Acta Biol. Univ. Daugavp. 15 (1) 2015
ISSN 1407 - 8953

NATURAL AND HISTORICAL ASPECTS OF THE ORIGIN AND FUNCTIONING OF URBAN MAMMALS IN WESTERN SIBERIA, RUSSIA AND UZBEKISTAN

Elena A. Bykova, Sergey N. Gashev, Alena Yu. Levykh

Bykova E.A., Gashev S.N., Levykh A.Y. 2015. Natural and historical aspects of the origin and functioning of urban mammals in Western Siberia, Russia and Uzbekistan. *Acta Biol. Univ. Daugavp., 15 (1): 47 – 64.*

This article deals with complex systems of mammals in cities situated along the transect centered on the meridian 70th east of Greenwich, from the tundra zone to foothill deserts. The study shows that the level of animal habitat urbanization associated with technical and architectual characteristics of certain settlements, as well as with their natural and historical peculiarities, is consequential for systems of mammals living in Novij Urengoy, Tyumen, Ishim and Tashkent. The authors found basic peculiarities in the mechanisms of community formation and functioning for populations of dominant small mammals inhabiting different geographical zones. Urban ecosystem zonality shows that urban environment are more supportive for arid species living in open habitats of Russia's Western Siberia moderate subarctic climate and, hydrophilous species inhabiting closed habitats in the arid climate of Uzbekistan.

Key words: Western Siberia, Uzbekistan, urban ecosystems, mammals.

Elena A. Bykova. Institute of Gene Pool of Plants and Animals, Uzbek Academy of Sciences, Bogishamol str. 232, Tashkent, 100053, Uzbekistan, e-mail: esipov@xnet.uz
Sergey N. Gashev. Tyumen State University, Pirogova str., 3, Tyumen, 6250043, Russia
Alena Yu. Levykh. Tyumen State University, Lenina str., 1, Ishim, 627750, Russia

INTRODUCTION

Urbanization, being a complex of various environmental impacts, is one of the most important but at the same time under-studied phenomena in the system of human-animal relationships. Along with the process of city formation, there a new environment is created for animals with climatic, biotopic, sanitary and epidemiological characteristics different from natural habitats of animals. In this respect, a special emphasis should be placed on the study of animal response to specific characteristics of urban habitats. Specifically, though being of great theoretical and practical importance, the phenomenon of synanthropy has still received little attention.

Urbanization leads to a quick expansion of urbocenosis habitats, contributing to the formation of various unique landscapes with their own faunal complexes adapted to transformed environments which are new (in evolutionarily terms) for the majority of animals. At the first stage, the ecology of the cities developed in the framework of the traditional faunistic research into individual species or their complexes. In the mid-1970s, there appeared a new research

area called urban ecology. Scientific research into urban ecology has an important practical application. Many European countries have implemented research programs in order to cushion growing urbanization effects on urban animals, and to promote urban ecosystem stability (IUCN Urban Biodiversity and Ecosystem Services (URBES), UK-MAB Urban Forum and The Wildlife Trusts of England; the United Nations Educational, Scientific, and Cultural Organization's MAB Program). In the Netherlands, there is a plan to build "ecological landscapes" on new urban sites. In the USA, there is a program to preserve wildlife elements in cities (Adams 2005). In the Wildlife Society, there is an Urban Wildlife Working Group.

The study of peculiarities of mammal communities systems in urban areas is important from the viewpoint of urban development, epidemiology and human life support, and also because it reveals important universal biological mechanisms of animal adaptation to new (often extreme) environmental conditions, provides information to locally monitor the urban environment, allows introduction of norms

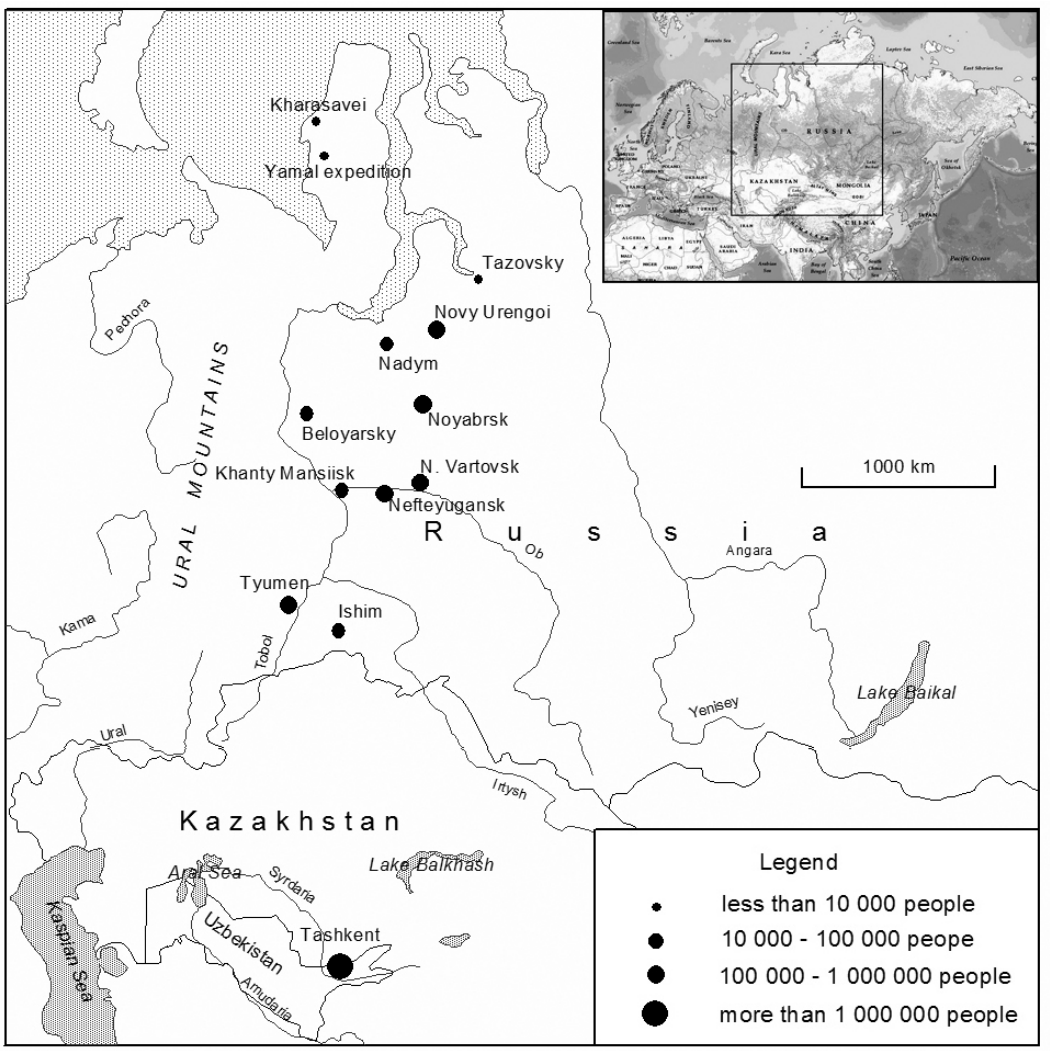

Fig.1. Yamal - Tashkent Transect (70+5° E, ca. 2200 miles). The studied cities are marked with black circles, their size depending on the number of inhabitants.

of anthropogenic load on certain functional zones of cities, and allows planning of effective environmental measures.

