The effect of the character of urban development on the small mammal communities in a northern city

E G Shadrina1,3, V A Odnokurtsev1, M M Sidorov1 and V A Danilov2

1Institute for biological problems of cryolithozone Siberian Branch Russian Academy of Sciences, Federal research centre "Yakut scientific centre SB RAS", 41, Lenin Ave., Yakutsk, 677980, Russia
2Research Institute of Applied ecology of the North, named professor D.D. Savvinov, North-Eastern Federal University, 43, Lenin Ave., Yakutsk, 677980, Russia
3E-mail: e-shadrina@yandex.ru

Abstract. Communities of small mammals on the territory of Yakutsk and in its vicinity have been studied. Residential areas, undeveloped sites, suburban zone, and agricultural lands are covered. A total of 2,736 cone-days and 525 trap-days are accumulated and 388 specimens of small mammals from 13 species belonging to Rodentia and Eulipotyphla orders are collected. The abundance of small mammals in different types of environment have varied from 2.2 to 22.9 individuals per 100 cone-days. The highest values of species diversity are found in the suburban zone in the areas of surviving natural biotopes. The zone of the city's residential areas is characterized by the lowest abundance and species diversity of small mammals, primarily Eulipotyphla, and also by the presence of eusynanthropic Mus musculus and Rattus norvegicus. The undeveloped territories of the city are characterized by a high total abundance of small mammals, but poor community composition, which is close in its structure to floodplain biotopes. Communities of agrocenoses are also poor, due to elimination of forest species, and characterized by uneven distribution of small mammals among the biotopes. On the whole, the anthropogenic effect of urbanization is manifested in poor composition of communities and changes in the dominance structure. The appearance of the house mouse in the zone of detached housing indicates intensifying urbanization of the territory and ongoing synantropization of the fauna.

1. Introduction
Urbanization is an integral part of human history, since cities have a whole range of merits that contribute to labor productivity and improve life quality [1]. At the same time, the development of cities is accompanied by higher intensity of anthropogenic impact on all components of ecosystems [2-6]. One of the important aspects of the relationship of urban systems with natural cenoses surrounding them is their effect on mammals: this group constitutes the basis of the biomass of the vertebrate population of terrestrial ecosystems and comprises species of economic value, as well as pests and carriers of infections and invasions. There are studies discussing the changes in the fauna of mammals caused by urbanization [2, 7, 8]. Also, many issues of adaptation to urbanized territories are studied by the example of small mammals (Rodentia and Eulipotyphla) [9-18]. Because it is one of the most numerous and ecologically flexible groups that actively adapts to coexistence with the man, this group is suited well to use it for analyzing various aspects of how urbanization affects the composition and structure of...
vertebrate communities. However, the theriofauna of the northern cities remain relatively poorly studied. On the territory of Yakutsk, no systematic studies of the theriofauna were carried out until recently. There are separate data on synanthropic Micromammalia of Yakutia [19-21], as well as on communities of small mammals in the suburbs of Yakutsk [22-23], with most studies dating back to 1970s–1990s. Since then, significant changes have happened in the character of the city development and anthropogenic pressure on the territory: between 1990 and 2020 the city's population increased by 45% and continues to grow, having reached now more than 322,000 people [24]. The official area of the city covers 122 km², and the territory of the urban district is 3.6 thousand km². Naturally, the distribution of small mammals over the territory depends on the character of transformation of natural biotopes. Our studies of the fauna of small mammals of the suburban zone were recommenced relatively recently [25]; this study continues our work on estimating the effect of urbanization on the population of small mammals in order to assess the effect of anthropogenic development on the abundance and community structure of small mammals of a northern city by the example of Yakutsk.

