

THE INFLUENCE OF URBANIZATION ON MAMMAL DIVERSITY AND THEIR POPULATION PATTERNS: A CASE STUDY OF TASHKENT, UZBEKISTAN

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Abstract

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The article provides a survey of the mammalian fauna and ecology in different habitats across the city of Tashkent that vary in the degree of urbanization. The current mammalian fauna of Tashkent is represented by 32 species; during the city's development, 9 species have disappeared from the place, either through an anthropogenic impact or having been forced out by alien species. The urban mammalian fauna has increased through arrival of five new invasive species. With the ongoing urbanization, the species diversity of small-sized mammals is decreasing, while their numbers are growing, resulting in simplification of the structure of small mammals' urban communities and lowering of their biodiversity. The urbanization does not impact the age and sex structure of the house mouse population noticeably. The urban population shows a productivity 1.7 times higher than the wild populations, which is a compensatory response to the relatively high embryonic mortality that is almost totally absent in natural populations. Differences in the morphophysiological indicators of the house mouse synanthropic population and those of populations in the wild are an adaptive response to anthropogenic impact, which appears in the form of more rapid growth, a higher metabolism, exchange of energies, and overall stress load on the rodents in urban biocoenoses. The study showed that the skulls of urban animals grow more rapidly than those of wild mice, while their proportions change following the development pattern of juvenile mice, which suggests that individuals from the Tashkent population can be referred to as rapidly growing animals, with outdoor individuals showing greater relative cranial parameters.

Key words: urban ecosystems, mammals, synanthropic species, morphophysiological indicators, cranial features.

Introduction

The issue of the development of animal communities in areas with various degrees of urbanization is not novel. The results of numerous studies can be found in various publications dedicated to the fundamental problems of urban ecology (Klausnitzer, 1990; Adams, 2005; Marzluff et al., 2008; Altherr, 2007; Gashev, Bykova, 2007; Gashev et al., 2015; and others), the faunas of a number of cities in the continental Europe, Great Britain, the United States, Russia, and Central Asia (Dickman, Doncaster, 1987; Kovshar, 1988; Baker et al., 2003; Bolshakov et al., 2006; McKinney, 2008; Tikhonova et al., 2012; Bykova et al., 2015; and others), the synanthropic urbanization and adaptive features of urban animal populations (Luniak, 1996), and the impact of urbanization on urban populations of animals in the context of the growing conflict between humans and wildlife (Baker et al., 2003). The urban environment is evolutionarily new to species because all of them formed long before the emergence of the earliest urban settlements. On the one hand, the relatively stable temperatures, high humidity, and food abundance combined with diverse environment and low to zero numbers of predators ensure ecological sustainability for animal populations. On the

other hand, urbanization leads to the formation of various unfavorable conditions, resulting in the degradation and elimination of natural habitats. The insufficient environmental capacity led to the disappearance of a number of species and the genetic isolation of populations of other species. The high pollution and disturbance, development of nonspecific mortality factors, competition with alien and domestic species, and higher rate of infection transmitted from domestic to wild animals – all these resulted in lower stability and disappearance of some species.

Not all species are able to adapt to a new environment. In comparison to wild populations, urban animals demonstrate changes in their diet, behavior, daily and seasonal dynamics, burrow-digging activity, biology (longer lifespan, changes in reproductive parameters, and so on), and physiological parameters. The mammal species that have best adapted to urban biocoenosis include the lesser white-toothed shrew (*Crocidura suaveolens*), yellow ground squirrel (*Spermophilus fulvus*), Zaisan mole vole (*Ellobius tancrei*), gray hamster (*Cricetulus migratorius*), tamarisk gerbil (*Meriones tamariscinus*), and others. The brown rat (*Rattus norvegicus*) has spread in urban areas by accident. Introduced species are represented by the red squirrel (*Sciurus vulgaris*) and the muskrat (*Ondatra zibethicus*).

The stabilization of populations results in synanthropy – close coexistence with the humans and dependence on human activity. Specialists' opinions as to how to classify synanthropy diverge, but, like many other researchers, we adhere to the simplest and commonest version: synanthropes, hemisynanthropes, and exoanthropes (Kucheruk, 1988; Tikhonova et al., 2012).

Synanthropes are divided into obligatory and facultative. Eusynanthropes, true synanthropes, or true commensals are represented by various species from the mouse family (Muridae) that largely inhabit man-made structures. Using the advantages of coexistence with humans, these rodents have become much more widely distributed (Lapshov, Kucheruk, 1994). In various parts of the world, these species include the house mouse, brown rat, and, partially, black rat (*Rattus rattus*) (Kucheruk, 1988). True synanthropes in Uzbekistan are the house mouse and the brown rat. True synanthropes coexist and spread together with humans by deeply penetrating into and using widely the products of the human environment-forming activity (Klausnitzer, 1990; Lapshov, Kucheruk, 1994). However, even these species cannot follow humans everywhere. So, the brown rat has failed to settle in a number of Central Asian cities (Kucheruk, 1988), including some in Uzbekistan, because it entered into complex interspecies relationships with aboriginal rats (Mitropolsky et al., 2007).

Hemisynanthropic or semisynanthropic animals are facultative synanthropes referred to as species with ecologically and geographically restricted synanthropy, most of which inhabit open biotopes, but are also quite common in man-made structures. In Uzbekistan, these are represented by the pygmy wood mouse (*Sylvaemus uralensis*), yellow ground squirrel, gray hamster, lesser white-toothed shrew, bats (*Rhinolophus ferrumequinum*, *Eptesicus serotinus*), Tien Shan vole (*Microtus ilaeus*), and Turkestan rat (*Rattus turkestanicus*). The brown rat has forced the Turkestan rat out of its former habitats and currently shows no tendency to spread further (Promtov, 1962; Promtov et al., 1981; Kucheruk, Kuzikov, 1985; Mitropolsky et al., 2007; Sokolov, Karaseva, 1990; Alymkulova, 2016).

We chose mammals for our research because they are a group closest to the humans from an evolutionary aspect and an important component of the terrestrial ecosystems, which may serve a good model, whereas their adaptivity to urban biocoenosis has not been studied properly. The highest adaptation to urban environment is shown by synanthropic rodents with highest ecological flexibility. The reference group consisted of small mammals (largely insectivorous animals and rodents). The goal of the research was to find regularities in transformation of the mammal fauna and identify the adaptive characteristics of mammalian complexes in the urbanized territories of Uzbekistan, with its largest city, Tashkent, used as a case study.