Evolutionary mammals are very close to the human, but this group of animals is very poor studies from the position of their adaptability to urban areas. The purpose of this study was to analyse characteristics of mammals of urban landscapes inhabiting along gradiend urbanization in different cities from different geographical zones of Western Siberia and Uzbekistan.

MATERIAL AND METHODS

In order to find zonalities of complex systems of mammals living in urban areas, we drew a comparison between mammals of Tashkent (semidesert and steppe zone), Uzbekistan, and northern cities of Western Siberia, Russia (Fig. 1). The transect includes Tashkent, Ishim, Tyumen and Novij Urengoy cities, and a number of settlements in different natural subzones of Western Siberia (Table 1) that have been studied earlier (Gashev 2000).

In order to study the mammal complexes of these cities, their territory was divided into four functional zones: zone 1 - multistorey buildings; zone 2 - private buildings; zone 3 – uninhabited city lands (i.e. wastelands, gardens, rivers and canal banks); zone 4 – woodland parks; and, zone 5 – wildlife areas used as control (Gashev et al. 1997, Gashev 2000). The species composition of mammals and their ecological characteristics were determined for each zone (Arefjev et al. 1997, Gashev 1998).

The data were collected both by means of trapping animals in sampling areas by standard trap-line method in all cities, and by additional methods as registering winter migration routes in Tashkent and Tyumen (totally 11 animals including, insectivores, hares, carnivores and ungulates) and visually registering chiropterans during the night time in Tyumen (totally 6 species). Totally, trap lines were operated for a total of 7152 trap-nights and collected 1573 samples of 22 small mammals species (insectivores, rodents and small carnivores). Trapping success is expressed as number of captures per 100 trap-nights (TN). We also collected pellets of Long-eared Owl *Asio otus* in Tashkent. A total of 8040 individual prey items belonging to 10 species of small mammals have been recovered from 4801 pellets. To study relative abundance of prey species we measured proportion of the prey items in pellets from each site. These pellets have been received from 5 locations throughout Tashkent and its vicinity. Usually owl pellet analysis, based on the proportions of the prey items, gives information on owl diet and availability of the prey species to the owl. In our case we tested this method as noninvasive technique to receive additional data about small mammals including species which is very difficult to capture (e.g. *Suncus etruscus*).

For integral anthropogenic impact assessment the following score system was used: 0 – no impact of the factor, 1 – low impact, 2 – medium impact, 3 – high impact (Kozhova 2000, Gashev 2000, Levykh & Bazhina 2012). In order to determine the degree of similarity of different types of small mammals urban communities, the authors used cluster analysis based on Euclidean distance between small mammals from different functional zones of the city and on species composition in the control area.

RESULTS

Tashkent (41°18’ N 69°16’ E) is situated in the north-easten part of Uzbekistan, in the valley of the Chirchiq River, at 440-480 masl. Tashkent covers 335 sq km, with a population of over 3 million people. Natural biotopes include steppe plains and inundated reed beds. Tashkent is situated at the boarder of subtropic and moderately continental climate zones. The city is in the zone of ancient irrigated lands or oases. Abundant water in channels and the high temperature expedite growth of trees, shrubbery and vegetation, giving the city a peculiar look

Table 1. The brief description of the settlements under study

№	Name	Nature Zone	Settlement Type	Number of Inhabitants (thousand people)	Age (years)	Type of Housing	Amount of Emissions to norm (%)
1.	Kharasavey	arctic tundra	village	< 3	about 40	permanent	-
2.	Yamal deep drilling expedition	typical tundra	rotational camp	< 2	about 30	temporary	-
3.	Tazovsky	forest-tundra	urban-type settlement	< 6	> 130	permanent	< 10
4.	Novij Urengoy	forest-tundra	city	109	> 40	permanent	50-100
5.	Nadym	northern taiga	city	49	> 40	permanent	50-100
6.	Beloyarsky	northern taiga	city	20	> 45	permanent	50-100
7.	Noyabrsk	northern taiga	city	107	about 40	permanent	10-50
8.	Khanty Mansiysk	middle taiga	city	57	> 430	permanent	50-100
9.	Nefteyugansk	middle taiga	city	111	> 50	permanent	10-50
10.	Nizhnevartovsk	middle taiga	city	240	> 105	permanent	10-50
11.	Tyumen	subtaiga forest	city	538	> 600	permanent	10-50
12.	Ishim	northern forest-steppe	city	65	> 300	permanent	50-100
13.	Tashkent	oasis in semidesert	city	> 2600	>2500	permanent	>500

in contrast to the surrounding landscape, and forming a unique environment for animals.

Historically, the complex systems of mammals in Tashkent comprise the inhabitants of steppes, semideserts and river forests, as well as alien species. The present-day city small mammalian fauna consists of 30 species, 3 of which belong to the order Insectivora, 10 to Chiroptera, 9 to Rodentia and 8 to Carnivora. Four species (*Sciurus vulgaris*, *Ondatra zibethica*, *Rattus norvegicus* and *Mustela vison*) are alien. Each functional zone is described in terms of specific mammal complexes changing in the urbanization gradient from the least urbanized forest-park zone (anthropogenic impact is 6.7 points) to multistory buildings with a high level of urbanization (anthropogenic impact is 22.2 points) (Table 2).

Nineteen species of mammals are recorded in zone 4, including 17 small mammals. The most frequently recorded (dominant species) is *Mus musculus* (70.17% of the prey items in pellets of long-eared owl, and its average number is 12.0 individuals trapped per 100 TN), subdominats are *Ellobius tancrei* (13.15% - in the pellets) and *Crocidura suaveolens* (7.44% - in the pellets, and 4.0 individuals/100 TN). *R. norvegicus* (5.28% in the pellets) and *Microtus ilaeus* (4.04% - in the pellets) are less numerous. Among the least common species there are *Meriones tamariscinus* (1.34% - in the pellets), *Cricetulus migratorius* (0.67% - in the pellets) and *Suncus etruscus* (0.37% - in the pellets). Moreover, there are the following residents in the citys recreational parks: *Pipistrellus pipistrellus, Nyctalus noctula, Hemiechinus auritus*, *Myotis mystacinus, S. vulgaris*, *O. zibethica, Mustela nivalis, M. vison, M. eversmanni*, *Canis aureus* and *Vulpes vulpes*.