2. Material and methods
Small mammals were collected using break-back traps and capture grooves with cones [26]. Break-back traps were set in lines of 50 pieces per biotope; for bait we used the standard variant: bread soaked in sunflower oil. Grooves 12–15 cm deep were 20 to 50 m long depending on the biotope size, with 1 cone installed per 10 m of the groove. Abundance was calculated as the number of individuals per 100 trap-or cone-days, i.e. ind./100 trap-days. On the territory of the city we covered two types of biotopes: yards of multi-storey or two-storey residential areas and undeveloped sites (vacant lands, lake shores). Also we covered all the biotope types of the suburban zone and in agricultural lands 13 km from the city. Landscape-wise all the covered sites are within Tuymaada valley (middle reaches of the Lena River, first and second terrace). A total of 2,736 cone-days and 657 trap-days were accumulated, and 388 specimens of small mammals were collected. Statistical treatment of the material was performed with standard methods. Diversity of communities was assessed using the Shannon, Pielou's, and Simpson indices.

The similarity of communities was assessed by the Jaccard index [2],

\[ K_J = \frac{C \cdot 100}{(A + B) - C} \]

where C, the number of the species common for the two compared biotopes; A, the number of species in the first biotope; B, the number of species in the second biotope;

the Zhivotovsky diversity indices [27], μ and r,

\[ \mu = \left( \sum_{i=1}^{m} \sqrt{p_i} \right)^2 \]

where μ, diversity measure; p, frequency of the species occurrence in the community; m, the number of species in the community,

\[ r = \left( \sum_{i} \sqrt{pq_i} \right)^2 \]

where r, similarity measure; p and q, the proportion of the species in the compared communities.

3. Results and discussion
During the summer of 2019, 42 specimens of small mammals belonging to 7 species were collected in agricultural lands (on hayland meadows and on the fringes of tilled areas) (table 1). In the studied sites the predominant biotope type was dry graminoid meadow, but we also covered adjacent biotopes, islands of birch forests, wet tussock fields, willow coppices, and forb-graminoid meadows. The community of
small mammals was monodominant, with the dominant represented by the narrow-headed vole, which accounted for 62% of the population; and the total capture rate was 8.97 individuals per 100 cone-days (table 1). Dominance of *Microtus gregalis* on dry meadows is typical for Central Yakutia [19]. The highest abundance was observed in wet sedge tussock fields (25 ind. per 100 cone-days), this is explained by good nesting and feeding conditions for the narrow-headed vole, whose abundance there reached 20.59 individuals per 100 cone-days. The population of small mammals in residual fragments of forests was represented by 6 species with the total abundance of 6.9 ind./100 cone-days, the dominant also was the narrow-headed vole, which is generally uncharacteristic of forest stations and indicates the lack of independence of the population of these forests, isolated from the main body of the taiga on the valley side. The biotopes adjacent to tilled lands were characterized with the lowest species composition, only two species were found: *Microtus gregalis* and *Micromys minutus*. Thus, the population of small mammals in agricultural lands is characterized by low values of abundance and species diversity.

**Table 1.** Abundance of small mammals on the territory of Yakutsk and in its vicinity according to the results of pitfall cones.

| Species                  | City          | Residential areas | Undeveloped areas | Suburb zone | Agrocnoses |
|--------------------------|---------------|-------------------|-------------------|-------------|------------|
| *Sorex tundrensis*       | -             | 5.99              | 3.29              | -           | -          |
| *Sorex daphaenodon*      | -             | -                 | 0.85              | 0.21        | -          |
| *Sorex caecutiens*       | -             | 0.75              | 4.45              | 0.21        | -          |
| *Sorex minutissimus*     | -             | -                 | -                 | 0.43        | -          |
| *Sorex roboratus*        | -             | -                 | 0.79              | -           | -          |
| *Myopus schisticolor*    | -             | -                 | 0.06              | -           | -          |
| *Myodes rutilus*         | 0.28          | -                 | 1.65              | 1.28        | -          |
| *Microtus gregalis*      | -             | 0.37              | 1.22              | 5.77        | -          |
| *Microtus oeconomus*     | 1.11          | 15.73             | 1.58              | 0.43        | -          |
| *Micromys minutus*       | -             | -                 | 1.10              | 0.64        | -          |
| *Apodemus peninsulae*    | 0.28          | -                 | 0.12              | -           | -          |
| *Rattus norvegicus*      | 0.56          | -                 | -                 | -           | -          |
| **Total abundance**      | **2.23**      | **22.85**         | **15.17**         | **8.97**    | -          |
| **Total cone-days**      | 360           | 267               | 1641              | 468         | -          |