Material and methods

Study area

The city of Tashkent, whose age is estimated to be over 2000 years, is situated in the northeastern part of Uzbekistan (41°18' N, 69°16' E), in the Chirchik river valley, at altitudes between 380 and 520 m above sea level. The city's area is 33,155 ha. As of October 1, 2019, the population is 2554.2 thousand people, according to the State Committee of the Republic of Uzbekistan

for Statistics (2021). Natural biotopes include steppe plains and riparian reed thickets. Tashkent lies at the border between the subtropical and moderately continental climatic zones. The city is located in an area of ancient, irrigated lands and forms a part of an anthropogenic oasis, where it stretches along the fluvial terraces produced by numerous natural and artificial streams (over 100 canals of varying size with a total length of 240 km) fed by the Chirchik River. Abundance of water and high temperatures facilitate the growth of trees and shrubs and the development of agriculture, which endows Tashkent with a unique appearance contrasting with the surrounding landscapes and creates specific habitats. At the same time, the city is the largest industrial and transportation center in the region, with about 300 large and medium-size enterprises functioning in it and extensive railway and road networks covering its area.

The fauna and ecology of mammalian populations in Tashkent and adjacent territories were studied in 1991–2004, 2006, and 2010–2016. The reference group consisted of small terrestrial mammals (mainly insectivores and rodents). Being primary consumers, small mammals play an important role in ecosystems. Their status indicates the status of plants and insects they eat as well as the status of the secondary consumers (predators) for which they can serve as food source (Kalivodová et al., 2018).

In total, 22 experimental sites were created (Fig. 1). The reference sites were organized in the Saykhun nature protection enterprise on the left bank of the Syrdarya river valley (Syrdarya Province), in the same natural and climatic zone as the impacted area. This territory has biotopes similar to habitats on the floodplain of Chirchik, where the Tashkent oasis has developed. To study changes in house mouse populations impacted by urbanization, we also did research on the free-living house mouse population on the southern shore of the Aydar Lake (Jizzah Province).

The anthropogenic impact (noise, transport load, degrading vegetation, dumps, food waste, gas pollution, dust and ash, disturbance factor, heavy metals) and the stress it caused were assessed in the experimental sites. To make an integral estimation of the anthropogenic load in experimental urban sites, we used the following scoring system: 0 – zero anthropogenic impact; 1 – weak anthropogenic impact; 2 – moderate anthropogenic impact; 3 – strong anthropogenic impact (Gashev, 2000; Levykh, Bazhina, 2012).

Study samples and data analysis

The city's area was divided into four functional zones: zone 1 – multistory 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, 2000) (Fig. 2). We specified the species composition and ecological characteristics of the mammal community within each of these zones (Gashev, 1998). In total, 340 individuals of six species were captured during 2500 camera-days; five more species were identified during transect surveys in winter. Also, 5291 pellets left by the long-eared owl (*Asio otus*) were analyzed in its regular wintering grounds in Tashkent and the reference territory in Saykhun – in five sites in total, where the skulls of 9355 individuals of 10 small mammalian species were found. Proportions of the small mammal's species in the owl diet are representative of the proportions of the species in

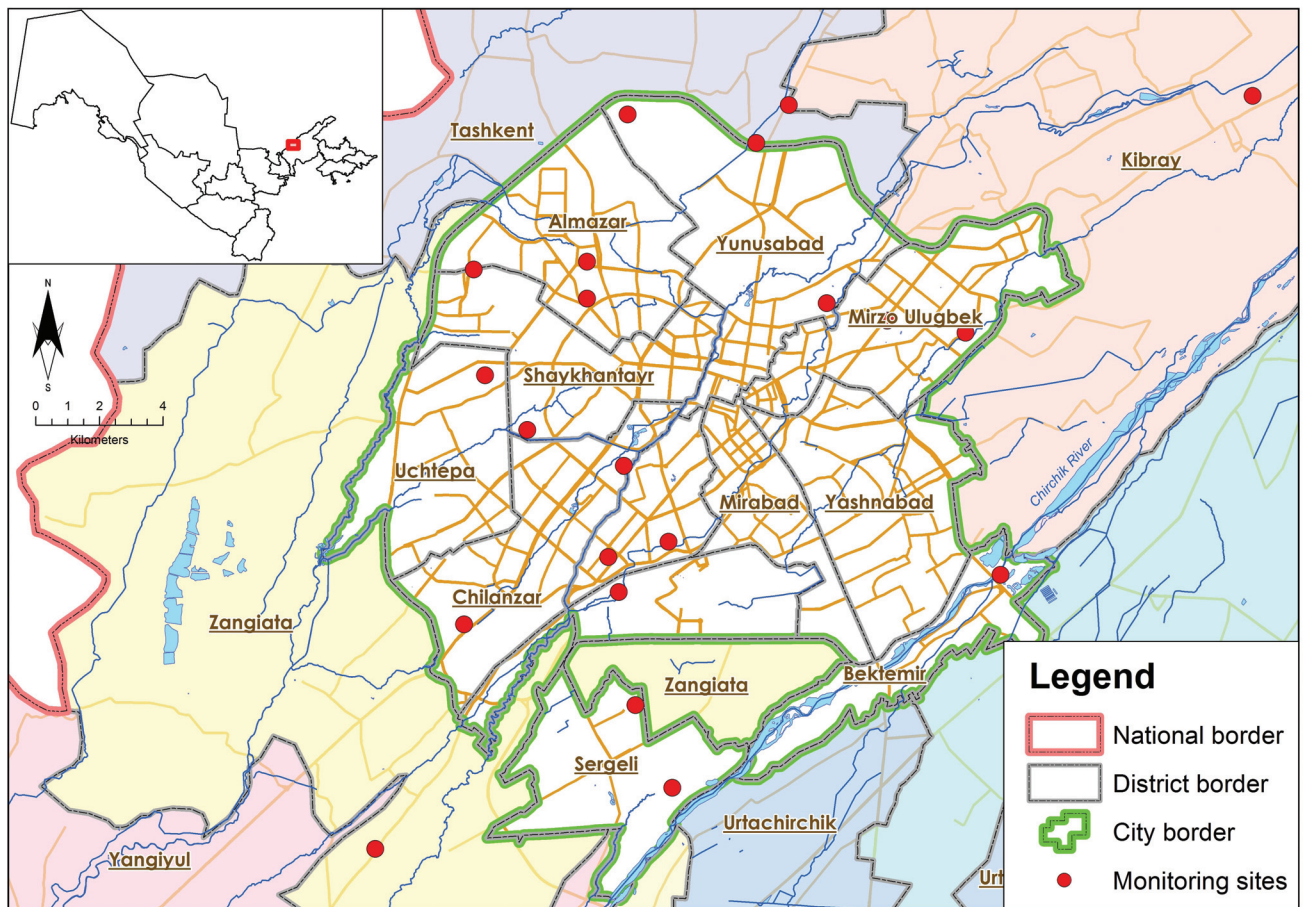


Fig. 1. Locations of monitoring sites in Tashkent and suburbs.