There are 26 mammal species in zone 3, including 23 small mammals. Eight species of small mammal were registered in city orchards and vineyards. *M. musculus* (78.05% - in pellets, avarage number - 17.7 individuals/100 TN) is the most abundant, *E. tancrei* is subdominat (9.0% - in the pellets). After them there follow *C. suaveolens* (4.48% - in the pellets), *M. ilaeus* (3.72% - in the pellets) and *R. norvegicus* (1.35% - in the pellets). In gardens one may record *C. migratorius*, *P. pipistrellus*, *N. noctula* and *M. mystacinus*. The uninhabited areas of the city include those areas along canal beds, highways and railroads. These patches of land are free from buildings and represent a transit zone connecting - as a green corridor - urbocenoses with natural biocenoses. They promote penetration, distribution and exchange between the city and suburban inhabitants. The following species are registered here: *Spermophilus fulvus* (population density is 4.3 animals/ha), *M. musculus* (avarage number - 4 individuals/100 TN)*, R. norvegicus*, *E. tancrei*, *M. tamariscinus*, *H. auritus*, *M. nivalis*, *Vormela peregusna*, *O. zibethica*, *M. vison*, *V. vulpes* and *C. aureus*. Caves and precipitous canal banks are inhabited by *Rhinolophus ferrumequinum*, *Rh. bocharicus, Myotis blythi, M. emarginatus*, and probably *Barbastella leucomelas* and *Eptesicus sirotinus*.

There are ten species of small mammals registered in zone 2. *M. musculus* and *R. norvegicus* predominate. The average number of *M. musculus* is 24 individuals/100 trap-days, *R. norvegicus* – 13 individuals/100 trap-days, *C. suaveolens* – 10 individuals/100 TN. *H. auritus*, *C. migratorius*, *Rh. ferrumequinum*, *M. mystacinus*, *N. noctula*, *E. sirotinus* and *P. pipistrellus* also inhabit here.

In zone 1 we recorded seven species of rodents overall. *M. musculus* is more common and registered mostly in winter in cellars and homes regardless of the number of stories. Average number of *M. musculus* is 15.8 individuals/100 TN. *R. norvegicus* dwells in cellars, refuse chutes, and the first stories of multistory buildings. Its average numbers is 12.5 individuals/100 TN. Multistory areas of the city (apartment houses, city buildings, mosques, markets' slabs) are often inhabited by such chiroptera as *P. pipistrellus*, *E. sirotinus*, *N. noctula*, *M. blythi, M. mystacinus*, *Rh. ferrumequinum*.

The control was the territory of the conservation establishment Sayhun, located on the right bank of the Syr Darya in the flood plain ('tugay') forest ecosystem. The Sayhun environment is similar to that of original riverside ecosystems of the Syrdarya tributary – the Chirchiq River with Tashkent on its terraced banks. *M. musculus* dominates here just as it does in the city area (its share in the pellet is 59.8%, 25.1 animals/100 TN). The following species subdominate: *E. tancrei* (its share in the pellet is 5.89%), *M. tamariscinus* (its share in pellet - 5.65%) and *C. suaveolens* (its share in pellet - 4.44%). It is notable that the proportion of exsoanthropes *M. tamariscinus* and *S. etruscus* in Sayhun is considerably more substantial than in the urban habitats. On the contrary, the proportion of eusynathrope *R. norvegicus* here is considerably lower than in the city. At the control area there are *H. auritus*, *C. suaveolens*, *P. pipistrellus*, *Rh. bocharicus*, *M. nivalis*, as well as there are

Table 2. Division of the urban territory of Tashkent according to the level of urbanization and indices of small mammalian communities

Functional Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5 (control)
Type	Multistory area	Private residential area	Uninhabited area	Woodland parks	River forest
Anthropogenic impact, score	22.2	19.7	16.9	6.7	6
Total number of species MM	7	10	23	17	14
Relative abundance (individuals per 100 trap-days)	14.5	15.6	13.8	10.8	19.12
Dominant groups	eusynathropes	eusynathropes/ exoanthropes	exoanthropes	exoanthropes	neutrals
Urbanization level	typical urban biocenoses	urbanized biocenoses	man-made transformed biocenoses	close to natural biocenoses	natural biocenoses
Species richness index R	0.69	1.2	5.34	5.43	3.88
Shennon's diversity index H	0.99	1.48	2.09	2.41	1.51
Simpson's diversity index D	0.49	0.62	0.64	0.75	0.47
Polydomination index P	1.97	2.61	2.82	4.06	1.90
Simpson's dominance index C	0.51	0.38	0.35	0.25	0.53
Index of anthropogenic adaptation IAA, %	100	100	100	100	13.02
Zhivotovsky Index M	1.99	2.90	5.95	6.62	4.27
Overall biocenosis stability U	4.06	4.32	2.48	2.48	1.66
Gerenal well-being index SSS	30.7	27.79	4.32	30.85	18.65

O. zibethica and *Myocastor coypus* naturalized in the 1980s. In total, the authors registered 14 species of small mammal (Table 2). Moreover, one may encounter here a number of tugay complex species extinct in Tashkent area (*Lepus capensis tolai*, *Sus scrofa*, *Meles meles*, *Felis libyca*). Here, there are also *C. aureus* and *V. vulpes*, as recorded in city recreational parks and in the Chirchiq bordering the city, but these two species are much more common. The list of Sayhun mammals consists of 19 species of mammals, but the list of chiroptera is incomplete.

Ishim (56° 07'N 69°30'E) is situated on the left bank of the Ishim River (the Irtysh River tributary). Its area covers 46.1 sq km, population – 64.9 thousand people. This town is situated on the Trans-Siberian railway and at the cross-roads of federal highways. Ishim is situated in the northern forest-steppe belt and in a continental climate zone. The bulk of precipitation falls in Ishim in July and August. Nevertheless, due to high temperatures, air humidity is usually low in summer.In different structural-functional zones of Ishim, the age of which is more than 300 years, we revealed thirteen species of small mammalians from orders Rodentia and

Insectivora, in the span from 2007 to 2011. The species were distributed unevenly in the town territory. The highest number of species (12) was noted in the territory of a large woodland park, which is connected with natural landscape. The fauna of small mammalians in this park is represented by eusynathropes *M. musculus* and *R. norvegicus*; exoanthropic species: *Apodemus agrarius*, *Cricetus cricetus*, *Microtus arvalis*, *Sorex araneus*; anthropophiles: *Sylvaemus uralensis*, *Sorex minutus*, *Sciurus vulgaris*; neutrals: *Clethrionomys rutilus*, *Microtus gregalis*, *Microtus oeconomus, Micromys minutus*, and *Sorex daphaenodon*. In general, the species composition of small mammalians is characteristic of the northern forest-steppe. The subspecies of *S. v. exalbidus*, was introduced into Ishim from Novosibirsk in 1987-1989 (Sozinova 1993, Levyh 2008).

