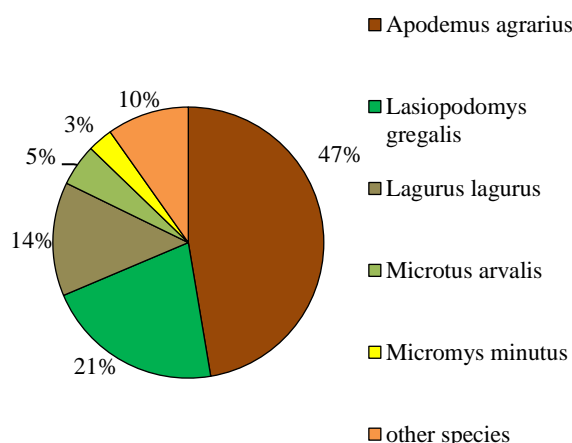


Fig. 8: Leaders by abundance (first five) in small mammal communities of the Khakass key site, %

Population of Small Mammals of the Baikal Key Site

The study area was located in the neighborhood of Lake Baikal in the Tazheran steppes and on Olkhon Island. Natural conditions are characterized by the predominance of semi-desert-steppe landscapes. The hilly relief with surface occurrences of small demoiselle rock and small ridges is widespread. Small groups of larch and pine-larch thin forests are located among the steppes. Moisturized areas with elements of meadow vegetation are widespread in low-relief depressions. Low precipitation falls here (170-370 mm per year), which is explained by the orographic shadow created by the Primorsky and Baikal ridges. In the period 2000-2004, various variants of steppe habitats, larch-thin forests, and ecotone areas were examined here.

The community of small mammals of the Baikal area is represented by 14 species, eight of which (57%) belong to the rodent group and six species (43%) to the

insectivores group. The high proportion of insectivores in the community can be explained by the presence of moisturized boggy lowlands and larch copses intersecting with steppe landscapes preferred by them. Four dominant species were recorded in the microterio-complex of the Baikal area: The narrow-headed Vole (23%), the striped hamster (19%), the tundra Shrew (16.5%), and the Korean field mouse (12.4%). In larch copses and boggy habitats, the abundance of Laxmann's Shrew and Eurasian Least Shrew, and Northern Red-backed Vole was relatively high and they generally occupied a subdominant position (5-8%) in the analyzed area. Secondary species in the study area include the Root Vole, Eurasian pygmy Shrew, gray red-backed Vole, and harvest mouse Fig. (9).

Based on the analysis of small mammal populations, it was revealed that the dominant species at all sites under consideration was the narrow-headed Vole, which has a wide distribution in the Eurasian forest-steppe and steppe zone, which confirms its ecological plasticity. In addition, at different sites, the tundra Shrew, Southern Birch mouse, steppe lemming, common Vole, striped field mouse, and harvest mouse are most often included among the leaders in terms of abundance. Of these, the tundra Shrew and harvest mouse were recorded as dominants in 50% of the studied areas, both in Western and Central Siberia. The Southern Birch mouse is the leader in the Pre-Irtysh and Tuva regions and the steppe lemming in the Kulunda and Khakass regions. Striped field mice and common Vole are no less widespread and occupy the leading position in small mammal communities in forest-steppe and steppe territories of Western and Central Siberia (Tyumen, prealtai, and Khakassia sites). For the south of Central Siberia, the characteristic species is the striped hamster, which predominates in the steppes of Tuva and Baikal region, while for western Siberia it is the Siberian (striped) Desert hamster, which is prevalent in the territory of the Pre-Irtysh plain.