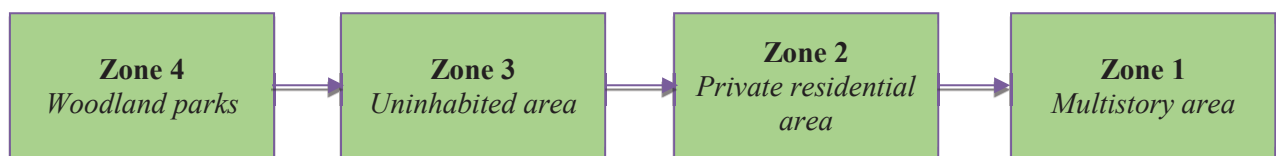


Fig. 2. Scheme of urbanization level changes depending on the type of functional urban zone (by urbanization gradient).

their communities (Andrade et al., 2016). To study the relative abundance of prey species, we measured the proportion of the prey items in pellets from each site.

To study the rodents' adaptation to urban environment, we analyzed the structure, reproductive characteristics, and morphophysiological and cranial indices of the population of the reference species, *Mus musculus*. The research was made in various types of urban habitats. We examined the following types of urban landscape: multistory buildings, private buildings, wastelands, and woodland parks. Two free-living populations of the house mouse inhabiting the riparian forest (tugai) in the Saykhun nature protection enterprise and the shore of the Aydar Lake were used as reference groups. We examined a total of 250 individuals of the house mouse, of which 128 were from the Tashkent population, 90 from the Aydar population, and 32 from

the Saykhun population. To study the Aydar population, we used the results of our own measurements and those obtained from specimens in the mammalian collection in the Institute of Zoology, Academy of Sciences of Uzbekistan, Tashkent.

The community's reproductive characteristics were studied based on the integral productivity index URZ, expressed as a percentage of the number of offspring 100 females could potentially bear in these circumstances in one generation (Gashev, 1992, 2008), which is given as follows:

$$URZ = UBS \times (100 - URE) \quad (1),$$

where UBS is the portion of pregnant females from the total of females in the community and URE is the portion of resorbed embryos from the total of embryos.

The method of morphophysiological indicators (MMPI) (Schwartz et al., 1968) was used to study small rodents' response to environmental changes. This method is widely used in practical ecology and bioindication to analyze the potential impacts of varying environment on the organism (Pyastolova, 1987; Gashev, 2000; Olenev, Grigorkina, 2019; and others). To describe the animals' external characteristics, body indices were used (ratios between the lengths of various parts of the body, such as tail, foot, ear, and the length of the body). The internal characteristics were described using organ indices (ratios between the weights of various organs and the weight of the body) (Schwartz et al., 1968).

To analyze the cranial characteristics in populations of dominant urban rodents, we studied 67 skulls of the house mouse: an urban population ($n = 25$) and natural populations ($n = 42$). The following cranial characteristics were measured: 1 – condylobasal length (CL); 2 – facial length (FL); 3 – brain length (BL); 4 – brain height (BH); 5 – zygomatic width (ZW); 6 – interorbital width (IW); 7 – braincase width (BW); 8 – diastema length (DL); 9 – maxillary tooth-row length (UMLI) (UML); 10 – mandibular tooth-row length (LML); 11 – mandible height (MH); 12 – mandible length (ML); and 13 – nasal bones length (NBL). Measurements were taken on each skull using sliding calipers with a minimum scale of 0.1 mm. To compare the cerebral activity in urban and wild populations, we used the relative braincase volume (*relativus cerebral cranium volumen* [RCCV]) index equal to the product of braincase dimensions (BL, BH, and BW) divided by CL (Bykova, Gashev, 2013):

$$RCCV = BL \times BH \times BW / CL \quad (2).$$

To make a comprehensive estimation of small rodents' communities, we used the species abundance index (R) and the Shannon (H) and Simpson (D) species diversity indices. The degree of similarity between various types of urban mammal communities was measured using Jaccard's coefficient of faunistic similarity:

$$Kf = C / A + B - C \times 100 \quad (3),$$

where A is the number of species in group 1, B the number of species in group 2, and C is the number of species common for both groups.

Results

Mammalian species composition in Tashkent

Based on the results of our research, literature data (Kashkarov, 1925; Kuzyakin, 1934; Bogdanov, 1950, 1953; Meklenburtsev, 1982; Promptov et al., 1984; Mitropolsky et al., 2007; and others), oral messages from biologists, and analysis of the mammalian collection in the Institute of Zoology, Academy of Sciences of Uzbekistan, we attempted to give a description of the contemporary and historical situation of fauna in the city of Tashkent. Remains of wild animals excavated within the territory of present-day Tashkent helped obtain a full picture of the historical transformation of the mammalian fauna.

Historical data on the vertebrate fauna in Tashkent and adjacent areas was obtained through excavations in the archaeo-

logical sites of Shashtepa, Kugaittepa, and Taukattepa dating back to 6th century BCE – 5th–7th century AD. The bones of 19 mammalian species were found in the same occupation layer as the archaeological monuments (Khudaiberdyev, 1982). Most of them were game species for the ancient inhabitants of the Tashkent oasis: red deer (*Cervus hanglu*), goitered gazelle (*Gazella subgutturosa*), kulan (*Equus hemionus kulan*), and wild boar (*Sus scrofa*). Red fox (*Vulpes vulpes*), corsac fox (*Vulpes corsac*), and tolai hare (*Lepus tolai*), also found in the sites, were not so important as game species. Among other animal finds discovered in the occupation layer of ancient human settlements were the bones of long-clawed ground squirrel (*Spermophilopsis leptodactylus*), jerboa (*Allactaga* sp.) and long-eared hedgehog (*Hemiechinus auritus*).

Historically, the fauna that used to inhabit the territory of present-day Tashkent represented the following types of landscape: 1) steppes, semi-deserts, and piedmonts (*H. auritus*, *Vormela peregusna*, *Mustela eversmanii*, *Meles leucurus*, *Vulpes corsac*, *Spermophilopsis* sp., *Spermophilus* sp., *Allactaga* sp., *Meriones* sp., *Rombomus opimus*, *Gazella subgutturosa*, *Equus hemionus kulan*); 2) riparian forests and reed thickets (*Microtus ilaeus*, *Radetest turkestanicus*, *Lepus tolai*, *Canis aureus*, *Panthera tigris virgata*, *Sus scrofa*, *Cervus hanglu* ssp. *bactrianus*); and 3) intrazonal biotopes (*Suncus etruscus*, *Crociodura suaveolens*, *Mustela nivalis*, *Vulpes vulpes*, *Cricetulus migratorius*, *Ellobius tancrei*).