The exoanthropic species *S. araneus* is dominant in park zone; its proportion varies from 39 to 61.5% in different years. Co-dominants are neutral species *C. rutilus* and *M. gregalis* (5.9-29.2% and 1.5–18.6%, respectively). In separate years, the number of *M. gregalis* is lower than that of *M. arvalis*. In general, the proportion of exoanthropic species varies from 45.8 to 76.5%; the proportion of species neutral to anthropogenic factors reached 20-54.2%; the proportion of anthropophiles is 0-7.7%. Six species were revealed in zone 3: eusynathropic species, *M. musculus*; exoanthropic species, *S. araneus, A. agrarius*, *M. arvalis*; anthropophilous species, *S. uralensis*; and neutral species, *C. rutilus.* The proportion of exoanthropic species reaches 67.2%; the proportion of the single eusynathropic species, *M. musculus*, is 25.9%. Anthropophiles and neutral species constitute an insignificant part in the numbers of small mammalians in this territory (1.7% and 5.2%, respectively). Of the exoanthropic species, the absolute dominant is *A. agrarius*, whose proportion reaches 48.3%; the co-dominant is *M. arvalis* (15.5%). The number of species from different plots within the given territory varies from two to four. The mammalian complex in the zone of private residential areas (zone 2) is represented by five species from the group of eusynathropic species (*M. musculus* and *R. norvegicus*) and exoanthropic species (*S. araneus, A. agrarius* and *M. arvalis*). The proportion of exoanthropic species is a little lower (64.7%) when compared with the previous zone, while that of eusynathropic species is higher (35.3%). Of exoanthropic species in comparison with zone 3, *A. agrarius* is no more a dominant, being replaced by *M. arvalis*; their proportion constitutes 20.6% and 32.4%, respectively.

Two eusynathropic species, namely, *M. musculus* (93.8%) and *R. norvegicus* (6.3%) were reported from the multistory area. The method of monitoring in the multistory area revealed the species *Vespertilio murinus*, which was not included into analysis due to the differences in the methods of quantitative counts.

The maximal level of the anthropogenic impact is noted in the multistory area (27 points), while the minimal (8 points) is in the park zone (Table 3).

The site near the nature monument “Sinitsinsky pine forest” situated 16 km away from the Ishim was selected as the control. The small mammalian community in this zone is represented by thirteen species, of which *C. rutilus* is a clear dominant. However, together with typical “neutrals” (*S. uralensis*, *Sorex caecutiens*, *Tamias sibiricus* and other) there are exoanthropic species (*A. agrarius*, *M. arvalis* and *S. araneus*) and a significant number of anthropophilous species.

Tyumen (57°09’ N 65°32’ E) is situated in the south-western part of the West-Siberian plain in the territory of Turan Lowland, along the banks of the Tura River. The city is located in a river valley containing medium hills and small ridges, and covers over 86 sq km. The climate in Tyumen is characterised by long cold snowy winters, long hot summers, short springs and autumns with weather regularly changing from cold to warm. The Tura softens the harsh climate, its banks being most comfortable city zones.

Table 3. Division of the urban territory of Ishim according to the level of urbanization and indices of small mammalian communities

Functional zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5 (control)
Type of habitat	Multistory area	Private residential area	Uninhabited area	Woodland park	Pine forest
Anthropogenic impact, score	27	22	19	8	0
Total number of small mammals	2	5	6	12	13
Relative abundance (individal/100 traps/day)	13.2	13.4	14.9	17.7	22.5
Dominant groups	Eusy-nathropic species	Exoanthropic species Eusynathropes	Exoanthropic species Eusynathropes	Exoanthropic species Neutrals	Neutrals Exoanthropic species
Level of urbanization	typical urban biocenoses	urbanized biocenoses	man-made transformed biocenoses	close to natural biocenoses	natural biocenoses
Index of species richness R	0.47	1.21	1.57	3.98	10.3
Shannon index of species diversity H	0.15	1.14	0.89	2.17	1.89
Simpson's diversity index D	0.04	0.50	0.43	0.70	0.83
Index of polydominance P	1.05	2.10	1.76	3.41	6.78
Simpson index of dominance C	0.96	0.50	0.57	0.30	0.18
Index of anthropogenic adaptation, %	100	100	100	30.0	1.72
Index of Zhivotovsky M	1.3	2.38	1.92	5.78	9.14
General sustainability of community U	1.66	3.27	2.84	3.7	25.8
General well-being index (SSS)	18.7	46.75	21.9	24.17	87.1

Table 4. Division of the city territory in Tyumen by the level of urbanization and indices of small mammalian communities

Functional zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5 (control)
Type of habitat	Multistory area	Private residential area	Uninhabited area	Woodland parks	Green zone of Tyumen
Anthropogenic impact, score	28	20	11,8	11,3	0
Total number of small mamals	2	5	9	11	27

Functional zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5 (control)
Relative abundance (individal/100 traps/day)	18.0	19.0	41.0	48.0	52,5
Dominant groups	Eusynathropic species	Eusynathropic species +exoanthropic species	exoanthropic species	"Wild" species	"Wild" species
Level of urbanization	typical urban biocenoses	urbanized biocenoses	man-made transformed biocenoses	close to natural biocenoses	natural biocenoses
Index of species richness R	0.32	1.25	4.45	4.78	4.01
Shannon index of species diversity H	0.35	1.54	1.23	2.34	3.17
Simpson's diversity index D	0.15	0.57	0.34	0.73	0.87
Index of polydominance P	1.19	2.54	2.87	3.92	7.05
Simpson index of dominance C	0.60	0.42	0.34	0.27	0.12
Index of anthropogenic adaptation, %	100	100	100	30.03	12.54
Index of Zhivotovsky M	1.54	2.87	3.89	5.98	7.86
General sustainability of community U	1.30	4.16	2.33	9.56	14.23
General well-being index (SSS)	3.1	3.95	3.79	4.26	18.23

Tyumen, which has existed for more than 600 years, is inhabited by 202 species of terrestrial vertebrate, of which 30 species are mammalians belonging to 5 orders: Insectivora, 6 spp.; Chiroptera, 4 spp.; Lagomorpha, 1 spp.; Rodentia, 14 spp.; and Carnivora, 5 spp. Because of the diversity of plant communities and other factors (including anthropogenic factors) small mammalians are distributed in the city zones irregularly. The highest number of species was recorded in woodland parks (11) in the city outskirts, while the lowest number (1) in the central city garden (Table 4).