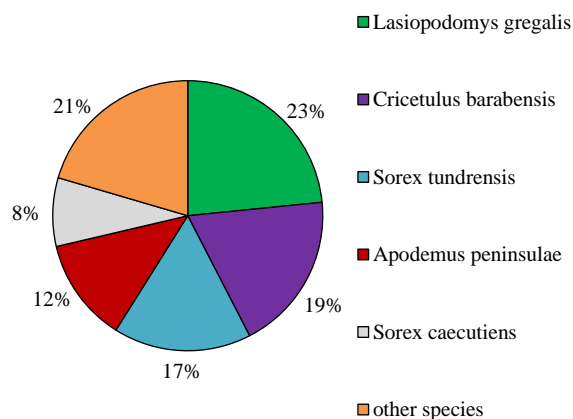


Fig. 9: Leaders by abundance (first five) in small mammal communities of the Baikal key site, %a

Discussion

The microteriofauna of forest-steppe and steppe landscapes in the south of western and central Siberia includes 37 species, of which rodents account for 57-70% and insectivores for 30-43%. The maximum number of species (20-24) was revealed for the steppe territories of Khakassia (Khakassky site), Prealtai Plain (Prealtai site), and Northern Kulunda (Kulunda site), where the surrounding natural conditions are characterized by a diversity of represented habitats. The least number of small mammal species (14-16) is specific to the aridest and relatively monotonous in landscape terms territories (Pre-Irtysh, Tuva, and Baikal sites).

In the western part of the analyzed territory, which includes forest-steppe and steppe landscapes of Western Siberia up to the Yenisei valley (Tyumen, Pre-Irtysh, Kulunda, and Prealtai sites), 33 species of small mammals were recorded. In the eastern part of the study area covering the south of Central Siberia (Tuva, Khakassia, and Baikal areas) 6 species fewer (27) were recorded. Only in Western Siberia, 10 species were recorded, five of which are typical western Palearctic species whose range in the east is restricted to the Altai and Ob valley (Lesser white-toothed Shrew, steppe pika, northern red-backed Vole, northern mole Vole, and herb wood mouse). The Altai Birch Mouse was recorded only within the boundaries of the altai. The remaining four species (Siberian large-toothed Shrew and Taiga Shrew, house mouse, and brown rat) are widespread. The Altai Mole, Flat-skulled Shrew, Daurian Pika, and the Midday Jird, species typical to the steppes of Central Siberia and Central Asia, are established exclusively in the steppes and forest-steppes of Central Siberia. The remaining 23 species are distributed everywhere, among which the tundra Shrew, Southern Birch mouse, Steppe Lemming, narrow-headed Vole, harvest mouse, and striped field mouse are among the leaders in terms of abundance both in Western and Central Siberia.

The dominant structure of small mammals at all study sites is characterized by the uneven distribution of species, which confirms the disturbance of these ecosystems. It concludes in a sharp predominance of one or two species. On average at key sites in forest-steppe and steppe landscapes of both compared regions, small mammal communities are dominated by the Narrow-headed Vole (28-29%, respectively) and striped field mouse (12 and 16%, respectively). In addition, the harvest mouse (11%) is the dominant species in western Siberia on average, while in central Siberia striped hamster (13%) and tundra Shrew (10%) are also dominant Figs. (10-11). In addition to the dominant species, small mammal communities in western Siberia have a relatively high proportion of common and tundra Shrews, southern birch mice, and common Vole, which are considered subdominants (6-7%). In the steppes of central Siberia, probably due to more aridity of climate and less diversity of surrounding landscapes, the share of other

species, compared to dominant species, is much lower, which indicates less diversity and homogeneity of local communities.

A similar composition of dominant species was recorded in the steppe belt of the Munku Sardy Range, located in the mountains of the south of central Siberia, where the striped hamster, narrow-headed vole, and tundra shrew were dominant (Litvinov *et al.*, 2021). In Europe, in agricultural lands (Eastern Ukraine, Northeastern Italy), the striped field mouse remains the dominant species, while the other leaders are replaced by the herb wood mouse and long-tailed wood mouse (Dorigo *et al.*, 2021; Karazin and Markovska, 2022). These differences in the composition of the leading species are due to the different geographical locations, climatic features of these territories, and the nature of species occurrence and settlement. In the forest-steppe and steppe of Western and Central Siberia, as well as in the steppe belt of the mountains of the south of Central Siberia, species of the Kazakh-European and Mongolian faunal complexes (narrow-headed vole and striped hamster) predominate, while in Europe the proportion of species of the European faunal complex (herb wood mouse and long-tailed wood mouse) is high.