The current mammalian fauna of Tashkent comprises 32 species, 3 of which are from the order Insectivora, 10 from Chiroptera, 1 from Lagomorpha, 11 from Rodentia, and 7 are from Carnivora (Table 1); however, the habitation of two species (Vinogradov's jerboa and Asian wildcat) requires confirmation. *Sciurus vulgaris*, *Myocastor coypus*, *Ondatra zibethicus*, *Rattus norvegicus*, and *Neovison vison* have been introduced into the area. The brown rat, which came to the Tashkent oasis in the second half of the 1940s (Promptov, 1962; Promptov et al., 1981; Kucheruk, Kuzikov, 1985; Mitropolsky et al., 2007; Sokolov, Karaseva, 1990; Alymkulova, 2016), continues to spread in Uzbekistan and adjacent regions. Other alien species include the muskrat, nutria, and American mink, which penetrated into the city via the rivers and canals of Tashkent Province, where they had been released for acclimatization. The red squirrel was also brought to Tashkent for acclimatization, and now it can be recorded in just a few small sites within the city (Gashev et al., 2012).

Mammalian complexes in various functional zones of the city

The composition of mammalian complexes varies across the urban zones according to the degree of urbanization, from the least urbanized woodland parks (zone 4) to multistory buildings (zone 1). The woodland parks are inhabited by 19 mammalian species, 17 of which are identified as small mammals. Also, 26 mammalian species are recorded in urban wastelands (zone 3), with 23 of them identified as small mammals. Residential areas are inhabited entirely by small mammals, with 10 species recorded in private buildings (zone 2) and 7 species in multistory buildings (zone 1). The reference site (zone 5) in the Saykhun nature protection enterprise in the Syrdarya river valley is a habitat for 19 mammalian species, 14 of which are small mammals (Table 2). The site features a number of tugai-specific species that have

Table 1. List of mammal species recorded in Tashkent city by our data gathered in 2016–2017 and literature sources.

No.	Common name, scientific name	Status	Abundance/distribution	IUCN Red List (2021)/ Red Data Book of Uzbekistan assessment (2019)
Insectivora				
1	Long-eared hedgehog, <i>Hemiechinus auritus</i> Gmelin, 1770	Common	Numerous, widespread	-
2	Pygmy white-toothed shrew, <i>Suncus etruscus</i> (Savi, 1822)	Rare	Few, sporadically distributed	LC/-
3	Lesser shrew <i>Crociodura suaveolens</i> Pallas, 1811	Common	Not numerous, locally distributed	LC/-
Chiroptera				
4	Greater horseshoe bat <i>Rhinolophus ferrumequinum</i> (Schreber, 1774)	Rare	Few, sporadically distributed	LC/-
5	Bokhara horseshoe bat <i>Rhinolophus bocharicus</i> Kastschenko, Akimov, 1917	Common	Not numerous, locally distributed	LC/-
6	Lesser mouse-eared myotis <i>Myotis blythii</i> (Tomes, 1857)	Rare	Few, sporadically distributed	LC/-
7	Whiskered bat <i>Myotis mystacinus</i> Kuhl, 1819	Rare	Few, sporadically distributed	LC/-
8	Geoffroy's bat <i>Myotis emarginatus</i> (E. Geoffroy, 1806)	Rare	Few, sporadically distributed	LC/-
9	Asian barbastelle <i>Barbastella leucomelas</i> (Cretzschmar, 1826)	Rare	Few, sporadically distributed	LC/-
10	Common pipistrelle <i>Pipistrellus pipistrellus</i> (Schreber, 1774)	Common	Numerous, widespread	LC/-
11	Noctule <i>Nyctalus noctula</i> (Schreber, 1774)	Common	Numerous, widespread	LC/-
12	Serotine bat <i>Eptesicus sirocinus</i> Schreber, 1774	Common	Numerous, widespread	LC/-
13	Particoloured bat <i>Vespertilio murinus</i> Linnaeus., 1758	Rare	Few, sporadically distributed	LC/-
Lagomorpha				
14	Tolai hare, <i>Lepus tolai</i> Pallas, 1778	Rare	Few, sporadically distributed	LC/-
Rodentia				
15	Red squirrel <i>Sciurus vulgaris</i> Linnaeus., 1758 – alien species	Common	Not numerous, locally distributed	LC/-
16	Long-clawed ground squirrel <i>Spermophilopsis leptodactylus</i> (Lichtenstein, 1823)	Extinct	NA	LC/-
17	Yellow ground squirrel <i>Spermophilus fulvus</i> (Lichtenstein, 1823)	Common	Numerous, locally distributed	LC/-
	Coypu <i>Myocastor coypus</i> (Molina, 1782) – alien species	Common	Not numerous, locally distributed	LC/-
18	Vinogradov's Jerboa <i>Allactaga vinogradovi</i> Argyropulo, 1914	Data deficient	NA	NT/ 2(VU:R)
19	Gray dwarf hamster, <i>Cricetulus migratorius</i> Pallas, 1773	Common	Not numerous, locally distributed	LC/-
20	Zaisan mole vole <i>Ellobius tancrei</i> Blasius, 1884	Common	Numerous, locally distributed	LC/-
21	Muskkrat <i>Ondatra zibethicus</i> (Linnaeus, 1766) – alien species	Common	Not numerous, locally distributed	-
22	Tien Shan vole <i>Microtus ilaeus</i> (Thomas, 1912)	Common	Not numerous, locally distributed	LC/-
23	Tamarisk gerbil <i>Meriones tamariscinus</i> Pallas, 1773	Common	Not numerous, locally distributed	LC/-
24	House mouse, <i>Mus musculus</i> Linnaeus, 1758	Common	Numerous, widespread	-
25	Brown rat <i>Rattus norvegicus</i> (Berkenhout 1769) – alien species	Common	Numerous, widespread	-
26	Turkestan rat <i>Rattus pyctoris</i> [turkestanicus] (Hodgson, 1845)	Extinct	NA	LC/-
Carnivora				
27	Golden jackal <i>Canis aureus</i> Linnaeus, 1758	Common	Not numerous, locally distributed	LC/-
28	Red fox <i>Vulpes vulpes</i> Linnaeus, 1758	Common	Not numerous, widespread	LC/-
29	Corsac fox <i>Vulpes corsac</i> (Linnaeus, 1768)	Extinct	NA	LC/2(VU:D)
30	Weasel <i>Mustela nivalis</i> Linnaeus, 1766	Rare	Few, sporadically distributed	LC/-
31	Marbled polecat <i>Vormela peregusna</i> (Gueldenstaedt, 1770)	Rare	Few, sporadically distributed	VU/ 2(VU:D)
32	Steppe polecat <i>Mustela eversmanii</i> Lesson, 1827	Rare	Few, sporadically distributed	LC/2(VU:D)
33	Asian badger <i>Meles leucurus</i> (Hodgson, 1847)	Extinct	NA	LC/-
34	American mink <i>Neovison vison</i> Shreber, 1777 – alien species	Rare	Few, locally distributed	LC/-
35	Asian wildcat, <i>Felis silvestris</i> ssp. <i>ornata</i> Gray, 1830	Data deficient	NA	LC/-
36	Caspian tiger <i>Panthera tigris virgata</i> (Illiger, 1815)	Extinct	NA	EX/0(EX)
Cetartiodactyla				
37	Wild boar <i>Sus scrofa</i> Linnaeus, 1758	Extinct	NA	LC/-
38	Bukhara red deer <i>Cervus hanglu</i> ssp. <i>bactrianus</i> Lydekker, 1900	Extinct	NA	LC/1(EN)
39	Goitered gazelle <i>Gazella subgutturosa</i> (Guldenstaedt, 1780)	Extinct	NA	VU/ 2(VU:D)
Perissodactyla				
40	Kulan <i>Equus hemionus</i> ssp. <i>kulan</i> Groves and Mazak, 1967	Extinct	NA	EN/ 1(CR)