No such regularity was traced in respect to the general and relative abundance of small mammalians: in central habitats of the zone 3, which are far from natural biotopes, the number of mammalians was equal to that of woodland parks in the city outskirts, but was conditioned by other species: anthropophilous and synanthropic species, which were obvious dominants. As the distance from residential and industrial buildings grows, the species composition of small mammalians becomes more diverse with almost unchanged numbers. In zones 2, 3 and 4, the field mouse constituted a significant part of caught animals: 45.8; 62.6 and 27.4 %, respectively.

We believe that it is the character of domination of some groups of species in urban cenoses that is necessary and convincing criterion for the assessment of the urbanization level of

Table 5. Division of the urban territory of Novij Urengoy by level of urbanization and indices of small mammalian communities

Functional zones	Zone 1	Zone 3	Zone 4	5 – control
Type of habitats	Multistory area	Industrial zones, forest belts, etc.	Woodland-parks	Green zone of Novij Urengoy
Average point of anthropogenic load	30	25	5	0
Total number of micro-mammalian species	2	4	7	14
Relative abundance (individuals/100 traps/day)	14.5	12.0	2.8	22,1
Dominant groups	Eusynathropic species	Eusynathropic + anthropophilous species	“Wild” species	“Wild” species
Level of urbanization	Typical urban cenoses	Anthropogenically transformed communities	Communities close to natural	Natural communities
Index of species richness R	1.43	3.14	4.80	4.61
Shannon index of species diversity H	0.72	1.66	2.37	3.16
Simpson’s diversity index D	0.32	0.62	0.78	0.82
Index of polydominance P	1.47	2.61	4.48	6.13
Simpson index of dominance C	0.68	0.38	0.22	0.19
Index of anthropogenic adaptation, %	100	100	20.2	6.13
Index of Zhivotovsky M	1.80	3.55	5.57	6.56
General sustainability of community U	1.28	2.01	12.73	13.76
General well-being index (SSS)	35.02	26.68	14.16	10.50

specific habitats and anthropogenic impact. By dominant species and character of domination, the city territory is clearly divided into four zones, which coincide with functional zones of Tyumen that we marked out before (Table 4).

In the multistory area, the obvious dominants are eusynathropic species (*M. musculus*, *R. norvegicus*), the proportion of which in the total number constitutes 89% and 11%, respectively. In the private residential area, the proportion of eusynathropic species drops to 21%, whereas the percentage of exoanthropic species (*A. agrarius*, *M. arvalis*) increases to 71%. In zone 3, a high percentage of exoanthropic species is noted (79%); in woodland parks the percentage drops and they are replaced by “wild” species with the anthropophilous trend: *Clethrionomys glareolus Cl. rutilus*, *S. araneus*, etc. (53.6%).

Novij Urengoy (66^0 05’ N 76^0 41’ E) is one of the youngest cities of the Tyumen Region. It is situated on a small Evo-Yaha river in the forest-tundra subzone of the West-Siberian Plain. The city stretches over the 16 sq km. The average annual temperature is about -7^0C, the absolute

minimum is about -60^{0}C. There is continuous permafrost around the city.

In the town of Novij Urengoy, which is about 30 years old, only seven species of small mammalians belonging to three orders (Insectivora, Rodentia and Carnivora) were caught. We isolated three zones: 1. multistory area; 2. industrial zones and 3. woodland parks. Natural forest-tundra biogeocenoses in the outskirts of this town were the control. The highest anthropogenic load was noted for zones 1 and 3 (Table 5).

The absolute dominant in the multistory area is *M. musculus*; *R. norvegicus* is relatively rare.

There is practically no private residential area in Novij Urengoy as such; the districts of residential areas consisting of temporary trailers resemble to a larger extent industrial zones of other towns. Anthropophiles *Sorex tundrensis* and *M. nivalis* were noted there besides *M. musculus* and already numerous *R. norvegicus*, which forms the basis of small mammalian population. The zone of woodland parks is represented by the fragments of natural forests, which resemble natural forest communities along river valleys in the forest-tundra zone. The "wild" species dominating in the community of small mammalians, namely, neutrals *Cl. rutilus* and *M. oeconomus*; less represented are anthropophiles *Microtus agrestis* and *S. tundrensis*. Of other species, the house mouse is often encountered.

Many insectivorous species recorded in natural communities are absent, which is connected, in our view, with the heavy compaction of soil and the trampling down of herb-dwarf shrub cover resulting from recreation. The communities of the town "green zone" are represented by 14

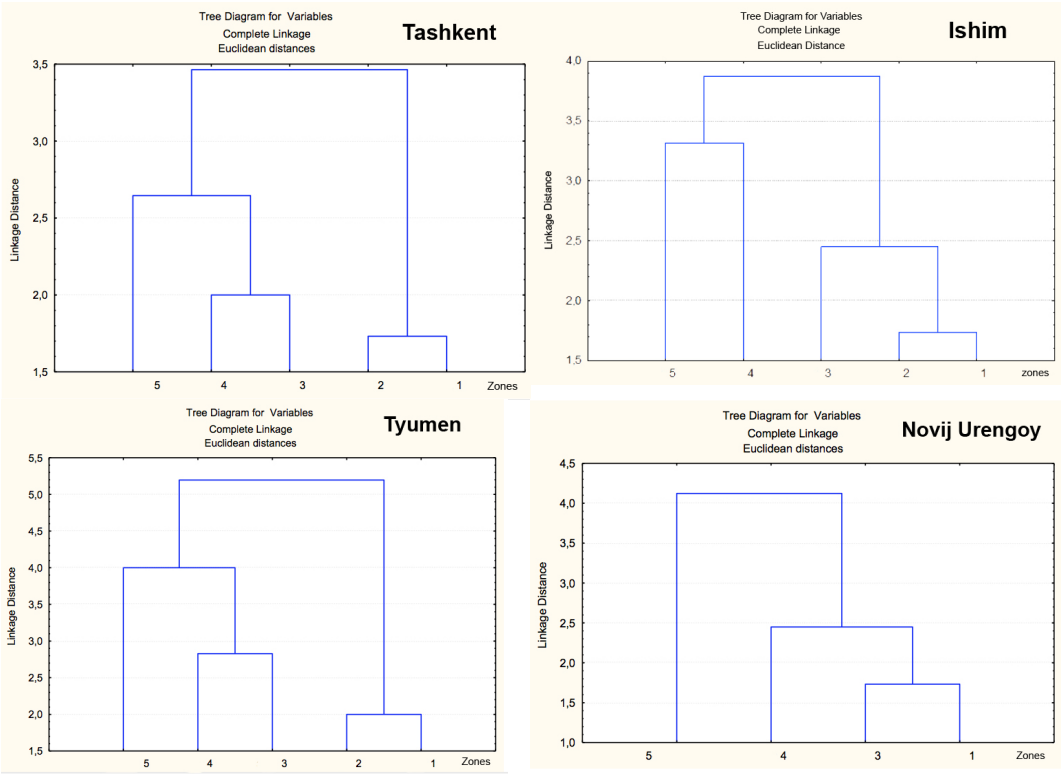

Fig. 2. The similarity of small mammalian communities from different structural-functional zones of cities by species composition.