Natural biotopes in vicinity of a dacha settlement were studied, a total of eight biotopes: meadow habitats of varying moisture level, and birch, larch, and pine forests. The total abundance of small mammals here was almost twice as high as in agricultural lands (table 1) and varied between biotopes from 7.35 to 61.3 ind./100 cone-days. Relatively low values of abundance characterize the biotopes with highly moisture on the shores of a lake and two types of coniferous forest. This is explained by the low nesting capacity of these habitats, and for coniferous forests (very dry) also by a relatively low food amount. The highest levels of abundance and species diversity are registered on the territory of a dry graminoid meadow. On the whole, the structure of communities and distribution on the territory are similar to those observed previously [25], and abundance, as compared to the previous year, has increased 5 times, mainly due to insectivores, which accounted for more than 60% of the population of small mammals. Communities of small mammals in the natural biotopes are typical for the region: meadow stations are dominated by *Sorex tundrensis, Microtus oeconomus,* and *Microtus gregalis,* forest stations by *Sorex caecutiens* and *Myodes rutilus.* The population of small mammals of the suburban zone is represented by 11 species, of which 10 are aboriginal and found in natural biotopes, and one species, *Mus musculus,* is an invasive synanthrope that appeared in Yakutsk in the XX century [19, 20],...
it was found in summer houses, so it is not included into the results collected with cones. Previously we had not found the house mouse in the suburb zone [25], its appearance there indicates an intensification of the anthropogenic development of the territory. This can be explained, first of all, by the advent of detached houses. It is known that in the climatic conditions of Yakutia, eusynathropes do not survive in natural biotopes in winter [20], so in dacha houses used only in summer they are almost never found, but the advent of the houses where people live all year allows synanthropes to expand their habitable territory.

On the territory of Yakutsk the capture was performed in the residential areas in the center of the city and on the outskirts (concrete multistorey and wooden two-storey buildings respectively), and also in undeveloped areas on the outskirts. The conditions for small mammals in these types of environment differ in nesting conditions, food availability, the presence of synanthropic predators, and disturbance factor.

In the residential zone the capture was performed in the yards, on lawns, near works and utility areas. The abundance of small mammals can be characterized as very low: according to the results obtained with cones it was, on average, 2.3 ind./100 cone-days, and according to break-back traps it was 4.72 (table 2). Rodents are represented by a total of 5 species, of which only 3 are indigenous, and 2 are invasive eusynantropes (Mus musculus and Rattus norvegicus), while insectivores were not found. It seems impractical to discuss dominance in any particular biotope, because the population at each specific site was represented by only 1–2 species. Note also that no animals were captured in 9 out of 16 sites where cones were used and in 2 out of 6 sites where traps were used. The comparison of the 2 capture methods presented a different proportion, which is due to the specifics of these methods (figure 1). The brown rat is practically never caught by standard break-back traps due to its large size, and cones capture only juvenile individuals migrating after leaving the litter (adult rats are able to get out of the standard pitfall cones and cylinders). Also, due to its food preferences, the northern red-backed vole is captured by break-back traps more often than herbivorous voles [19, 28]. The higher capture rate of the northern red-backed vole in the two-storey residential area is explained additionally by the fact that it borders with a residual pine forest, a favorable habitat for the species. Nevertheless, it should be noted that from the middle of the twentieth century, some local populations of the northern red-backed vole have been observed in the central areas of Yakutsk [20]. We also found it in the yards of multistorey houses, at a great distance from natural biotopes.