Table 2. Division of the urban territory of Tashkent according to the level of urbanization, and indices of biodiversity and species richness for each functional urban zone and control area.

Functional zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Type	Multistorey area	Private residential area	Uninhabited area	Woodland parks	Wildlife areas (Sayhun)
Anthropogenic impact, score	22.2	19.7	16.9	6.7	6
Total number of small mammals	7	10	23	17	14
Relative abundance (individuals per 100 trap-days)	14.5	15.6	13.8	10.8	19.12
Dominant groups	Eusynanthropes	Eusynanthropes/semisynanthropes	Semisynanthropes	Semisynanthropes	Neutral species
Species richness index R	0.69	1.2	5.34	5.43	3.88
Shannon'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
Simpson's dominance index C	0.51	0.38	0.35	0.25	0.53

practically disappeared from the Tashkent oasis (*Lepus tolai*, *Sus scrofa*, *Meles leucurus*, *Felis libyca*), while some others (*Canis aureus* and *Vulpes vulpes*) can only be found in the woodland parks of the city and on the floodplain of the Chirchik River adjacent to Tashkent area, but in the reference site, they are more abundant. During the 20th century, two native species disappeared from the regional fauna (Caspian tiger and Bukhara red deer), while three alien species came to the region (*Ondatra zibethicus*, *Myocastor coypus*, *Rattus norvegicus*).

The average scores for the anthropogenic impact in zones 1 and 2 were 22.2 and 19.75, respectively. The anthropogenic impact in zone 3 was estimated at 16.88. The anthropogenic impact in zone 4 and reference site 1 (Saykhun) resulted in scores of 6.75 and 6, respectively, and the score was only 1 in reference site 2 (Aydar Lake) (Table 2).

Parameters of urban and wild populations of the house mouse

In order to study the mechanism of the adaptation of rodents to urban biocoenoses, we analyzed one urban population of *Mus musculus* in Tashkent and two wild populations inhabiting the Saykhun nature protection enterprise and the shore of the Aydar Lake to record the population parameters of the house mouse, a species dominating small urban mammal communities.

Sex and age structure and productivity of house mouse populations

The sex ratio in the urban and Saykhun populations of the house mouse is close to 1:1, with males slightly predominating over females (52% in Tashkent and 53% in Saykhun), which does not depend on the season. In the Aydar population, males are twice as numerous as females (2:1). The sex ratio varies according to the animals' age and type of area.

According to their age, we divided the animals into three categories: juveniles (weighing below 10.0 g), subadults (10.1–15.0 g),

Table 3. The similarity of small mammalian communities from different structural–functional zones of Tashkent by Jaccard similarity index, %.

	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1		66.6	15.4	20.0
Zone 2	66.6		23.0	30.0
Zone 3	15.4	23.0		35.3
Zone 4	20.0	30.0	35.3	

and adults (15.1 g and more). Analysis of the age structure of the urban house mouse population showed that juveniles comprised 20.5%, subadults 64.1%, and adults 15.4% (1:3:1). Subadult animals also predominated in the reference sites.

To estimate the productivity of synanthropic and natural populations of the house mouse, we measured the portion of pregnant females, the number of embryos per pregnant female, and the portion of resorbed embryos. The highest integral productivity index URZ was recorded in the Aydar population (URZa) and the lowest in the Saykhun population (URZs), while the Tashkent population (URZt) took the mean position, which is shown below:

$$URZa = 3236.25 > URZt = 1875.3 > URZs = 1330.$$

Morphophysiological indices of house mouse populations

The comparative analysis of the morphophysiological indices of the urban and two reference populations showed that absolute body dimensions and absolute and relative body mass were reliably higher in the “wild” populations than in the urban one. Tail and ear indices were reliably higher in Tashkent mice than in the Saykhun population, which together with the smaller body dimensions indicated an adaptive response to a strong anthropogenic impact demonstrated by the synanthropic population. As for internal characteristics, adrenal and spleen indices were

Table 4. Morphophysiological indices of house mice depending on the functional zone of Tashkent.

Features	Residential areas, $\bar{X} \pm m$			Non-residential areas, $\bar{X} \pm m$		
	Indoor generally	Zone 1	Zone 2	Outdoor generally	Zone 3	Zone 4
Body mass, g	13.56 $\pm$ 0.391	15.58 $\pm$ 0.263***	13.36 $\pm$ 0.404	14.6 $\pm$ 0.785	13.033 $\pm$ 0.786*	16.34 $\pm$ 1.209
Body length, mm	73.96 $\pm$ 0.729	78.0 $\pm$ 0.394***	73.45 $\pm$ 0.732	74.56 $\pm$ 1.108	74.666 $\pm$ 1.431	74.45 $\pm$ 1.757
Relative body mass, g/mm	0.180 $\pm$ 0.004	0.199 $\pm$ 0.003***	0.179 $\pm$ 0.004	0.196 $\pm$ 0.010	0.173 $\pm$ 0.008*	0.219 $\pm$ 0.016
Tail index	0.80 $\pm$ 0.007**	0.847 $\pm$ 0.009***	0.802 $\pm$ 0.007	0.76 $\pm$ 0.013	0.75 $\pm$ 0.012	0.78 $\pm$ 0.024
Foot index	0.21 $\pm$ 0.002	0.198 $\pm$ 0.002***	0.213 $\pm$ 0.003	0.20 $\pm$ 0.003	0.21 $\pm$ 0.004	0.20 $\pm$ 0.005
Ear index	0.17 $\pm$ 0.009	0.160 $\pm$ 0.001	0.176 $\pm$ 0.010	0.16 $\pm$ 0.003	0.16 $\pm$ 0.005	0.16 $\pm$ 0.004
Heart index	6.87 $\pm$ 0.031	6.29 $\pm$ 0.018***	6.93 $\pm$ 0.032	7.29 $\pm$ 0.292	7.36 $\pm$ 0.435	6.41 $\pm$ 0.295
Liver index	56.59 $\pm$ 0.029	52.64 $\pm$ 0.017***	57.04 $\pm$ 0.03	72.90 $\pm$ 2.183	81.34 $\pm$ 2.870	64.47 $\pm$ 0.303
Kidney index	7.32 $\pm$ 0.027+	8.10 $\pm$ 0.016***	7.23 $\pm$ 0.028	7.89 $\pm$ 0.285	7.65 $\pm$ 0.451	8.59 $\pm$ 0.113
Adrenal index	0.22 $\pm$ 0.026**	0.248 $\pm$ 0.015	0.225 $\pm$ 0.026	0.26 $\pm$ 0.01	0.27 $\pm$ 0.0257	0.23 $\pm$ 0.030
Spleen index	3.73 $\pm$ 0.024	4.30 $\pm$ 0.014***	3.66 $\pm$ 0.025	4.11 $\pm$ 0.216	3.99 $\pm$ 0.341	4.51 $\pm$ 0.208
HGSI	332.5 $\pm$ 36.65	227.2 $\pm$ 59.26	348.7 $\pm$ 40.35	299.7 $\pm$ 34.97	261.1 $\pm$ 39.7	328.7 $\pm$ 53.4