species of micro-mammalians, of which, as in the previous zone 4, neutrals dominate (the northern red-backed vole and the tundra vole); however, the level of domination is significantly lower than in any other zone of the urban territory, as different species of common shrew and other vole species are well represented. Such neutrals as the Siberian chipmunk, muskrat, harvest mouse and anthropophobic species – *Neomys fodiens*, *Sorex minutissimus* were noted only there. Eusynathropic and synanthropic species have completely vanished from this zone.

Maximal relative abundance of small mammalians was recorded in zone 1 of the town center: 14.5 individuals/100 TN; in zone 3, 12.0 individuals/100 TN; in zone 4, only 2.8 individuals/100 TN even at a generally low point of the anthropogenic impact. This regularity may be connected with the general decrease in the ecological capacity of habitats situated in woodland park zone compared to natural habitats in the course of recreation at the absence of ecological niches for the synanthropes there (unlike zones 1 and 3). All these provide the maximal similarity in species composition between communities of zones 1 and 3 (Fig. 2), while zone 4 occupies an intermediate position between these and natural communities of small mammalians.

There appears a high level of domination of *Cl. rutilus* in zones 4 and 5, and *M. musculus*, in zone 1. The absence of typical anthropophilous species in natural habitats unlike the south of western Siberia and Uzbekistan leads to an extreme poverty of species diversity of urban cenoses, particularly in residential area and industrial zones.

DISCUSSION

In biotopes of Tashkent, which experience a strong influence from urbanization, the total number of species is declining. In terms of animal abundance there is an inverse correlation for obligate synanthropes (*M. musculus*, *R. norvegicus*) – they become more numerous in more urbanized areas, just as exoanthropes (*M. tamariscinus*, *M. ilaeus*, *C. suaveolens*, *C. migratorius*) and neutral species (*E. tancrei*) become less common. High indices of species diversity and abundance of small mammals are characteristic of natural habitats with a very low anthropogenic load.

In terms of dominance pattern, building zones differ from the zones close to the natural ones. In each zone discussed by the authors, there are obligate synanthropes, but their share declines from the multistory buildings zone to the zone of recreational parks. At the same time exoanthropes and anthropophilic species become more numerous. Exoanthropes dominate in communities of zones 3 and 4, the share of anthropophilic species grows, there occur neutral species. In this respect, the green unpopulated areas of the city are similar to the control territory, where the neutrals dominate. Thus, from the analysis it is obvious that synanthropy goes up due to anthropogenic load escalation in the urbanization gradient from recreational parks to multistory buildings area.

The cluster analysis of the faunistic composition in different city zones of Tashkent and the control area shown that samples from building zones (zones 1 and 2), control (zone 5) and zones close to natural habitats (zones 3 and 4) make up two separate clusters. Samples from zones 3 and 4 show that there is a considerable similarity between the faunas, and they grouped together with the control. The building zones have the similarity with control (Fig. 1).

Comparative indices of the species diversity in mammalian communities from various functional zones of the city are reflected in Table 2. The number of species, species richness and species diversity increase against the urbanization gradient, i.e. from the residential area to undeveloped sites of the city, which is witnessed by the increase of the index of species richness and Shannon and Simpson indices of diversity. The growth of the number of small mammals ranges from zones 1 and 2 to zones 3 and 4. At the same time, a drop in the

index of system order and increase in the size of the maximum chaos is noted. The index of domination C increases along the urbanization gradient reaching its maximum in the zone of multistory area, which suggests high species diversity in the community and a decrease in the proportion of dominant species, such as *M. musculus* and *R. norvegicus* in the park zone. An increase in the index of polydominance may also suggest more complex and diverse interspecific relations in territories close to natural ones, and the emergence of obvious subdominants such as *E. tancrei* and *C. suaveolens*.

The Zhivotovsky index decreases along the urbanization gradient, its maximal values being characteristic for the small mammalian community in the park zone. At the same time, in a site of the tugai forest we encountered species that vanished as a result of the development of the territory of Tashkent oasis. These were representatives of the families Leporidae, Canidae and Suidae. The other cause of a high diversity of urban communities of the natural type is the presence of diverse ecological niches not typical of natural habitats, to which small mammalians are best adapted.

A comparative-faunistic analysis of mammalian communities from different structural-functional zones of Ishim and the control showed that samples from natural habitats and woodland park on the one hand and two residential areas, on the other, make up two separate clusters according to the Euclidean distance. The sample from zone 3 occupies an intermediate position, but according to the method of complete association they join the cluster from the residential zones (Fig. 2).

The analysis of the domination in the studied zones showed a clear differentiation between the park zone and the multistory area. The community of small mammalians in the first of them is represented by exoanthropic and neutral species, while in the second one, by exclusively eusynathropic species (Table 3). The communities of small mammalians in the zones 2 and 3 are similar by the ecological structure – eusynathropic species in them are subdominant at the absolute domination of exoanthropic species. However, these communities differ in faunistic composition and in the ratio of various species. In the park, neutral species are subdominant against the domination of synanthropic species. The increase of the specific weight of exoanthropic and eusynathropic species from zone 4 to zone 1 predetermines the increase of the index of anthropogenic adaptation by the urbanization gradient. General sustainability of the system, the maximal value of which was recorded in the park zone and the minimal one in the most transformed zome of multistory area decreases in the same direction. However, the change of the general sustainability is not rectilinear as the anthropogenic impact grows. So, the index of general sustainability of the small mammalian community in private residential areas is only by 12% lower than that in the park community; and, on the contrary, it is 15% higher than that in the mammalian cenosis of zone 3. Small mammals from the zone of private residential areas are characterized by the highest general well-being index. This can be explained by more intensive reproductive processes due to the round-the-year breeding of eusynathropic species in human houses and sufficient resource capacity of habitats in this zone, which have not lost connection with natural habitats, for the breeding of “wild” species with exoanthropic and anthropophilous trend.