Table 2. The abundance of small mammals in the zone of residential and undeveloped areas of Yakutsk, according to the results obtained with break-back traps.

| Area                        | Trap-days | Amount of SM*, per 100 trap-days | Microtus oeconomus | Mus musculus | Myodes rutilus |
|-----------------------------|-----------|---------------------------------|--------------------|--------------|---------------|
| Residential area, center of the city | 315 | 2.22 | 0.96 | 0.63 | 0.63 |
| Residential area, outskirts  | 130 | 10.77 | 0 | 3.08 | 7.69 |
| Residential area, average   | 445 | 4.72 | 0.67 | 1.25 | 2.70 |
| Undeveloped areas           | 80 | 2.50 | 0 | 2.50 | 0 |

*SM, small mammals.

On the outskirts of the city the material was collected also in a forest tract adjacent to the territory of the city park, on the shores of lakes, and on vacant sites near nonresidential buildings (garages). According to the data obtained with cones, the abundance in undeveloped areas was, on average, 22.85 ind. per 100 cone-days, i.e. higher than in any other zone, including the suburbs, and varied from 0 in a bare-soil pine forest and birch forest to 37.31–51.35 in meadows. The break-back traps registered here only Mus musculus, while cones did 2 species of shrews and 2 species of herbivorous voles (table 1). The communities were monodominant, with the dominant being the root vole.
On the whole, the population of small mammals in the four discussed types of habitats was different both in figures of the total abundance and in the composition and structure of the communities (table 3, 4). The Jaccard index of faunal similarity varies from 7.7 to 54.6, which indicates significant differences in the species composition. Relatively high faunal similarity is observed between agricultural lands and the recreation area, while the lowest faunal similarity is noted for the pair "suburban zone — undeveloped zone", which is explained by the extremely poor species composition in the latter zone. Previously we noted that undeveloped city territories, due to the prevalence of the species characteristic of open biotopes, are faunistically similar to floodplain biotopes [25], a similar phenomenon and for the same reason is observed for agrocenoses. The Zhirovsky index reflects not so much the similarity in the fauna composition, as the ratio of different species, i.e. the community structure of different habitats; in this parameter the similarity varies within 0.08–0.41, i.e. the similarity is less than 50%. The suburban zone is characterized by a relatively high similarity with the agricultural one and with undeveloped territory of the city (due to the similarity in dominance). At the same time, the communities of agrocenoses differ widely from both city zones, and the residential area of the city is set apart from the recreational and agricultural zones, while demonstrating some similarity with the undeveloped territory of the city.

### Table 3. Parameters of species diversity in communities of small mammals of Yakutsk in 2019.

| Habitat type       | Species total | Share of rare species | Parameters of species diversity |
|--------------------|---------------|-----------------------|--------------------------------|
|                    | μ ± s         | H                     | E                     | S                     |
| Residential area   | 5             | 0.15                  | 4.26±0.33            | 1.33                  | 0.83                  | 0.31                  |
| Undeveloped area   | 5             | 0.35                  | 3.25±0.30            | 0.90                  | 0.56                  | 0.51                  |
| Agrocenoses        | 7             | 0.31                  | 4.81±0.50            | 1.22                  | 0.63                  | 0.44                  |
| Suburban area      | 10            | 0.22                  | 8.56±0.29            | 1.94                  | 0.81                  | 0.17                  |

Note: μ ± s, the Zhivotovsky index (average number of species); H, the Shannon's diversity index; E, Pielou's evenness; S, the Simpson's diversity index.

### Table 4. Parameters of the similarity in composition and structure of the communities of small mammals of Yakutsk and its vicinity in 2019 (by the cone-collected data).

| Area                      | Similarity in community structure, r |
|---------------------------|-------------------------------------|
|                           | AC | SUA | CUD | CRA |
| Agrocenoses               | AC | 0.38| 0.10| 0.08|
| Suburban area             | SUA| 54.55| -   | 0.41| 0.14|
| City. Undeveloped area    | CUD| 37.50| 7.69| -   | 0.30|
| City. Residential area    | CRA| 22.22| 27.27| 14.29| -   |