Notes: Statistically significant differences between house mouse groups inhabited in: *indoor and outdoor; *zones 1 and 2; *zones 3 and 4. One conventional sign means that the differences are significant at $P < 0.05$, two signs at $P < 0.01$, three signs at $P < 0.001$.

HGSI = hepato-suprarenal indices.

Table 5. Morphophysiological indices of house mice depending on sex and the functional zone of Tashkent.

Body measurements and indices (external and internal)	Residential areas, $\bar{X} \pm m$				Non-residential areas, $\bar{X} \pm m$			
	Zone 1		Zone 2		Zone 3		Zone 4	
	Males	Females	Males	Females	Males	Females	Males	Females
Body mass, g	16.4 $\pm$ 1.031**	14.87 $\pm$ 1.065	13.15 $\pm$ 0.370***	13.59 $\pm$ 0.691***	13.88 $\pm$ 1.176***	12.18 $\pm$ 1.025***	16.78 $\pm$ 1.711	15.74 $\pm$ 1.830
Body length, mm	78.33 $\pm$ 2.319	77.71 $\pm$ 1.873*	73.63 $\pm$ 0.721	73.23 $\pm$ 1.212	76.0 $\pm$ 2.033	73.33 $\pm$ 2.044	74.0 $\pm$ 2.760	75.1 $\pm$ 2.052
Relative body mass g/mm	0.209 $\pm$ 0.012**	0.191 $\pm$ 0.012	0.176 $\pm$ 0.004***	0.182 $\pm$ 0.007***	0.182 $\pm$ 0.011***	0.165 $\pm$ 0.01***	0.228 $\pm$ 0.024	0.208 $\pm$ 0.018
Tail index	0.877 $\pm$ 0.042*	0.822 $\pm$ 0.033*	0.785 $\pm$ 0.008	0.821 $\pm$ 0.010	0.742 $\pm$ 0.020	0.763 $\pm$ 0.015	0.774 $\pm$ 0.040	0.798 $\pm$ 0.023
Foot index	0.197 $\pm$ 0.006*	0.199 $\pm$ 0.008	0.213 $\pm$ 0.003	0.213 $\pm$ 0.003	0.211 $\pm$ 0.005	0.205 $\pm$ 0.007	0.208 $\pm$ 0.009	0.195 $\pm$ 0.006
Ear index	0.163 $\pm$ 0.009	0.158 $\pm$ 0.003	0.162 $\pm$ 0.002	0.191 $\pm$ 0.023	0.164 $\pm$ 0.008	0.155 $\pm$ 0.008	0.161 $\pm$ 0.006	0.161 $\pm$ 0.006
Heart index	6.446 $\pm$ 0.326	6.127 $\pm$ 0.851	6.830 $\pm$ 0.031	7.053 $\pm$ 0.358	7.943 $\pm$ 0.737*	6.670 $\pm$ 0.322	6.282 $\pm$ 0.353*	6.604 $\pm$ 0.546
Liver index	51.64 $\pm$ 1.627*	53.62 $\pm$ 6.042	55.51 $\pm$ 0.029	59.20 $\pm$ 4.006	75.97 $\pm$ 1.740	86.71 $\pm$ 7.613	63.79 $\pm$ 6.456	65.15 $\pm$ 5.957
Kidney index	10.35 $\pm$ 0.487***	6.302 $\pm$ 0.346	7.437 $\pm$ 0.027	6.973 $\pm$ 0.20	8.154 $\pm$ 0.634	7.154 $\pm$ 0.827	8.333 $\pm$ 0.978	8.864 $\pm$ 0.715
Adrenal index	0.265 $\pm$ 0.022	0.238 $\pm$ 0.075	0.222 $\pm$ 0.026	0.229 $\pm$ 0.022	0.286 $\pm$ 0.041	0.255 $\pm$ 0.033	0.172 $\pm$ 0.042	0.303 $\pm$ 0.046
Spleen index	2.325 $\pm$ 0.265***	5.880 $\pm$ 2.235	3.493 $\pm$ 0.024	3.875 $\pm$ 0.748	3.907 $\pm$ 0.587	4.071 $\pm$ 0.572	4.023 $\pm$ 0.456	5.0 $\pm$ 0.736
HGSI	196.9 $\pm$ 11.16***	257.5 $\pm$ 128.5	326.6 $\pm$ 27.12***	376.1 $\pm$ 85.24	198.8 $\pm$ 11.86	323.4 $\pm$ 62.15	296.6 $\pm$ 70.95	382.2 $\pm$ 86.87

Notes: Statistically significant differences were found between males and between females inhabited in: *zones 1 and 2; *zones 3 and 4; *zones 1 and 3; *zones 2 and 3; *zones 2 and 4. One conventional sign means that the differences are significant at $P < 0.05$, two signs at $P < 0.01$, three signs at $P < 0.001$. HGSI = hepato-suprarenal indices.

reliably higher in urban animals, while their kidney index was reliably lower than that of the wild populations (Tables 3, 4, 5).

Cranial indices of house mouse populations

Among the characteristics most often used to study animals' variability are the linear dimensions and proportions of the skull. On the one hand, cranial parameters are among the most stable parameters of the organism. Their changes suggest relatively long adaptive processes resulting from an environmental impact or a combination of impacts on the population. On the other hand,

cranial characteristics are as variable as external parameters and are also subject to changes in geography or biotopes and depend on a number of factors such as diet, air humidity, and others. To draw the cranial "portrait" of the population of the house mouse that has long been developing in the urban environment, we studied 13 basic metric cranial indices and compared them to those of natural populations. No clear sex dimorphism was recorded in any of the populations, but females demonstrated a somewhat more rapid growth of the skull, and this tendency was more obvious in the Tashkent population than in the natural ones.