The correlation analysis using the Spearman’s rank correlation index (R) showed the presence of authentic strong back-coupling ($R=-0,9$ at $P<0,05$) between the anthropogenic load on the habitat expressed in points and such indices of alpha-biodiversity as the index of species richness (R), Shannon index of species diversity (H), the index of polydominance (P), index of Zhivotovsky (M), as well as authentic strong direct coupling ($R=0,9$ at $P<0,05$) between the anthropogenic load on habitat, on the one hand, and Simpson index of dominance (C) and Shannon index of evenness (ES), on the other (Table 3).

Thus, the zone of uninhabited areas is well differentiated from the woodland park zone. This can be explained by a loss of connection with natural biotopes, growth of the complex effect of urbanization factors conditioning the reduction of the number of species in the community due to the loss of neutral and anthropophilous species. Change in the community structure is because of the breeding of animals from ecological groups of exoanthropic and eusynathropic species, decrease of the share of shrews-common shrews, which occupy a higher trophic level than rodents and respectively are more susceptible to pollutants, and the reduction of the resource capacity of habitats due to the degradation of soil and plants under the effect of uncontrolled recreation (Levyh & Bazhina, 2012).

Data obtained suggest that the major factors supporting the faunistic and species biodiversity of small mammalians in the territory of Ishim are the degree of connection with natural landscapes, a large area of green zones with developed grassy cover providing the protective capacity of habitat and diversity of microbiotopes.

The index of anthropogenic adaptation of small mammalian community in all zones of Tyumen except the woodland park was equal to 100%, which can be explained by taking into account a long-term effect of anthropogenic factors in these zones, which has resulted in adaptation of animal populations to these conditions. However, the general sustainability of small mammalian communities is highest in the woodland park zone and twice as low in the zone of private residential area, which is relatively close to natural biotopes, while the lowest sustainability is noted in the most transformed stations of the multistory areas.

The results of the cluster analysis of the faunistic composition in different city zones allow us to state that there is the most similarity between two residential areas (1 and 2), which is conditioned by the settlement of eusynathropic and synanthropic species there (Fig. 2). Farther by Euclidean distance is the zone woodland parks (zone 4) and zone 3. We established a clear correlation between indices of species diversity of small mammals in zone 3 and both the distance to natural habitats and the level of anthropogenic impact: correlation ratio between the distance from natural biotopes and species richness reaches 0.76±0.17. The distribution of the number of species along the gradient of distance to natural biotopes is described by the function of species: $y = -0.09 x+2.65$. The correlation ratio of the Pielu evenness index and distance to natural biotopes was 0.78±0.17, and this relation is described by the power function of species: $y = 0.752x^{0.033}$. The correlation ratio of the index of species richness and level of anthropogenic load expressed in points is 0.718±0.186. The inverse relation of these indices is noted, and the equation characterizing it is: $y = -0.15x+2.70$. A similar picture is noted for the index of resilient stability of mammalian communities (Gashev 2000) in the gradient of the growing anthropogenic impact: h=0.59±0.22, $y = -8.59x+1.33$. However, the most indicative is the character of domination: the coefficient of correlation of domination index with the level of anthropogenic load is equal to 0.96±0.12.

In general, highest values of the general index of small mammalian community well-being are characteristic of the woodland park zones, while the lowest, of the multistory area (Gashev 2000). Peculiar "intrazonal" territories in Tyumen are the alienation zones along railroads and river banks (Tura, Tyumenka, Babarynka), along which active movements of small mammalians take place and there is a connection between the urban and suburbian biotopes (Gashev et al. 2012).

The analysis of the results of winter en-route counts of small mammals in the woodland park in 1994-2005 suggests a clear tendency of the decline of animal numbers (*S. vulgaris* by 8 times, *Mustella erminea* and the least weasel by 7 times), which may be connected with the growth of recreation load on habitats observed at this time: periodical burnout of the soil surface during spring ground fires, and particularly with the growth of numbers of dogs taken out

for walking. It should be noted that *T. sibiricus*, which is encountered in natural biotopes similar to the studied ones, is completely unavailable in this woodland park. This may be connected with the way of life of this species on the ground, which is under the negative impact of recreation. The aforementioned observations suggest that even woodland park zones within Tyumen are subject to a negative effect from urbanization.

N.F. Chernousova (1996) also reported a significant effect of recreation on woodland park communities. She noted that it did not affect the species composition of the mammalian complex until a specific moment; rather, it only affected the total number of animals. However, as the load grew, the decline of some species took place and their place was occupied by synanthropic species.

The results of the cluster analysis of faunistic composition of different zones in Novij Urengoy indicate the highest similarity between zones 1 and 2, which is characterized by their occupation by synanthropic and eusynatrophic species (Fig. 2). Further by the Euclidean distance is the zone of woodland parks (zone 4).

The indices of species richness and diversity decrease as the urbanization increases; the lowest indices of species richness R, Shannon and Simpson species diversity are noted for the area of multistory houses. The index of polydominance P grows against the urbanization gradient saying about a higher diversity of natural communities and the growth of the role of “wild” species in them, whereas the index of domination C, on the contrary, increases along the urbanization gradient indicating domination of synanthropic species (Table 5).

The index of anthropogenic adaptation of small mammalian communities in zones 1 and 3 constitutes 100%, which suggests a complete anthropogenization of the given types of communities, which have become adapted to life in such conditions. This is confirmed by high values of the general well-being index for animals in the multistory area and industrial zone. However, the general sustainability of such communities is minimal. The highest sustainability is shown by the small mammalians from the woodland park zone (Table 5).

Hereby, in the zonal aspect, a general increase in species richness amongst small mammalians in settlements from north southwards is noted; which can be linked to the improvement of living conditions of these small mammalians, and a general increase in the number of species in this gradient in Yamal-Tashkent transect (Table 6). The correlation coefficient between the number of species in the city and the number of species in the natural sub-zone is highly significant and equal to 0.81±0.30. At the same time a decrease in the proportion of anthropophilously-positive species at the movement from south northwardly is observed. We should note that the prevalence of "wild" species (e.g., *Cl. rutilus* in Novij Urengoy) at a low proportion of eusynathropic species is partly connected with the young age of settlements in the north transect. Moreover, there are no eusynathropic species in some northern shift-work settlements (Gashev, 2000) while in the south of transect (i.e. Central Asia) they form stable populations even outside settlements (primarily, *M. musculus*); in the remaining territory only the temporary movement of eusynathropic species to natural biotopes in warm seasons is noted. As the settlements grow old, the populations of eusynathropic species develop a more established position there. The “wild” species cede to anthropophilous species, which are evolutionarily more adapted to these conditions.