Faunal similarity, K_J

### 4. Conclusion

Thus, the population of small mammals is distributed over the territory of Yakutsk extremely unevenly, both in quantitative and qualitative respect. The closest to the natural ones are communities in the suburban zone: there are habitats typical for the region, the man's presence is mainly seasonal, and the impact of agriculture is moderate. In the vicinity of agrarian settlements, the population of small mammals is poorer due to deforestation, so the conditions are more beneficial for the species adapted to meadow habitats. Agricultural lands are characterized by uneven distribution of species across their territory and a trend towards monodominance, and the community-forming species is the narrow-headed vole. In the residential zone the species richness grows even lower, with the changes in the actual residential area and in undeveloped areas being directed oppositely: in meadow habitats herbivorous species predominate, mainly *Microtus oeconomus*. The residential zone is extremely unfavorable for small mammals: due to the degradation of the soil cover and, as a result, the soil mesofauna, insectivores
are absent or very limited in number, and the rodent population in each separate biotope is often represented with 1–2 species, including Myodes rutilus and invasive eusynanthropes Mus musculus and Rattus norvegicus.

In total abundance the habitats also differ most significantly. The highest abundance values were recorded in undeveloped city areas, due to just one species, the root vole; while the residential area is characterized by a very low abundance. The suburban zone is characterized by the average abundance levels, but has the highest values of species richness and diversity, which indicates its closeness to natural cenoses and greater stability of its communities. At the same time, one should note the appearance of the house mouse in the detached housing zone; this indicates intensifying urbanization of the territory and synanthropization of its fauna.

Acknowledgments
The studies were carried out within the framework of the state task to IBPC SB RAS, project "Structure and dynamics of animal populations and communities in the cold region of the North-East Russia in contemporary conditions of global climate change and anthropogenic transformation of Northern ecosystems: factors, mechanisms, adaptation, conservation" (0376-2016-0002; reg. number AAAA17-11702011005-4) and the state task of the Ministry of education and science of the Russian Federation for 2020-2022. Project FSRG-2020-0018, "Study of the specifics of functioning of arctic and subarctic ecosystems of Yakutia in conditions of intensifying technogenic impact and global climate change». We are grateful to the student of the Biology Division of the North-Eastern Federal University Alexei Sofronov for his part in collecting the material.

References
[1] Lappo G M 2012 Cities of Russia. Geographer's View ed A A Tishkov (Moscow: New chronograph) p 504
[2] Klausnitcer B 1990 Ecology of urban fauna ed V Orlova and I M Marova (Moscow: Science Publishing house) p 246
[3] McKinney M L 2008 Effects of urbanization on species richness: a review of plants and animals Urban Ecosyst 11 161–76
[4] Gagné S A and Fahrig L 2011 Do birds and beetles show similar responses to urbanization? Ecol Applications 21 2297–312
[5] Helden A J, Stamp G C and Leather S R 2012 Urban biodiversity: comparison of insect assemblages on native and non-native trees Urban Ecosyst 15 611-24
[6] Wang G, Zuo J, Li X R, Liu Y, Yu J, Shao H and Li Y 2014 Low plant diversity and floristic homogenization in fast-urbanizing towns in Shandong peninsula, China: effects of urban greening at regional scale for ecological engineering Ecol Engineering 64 179-85
[7] Baranauskas K, Balciauskas L and Mazeikyte R 2005 Vilnius city theriofauna Acta Zool Lithuan 15 228-38
[8] Tihonova G N, Tihonov I A, Surov A V, Bogomolov P L and Kotenkova E V 2012 Ecological Aspects of Small Mammals Fauna Formation in Urban Areas of Central Russia Ed V S Gromov (Moscow: Tovarishchestvo nauchnyh izdanii KMK) p 372
[9] Kucheruk V V, Telicyna A Yu and Samojlov B L 1999 Mammals of Moscow in the past and present ed S A Shilova (Moscow: Science Publishing house) pp 165-237
[10] Frynta D, Vohralik V and Reznicek J 1994 Small mammals (Insectivora, Rodentia) in the city of Prague: distributional patterns Acta Soc Zool Bohem 58 151-76
[11] Karaseva E V, Telicyna A Yu and Samojlov B L 1999 Mammals of Moscow in the past and present ed S A Shilova (Moscow: Science Publishing house) p 245
[12] Baker P J, Ansell R J, Dodds P A, Webber C E and Harris S 2003 Factors affecting the distribution of small mammals in an urban area Mammal Rev 33 95-100
[13] Mahan C G and O’Connell T J 2005 Small mammal use of suburban and urban parks in Central
Pennsylvania *Northeastern Nat* 12 307-14