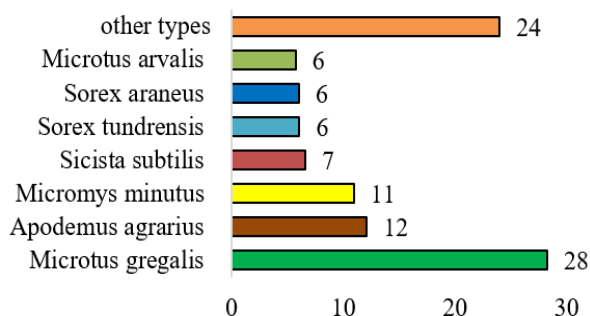


Fig. 10: Structure of small mammal community dominance in the south of Western Siberia

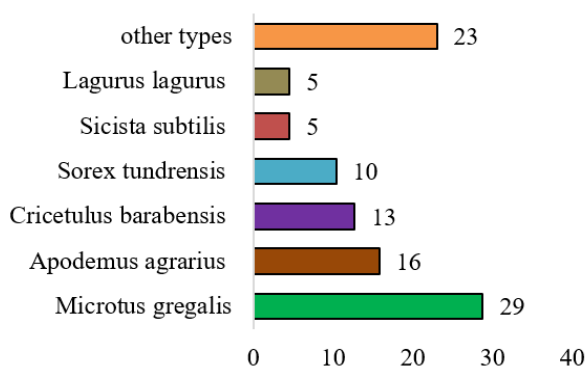


Fig. 11: Dominance structure of the small mammal community of the south of central Siberia

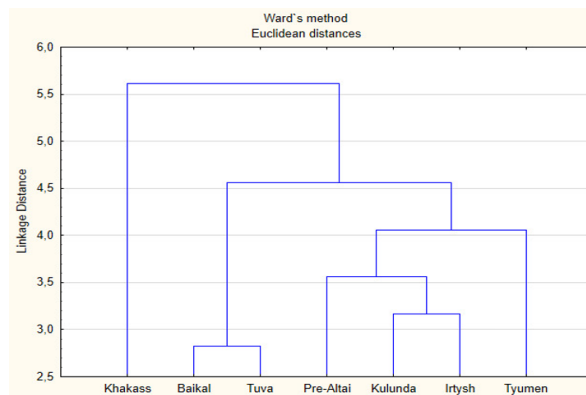


Fig. 12: Similarity of species composition of small mammals in different parts of forest-steppe and steppe landscapes of the south of Western and Central Siberia

A dendrogram of the similarity of the species composition of small mammals was constructed for all seven studied areas of forest-steppe and steppe landscapes in the south of Western and Central Siberia Fig. (12).

As can be seen from the presented dendrogram, the studied sites can be grouped into three clusters. The first cluster includes the sites of kulunda, pre-Irtysh, Prealtai, and Tyumen. All these sites are located on similar plain territories of Western Siberia, up to 200 m in height. The second cluster includes the Baikal and Tuva sites, located in central Siberia at elevations up to 800-900 m, with hilly and steply sloping landforms. One site belongs to the third cluster khakassky, which is located on the border of Western and Central Siberia and has a central spatial location between the studied sites, represented by hilly-knoll relief. Thus, having analyzed the species composition of these sites, it can be concluded that the dispersal of small mammals occurred along the natural boundaries of steppe ecosystems. However, the large length of the territory and the diversity of physical-geographical and climatic conditions cause a different level of similarity of the studied sites. That is why in our studies the greatest similarity of such sites as Baikal with Tuva and kulunda with pre-irtysh is observed. This is explained by similar habitat conditions, their proximity to each other, and, as a consequence, a similar process of fauna formation. The similarity of the Tuva and Baikal areas, in addition to the comparable species composition, is determined by the presence in these communities and the high abundance of species typical to the central and eastern Siberia striped hamster and the Korean Field mouse. In addition, the narrow-headed Vole and tundra Shrew are dominant species at both sites. Comparatively, high similarity indices of the kulunda and pre-Irtysh sites are caused by the proximity of their territorial location and, as a consequence, similar species composition of small mammals, including the presence in these communities of characteristic west Siberian species Siberian (Striped)