Discussion

Species composition of the Tashkent mammalian population

The history of the development of the Tashkent urban fauna can be divided into several stages, which are as follows:

Stage I: Before the early 20th century, when, as a result of excess hunting and irrigation, some typical inhabitants of desert landscapes (kulan, goitered gazelle, corsac fox, psammophilous rodents from the genera *Spermophilopsis*, *Meriones*, *Rombomus*) abandoned the area and more hydrophilous species, such as the large souslik and tamarisk gerbil, arrived. The expanding urban area further transformed the landscape, which was primarily associated with the shrinkage of riparian forest. This together with hunting brought about the disappearance of tigers, deer, and boars.

Stage II: The first half of the 20th century, when the riparian ecosystem (tugai forest and reed thickets) continued to shrink and fragment, resulting in the disappearance of the hare, badger, and, probably, the steppe cat. The utilization of new agrotechnical field treatment methods and the acceleration of urbanization and industrialization also impacted negatively the numbers of wild animals. This was also the period when the brown rat was brought to the area to force out completely the aboriginal Turkestan rat. At that very time, the jackal expanded its range and the muskrat acclimatized to the local environment.

Stage III: The second half of the 20th century, when the red squirrel and American mink were introduced into the area, while the brown rat spread beyond the territory of Tashkent. The increasingly rapid urbanization processes led to the expansion of the urban area, its merging with neighboring areas, and the transformation of the city's architectural aspect. This was the time when the current fauna formed.

Stage IV: The early 21st century, when the faunal composition is remaining largely unchanged, but there is a possibility that further shrinkage of potential habitats and reduction of undeveloped areas (wastelands) may lead to a decrease in the large souslik's range and population. The improvement of the streets' sanitary condition and reduction of the network of open water-courses (small canals and gutters) have limited the distribution and reduced the numbers of the brown rat.

The analysis of anthropophobia in the mammals of Tashkent (including species that have abandoned the area) showed that the highest adaptation to urban environment was demonstrated by rodents with a specific reproduction strategy (r-strategy), degree of anthropophobia (eusynanthropes, hemisynanthropes, and anthropophilous animals), and foraging behavior (pasturing or combined foraging). The most adaptive to urban coenoses are eusynanthropes (house mouse and brown rat). The disappearance of anthropophobic animals, such as large predators and ungulates, from Tashkent resulted from either direct human predation (tiger, deer, boar) or the development of land and reduction

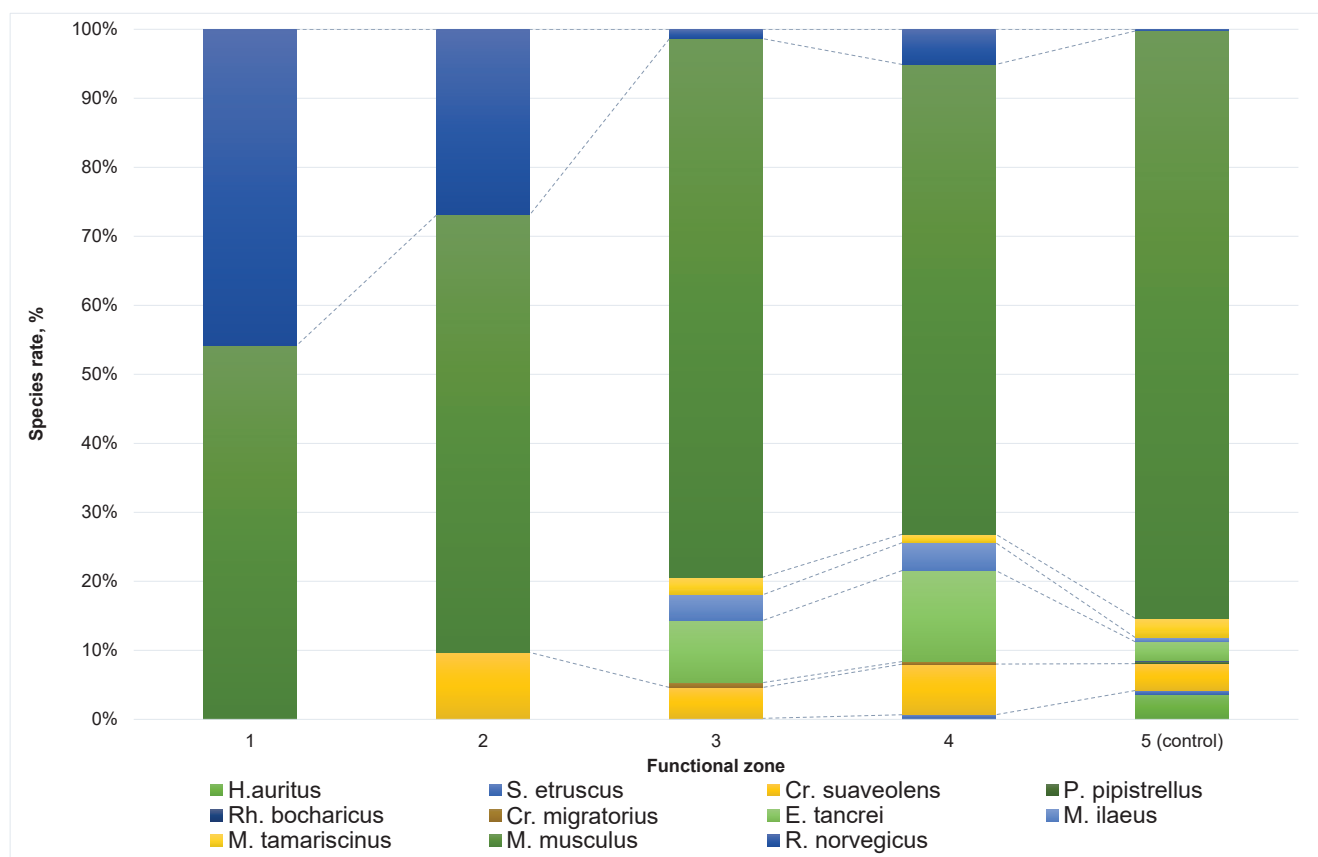


Fig. 3. Small mammals species rate in different functional urban zones and control (data collected by standard trap-line method and long-eared owl pellet analysis in 1991–1995 and 2010–2016).