[14] Chernousova N F and Tolkachev O V 2007 Specific Features of Population Dynamics and Species Diversity of Shrews in Urbanized Areas *Russ J Ecol* 38(3) 217-221

[15] Cavia R, Cueto G R and Suárez O V 2009 Changes in rodent communities according to the landscape structure in an urban ecosystem *Landsc Urban Plan* 90 11-19

[16] Gomes V, Ribeiro R and Carretero M A 2011 Effects of urban habitat fragmentation on common small mammals: species vs. communities *Biodiv Conserv* 20 3577-90

[17] Łopucki R, Mróz I, Berliński Ł and Burzych M 2013 Effects of urbanization on small-mammal communities and the population structure of synurbsic species: an example of a medium-sized city *Can J Zool* 91 pp 554-61

[18] Gortat T, Barkowska M, Gryczynska-Siemiatkowska A, Pieniazek A, Kozakiewicz A and Kozakiewicz M 2014 The effects of urbanization - small mammal communities in a gradient of human pressure in Warsaw city, Poland *Pol J Ecol* 62 163-72

[19] Tavrovskii V A, Egorov O V, Krivosheev V G, Popov M V and Labutin Yu V 1971 *Mammals Of Yakutia* ed V A Tavrovskii (Novosibirsk: Science publishing house) p 660

[20] Romanova G A 1989 Rodents of the settlements of Yakutia *Fauna and Ecology of Rodents* Ed V V Kucheruk (Moscow Publishing house MGU) 17 pp 198-215

[21] Egorov N G 1990 Grey rat settlement in Yakutia 1990 *The History of the Fauna and Ecology of the Mammals of Yakutia* ed Yu V Labutin (Yakutsk: Yakutsk Science Centre SB AS USSR) pp 81-6

[22] Vol’pert Ya L, Shadrina E G, Gerasimov K A and Kravtsova V M 1997 Small mammals of the recreational zone of Yakutsk city *Regional Hygiene, Sanitation and Epidemiology Issues* ed I Ya Egorov (Yakutsk: Yakutsk Publishing House) 4 pp 213-19

[23] Prokopiev N P and Nikiforov O I 2010 Small mammals in the area of a household dump in Yakutsk *Regional Hygiene, Sanitation, Epidemiology and Medical Ecology Issues* ed I YaEgorov and M E Ignatieva (Yakutsk: Yakut Scientific Centre SB RAN) pp 348-51

[24] *Cities of Russia* URL: http://города-россии.рф/sity_id.php?id=65

[25] Shadrina E G, Vol’pert Ya L, Odnokurtsev V A, Sidorov M M, Danilov V A and Yakovleva M L 2018 Small mammals communities in the suburban area and undeveloped areas of Yakutsk city *Arctic and Subarctic Natural Resources* 24(4) pp 97-108

[26] Karaseva E V, Telicyna A Yu 1996 *Methods for studying rodents in the field* ed V E Sokolov and V V Kuchuk (Moscow: Science Publishing house) p 277

[27] Zhivotovsky L A 1979 Indicator of similarity of populations by polymorphic traits *Biology Bul Rev* 40(4) 587-601

[28] Vol’pert Ya L and Shadrina E G *Small Mammals of the North-Eastern Siberia* ed L V Filippova (Novosibirsk: Science publishing house) p 246