The aforementioned regularity of the relationship between species richness of urban ecosystems and the presence of anthropophilous species in adjoining natural habitats is clearly traced in the latitudinal gradient within the entire transect. So, a strong positive correlation has been revealed between the number of species in town and a part of anthropophilous-positive species in natural biotopes of the subzone: 0.76±0.33, and between the part of only anthropophilous-positive species in town and the part of anthropophilous-positive species in

natural biotopes: 0.82±0.28, especially between the number of species in the residential area and the part of anthropophilous-positive species in natural biotopes: 0.88±0.24.

The comparative-faunistic analysis of mammalian communities from different structural-functional city zones has shown that there are similarities in the structure of mammalian complexes in Tashkent and Tyumen, on the one hand, and Ishim and Novij Urengoy, on the other (Fig. 2). It appears that beyond any natural and historic peculiarities of the mammalian complex formation, level and character of anthropogenic load on habitats, the structure of urban cenoses depends on the sizes of cities, their age and features of the urban infrastructure.

When comparing indices of anthropogenic adaptation of micro-mammalian communities from different functional zones of four cities (tables 2-5), it is clear that communities reach full adaptation in zones 1, 2 and 3 irrespective of the natural zonality and historic features of the cities. Differences are seen in the IAA level of zone 4. Whilst it is full in Tashkent, in the cities of west Siberia it constitutes only 30%. This is due to the secondary nature of tree plantings in Tashkent, which is itself an oasis in the zone of irrigated lands since ancient times inhabited by synanthropic species, as well as the anthropophilous and neutral species coming to settle in this type of urban cenoses from natural zones. Woodland parks in Siberian towns are islands of natural landscapes, which are gradually populated by synanthropic species. Unlike Tashkent in which anthropophobes are unavailable, they still inhabit the outskirts of younger towns in western Siberia (*Pteromys volans*, *N. fodiens*, *S. minutus*, etc.). As expected, the lowest index was obtained for the control territories within towns, where, despite a high proportion of synanthropic species, including eusynathropic species, the importance of anthropophilous and neutral species of small mammalians is high.

The peculiarity of all towns included in the study is the presence of introduced species such as *R. norvegicus*, *O. zibethica*, *S. vulgaris exalbidus* and *M. vison*.

The highest indices of general sustainability and well-being amongst small mammalian communities in the towns of Western Siberia were recorded for the zone of private residential area and woodland parks, and for both residential areas in Tashkent. A high general index of well-being for the small mammalian community of woodland-park zone was also noted there. Natural communities in Western Siberia generally show higher well-being index and sustainability in comparison with the urban communities, whilst in Central Asia, urban communities of small mammalians are on the contrary characterized by high indices of these general indices. This could be connected to the period of long-term historic adaptation. In the youngest of Siberian towns, where the indices of community sustainability and well-being grow against the gradient of urban community, the communities appear less successful in comparison with natural communities.

An interesting phenomenon is a clear tendency for the Zhivotovsky index to decrease in the towns of Western Siberia, with advancement from north southwards, and an inverse tendency for this index in natural communities of respective natural zones and sub-zones. At the same time the index of Zhivotovsky is maximal along the entire transect, while in natural communities near Tashkent its value is minimal (Tables 2-5).

Thus, the influence of the level of urbanization of habitats on the communities of small mammalians, which are connected with town planning nuances of separate settlements and their natural and historic peculiarities, can be clearly traced in the studied material.

CONCLUSIONS

In the zonal aspect, a general increase is noted in the species richness of small mammalians in settlements from north to south, which may be connected with the improvement of habitation conditions of small mammalians with the general increase in the number of species in this gradient on Yamal-Tashkent transect. A decrease is noted in the proportion of anthropophilous-positive species, to which we assigned eusynathropic, exoanthopic and anthropophilous species, in the south northwardly. The highest proportion of anthropophilous-positive species (84.6%) is noted in Tashkent. The decrease in the number of species inhabiting the residential area in the south-northward direction is recorded. A high proportion of eusynathropic species is characteristic of Tashkent (primarily, *M. musculus*), which form a stable population even outside the human settlements all the year round, unlike northern towns, where only temporary movement of eusynathropic species to natural biotopes in warm seasons is observed.

As the age of cities increases (unlike relatively new northern towns, Tashkent is more than 2,500 years old), the populations of eusynathropic species have a more established position there. "Wild" species are inferior to anthropophilous species, which are more adapted to these conditions evolutionarily.

Thus, the influence of habitat urbanization in small mammalian communities, which is connected with both technical town-planning nuances of individual human settlements and their natural and historic peculiarities, is established.

ACKNOWLEDGEMENT

The work has been carried out within the framework of the basic part of the state assignment of the Russian Ministry of Education and Science #01201460003.

REFERENCES

Adams L.W. 2005. Urban wildlife ecology and conservation: a brief history of the discipline. *Urban Ecosystems,* 8: 139-156.

Arefiev S.P., Arefieva, A.V., Gashev, S.N., Lomakin, D.E., Sharapova, T.A. 1998. The study of regularities of formation of biodiversity in urbanized territories of Tyumen region. Report on scientific and scientific-organizational activity in 1997. Tyumen. Pp. 57-67. (In Russian).

Gashev S.N. 1998. Ecological characteristics of mammalian communities. Biological diversity of animals in Siberia. Tomsk. Pp. 128-129. (In Russian).

Gashev S.N. 2000. Mammalians in the system of ecological monitoring (the case study of Tyumen province). Tyumen. Pp. 220. (In Russian).

Gashev S.N., Bykova, E.A., Sorokina, N.B. 2012. "Green corridors" as factor of biodiversity support in urbanized landscapes. *Journal of Samara Scientific Center of Russian Academy of Sciences*, v. 14 (7), 1 (9): 2395-2400. (In Russian; abstract in English).

Gashev S.N., Ivanova, E.A., Mukanova, A.A. 1997. The fauna and ecology of terrestrial vertebrate animals in the city of Tyumen. Problems of general biology and applied ecology. Saratov. Pp. 44-48.

Kozhova O.M., Izmet'eva, L.R., Pavlov, B.K. [et al.]. 2000. Methodology of assessment of ecosystem status. Rostov-on-Don. Pp. 128 (In Russian).

Levyh A.Yu. 2008. The population of small mammalians in woodland parks and gardens in Ishim. Ecology and Faunistics: the collection of scientific works. Ed. S.N. Gashev. Tyumen. Pp. 27-35. (In Russian).

Levyh A.Yu., Bazhina, A.N. 2012. The impact of urbanization on the community structure and the status of small mammalian populations. The Bulletin of Ishim State Pedagogical Institute after P.P. Ershov. Series “Natural Sciences”, 1 (4): 38-46. (In Russian).

Sozinova O.P. 1993. Introduction of the red squirrel into the woodland park zone of Ishim. Western-Siberian local history: Scientific-Information collection. Ishim. Pp. 63-69. (In Russian).

Received: 07.04.2015.
Accepted: 01.06.2015.