desert hamster, steppe lemming, and southern birch mouse. Similar small mammal communities in the Prealtai area and, to a lesser extent, in the Tyumen area adjoin the latter two classes. All these areas are united by the presence among the abundance leaders of the Tundra Shrew, Narrow-headed Vole, Harvest Mouse, and striped field mouse. The lower similarity of the Tyumen area is probably due to its westernmost location and slightly higher participation of elements of the Boreal and European faunal complexes in the species composition. The small mammal community of the Khakass area, which forms a separate class, is characterized by the least similarity with all other territories considered. This fact is probably due to the high local abundance of the Steppe Lemming in open steppes, which dominated here during the research period.

Conclusion

The diversity of physical-geographical and climatic conditions of forest-steppes and steppes of Western and Central Siberia creates unique conditions for the formation of species composition of microteriofauna. This diversity emphasizes the importance of landscape mosaicism for maintaining biodiversity in the region. A similar trend was revealed throughout the study area, which is expressed in the presence of two dominant species: The narrow-headed Vole and the striped field mouse. Nevertheless, microteriofauna complexes of Western Siberia are characterized by a relatively high species richness and a relatively uniform proportion of species. While in similar territories of central Siberia, small mammal communities have a more impoverished species composition and their dominant structure is characterized by a less uniform distribution of species.

The analysis of species composition using the similarity dendrogram revealed that the most similar areas are those located in the Central Tuva Basin and the Tazheran steppes of the Baikal Region. Also, due to the presence of common West Siberian species, the areas of the Kulunda and Pre-Irtysh plains are close to each other. The communities of small mammals in the Tyumen area show less similarity and the minimum level of similarity is noted for the steppes of Khakassia.

In general, the microteriofauna of the studied regions consists of typical steppe species (Southern Birch mouse, Steppe lemming, Siberian (striped) Desert hamster, and striped hamster), as well as species with a wider distribution (Tundra Shrew, Common Vole, striped field mouse, etc.). Typical forest species (Northern red-backed vole and gray red-backed vole, Korean field mouse, and Shrews) also play an important role in the formation of the fauna. A particularly important role in steppe communities of small mammals is played by the Narrow-headed Vole and striped field mouse, which

often act as the first and second dominants. These species are characterized by high abundance and adaptation to steppe conditions, which confirms their relatively high tolerance to anthropogenic and technogenic transformation of landscapes.

For further study of microteriofauna and assessment of species tolerance to the anthropogenic transformation of steppe territories, the following recommendations for future research can be considered: Inventory and long-term monitoring, with expansion of research territories and allocation of separate stationary sites for ecological and genetic studies.

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Author's Contributions

Zarina Mukhtarovna Sergazinova: Led the research, conducted fieldwork, conducted the literature review, prepared the map, and prepared the manuscript.

Alexander Vladimirovich Makarov: Conducted fieldwork, conducted literature review, and prepared the manuscript.

Aliya Toleuzhanovna Toleuzhanova and Altinay Naziulovna Kukusheva: Interpreted and analyzed the data, and proofread the manuscript.

Shynar Zhanybekovna Arynova and Irina Yurievna Chidunchi: Performed comparative analysis of the data. Performed comparative analysis of the data obtained.

Ethics

This article contains original, unpublished material. The corresponding author acknowledges that other authors have reviewed and approved this manuscript; no ethical issues are involved.

Conflicts of Interest

The authors declare no conflict of interest.

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