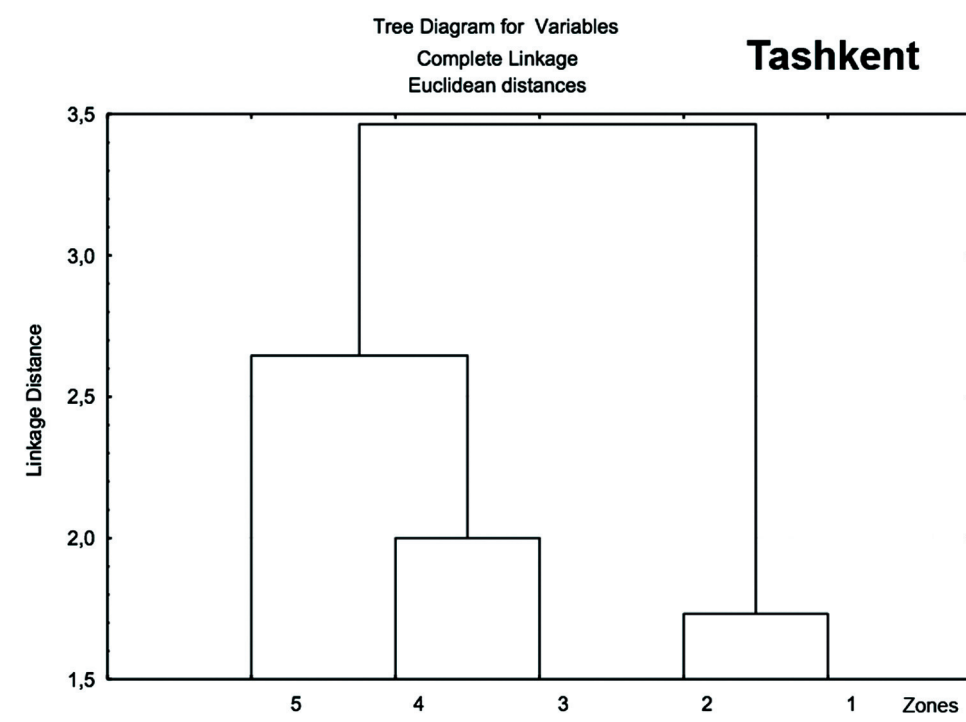


Fig. 4. The similarity of small mammalian communities from different structural–functional zones in Tashkent.

of natural habitats (goitered gazelle, kulan, tiger, deer, boar). The next species that abandoned the territory were medium-sized neutral ones (e.g., badger and corsac fox) and those that, regardless of their size, lost their habitats (e.g., psammophilous ground squirrels, jerboas, and gerbils were forced out of the area by its flooding). The impact by species alien in terms of competition and predation led to the disappearance of native species and arrival of adventitious ones. Eusynanthropes and hemisynanthropes (yellow ground squirrel, Tien Shan vole, gray hamster, Tamarisk gerbil, and others) demonstrated higher anthropogenic adaptivity indices in urban mammalian communities.

Mammalian complexes in various functional zones of the city

It was established that the house mouse unconditionally predominated in all the functional zones of the city, but its domination declined from the multistory area to the reference site (Saykhun). The subdominant species in residential areas was the brown rat, whose portion was the largest in the private residential area. In the other urban functional zones, the subdominant species were the Zaisan mole vole and the lesser white-toothed shrew and in the reference site, tamarisk gerbil was the subdominant species. The portion of the white-toothed pygmy shrew was higher in the reference site than in urban habitats (Fig. 3). The domination of the house mouse in all the functional zones is what differentiates Tashkent from other big cities, such as Moscow or Yaroslavl, where in undeveloped sites, both these synanthropic species are dominated by hemisynanthropes (Tikhonova et al., 2012). The communities of zones 3 (urban wastelands) and 4 in Tashkent

were characterized by the codominance of hemisynanthropes, a higher portion of anthropophilous species, and the appearance of neutral species. The highest anthropogenic stress was recorded in residential areas, as well as in urban wastelands, buffer areas along roads and railway lines, and in sections of canals in industrial areas with large quantities of domestic and oil product waste, toxic chemicals, and heavy metals. The lowest anthropogenic stress was registered in the relatively isolated woodland parks abundant in trees and shrubs, similar to the reference site. Thus, it was established that synanthropy depended on the anthropogenic impact and increased with the growth of urbanization, from woodland parks to multistory residential zones.

A comparative analysis of similarities between various types of urban communities of small mammals made using Jaccard's coefficient showed that the highest similarity was recorded between the communities of residential zones 1 and 2 (66.6%), which is associated with high level of urbanization and occupation by eusynanthropes, the house mouse and the brown rat. The lowest similarity (15.4%) was recorded between the multistory residential area and urban wastelands (Table 3). The woodland parks were relatively less transformed and similar to natural biocoenosis. These conclusions are supported by the results of the cluster analysis of the Euclidean distance, where samples of zones 1 and 2 formed a single cluster, while samples of zones 3 and 4 formed a common cluster with the reference site. The lowest level of similarity was between zone 1 and the reference site (Fig. 4).

A comparative analysis of species diversity in mammalian communities in different functional zones of the city showed that the communities' biodiversity decline and their structure simplified from undeveloped zones to residential areas (Table 2). The species diversity

Table 6. Comparative cranial indices of urban and wild populations of house mice.

Cranial and dental indices	Tashkent, X ± m			Saykhun, X ± m		
	General	Males	Females	General	Males	Females
CBL, mm	20.60 ± 0.198*	20.46 ± 0.311	20.73 ± 0.257*	21.31 ± 0.262	21.32 ± 0.403	21.29 ± 0.36*
FLI	0.501 ± 0.004***	0.492 ± 0.008+	0.508 ± 0.004*	0.525 ± 0.006	0.521 ± 0.010	0.528 ± 0.009*
BLI	0.504 ± 0.006	0.500 ± 0.011	0.510 ± 0.007	0.524 ± 0.009	0.530 ± 0.012	0.519 ± 0.014
BHI	0.345 ± 0.004**	0.349 ± 0.008**	0.341 ± 0.004	0.329 ± 0.005	0.323 ± 0.006	0.336 ± 0.007
ZWI	0.531 ± 0.008	0.523 ± 0.014	0.539 ± 0.010	0.535 ± 0.003	0.540 ± 0.005	0.531 ± 0.004
IWI	0.189 ± 0.004***	0.184 ± 0.004	0.194 ± 0.006***	0.171 ± 0.003	0.173 ± 0.006	0.170 ± 0.003***
BWI	0.463 ± 0.005	0.461 ± 0.008	0.464 ± 0.007	0.459 ± 0.006	0.463 ± 0.010	0.455 ± 0.008
DLI	0.284 ± 0.004***	0.285 ± 0.008***	0.284 ± 0.004***	0.237 ± 0.004	0.236 ± 0.005	0.239 ± 0.007***
UMLI	0.179 ± 0.003	0.175 ± 0.005	0.182 ± 0.004	0.179 ± 0.005	0.174 ± 0.008	0.184 ± 0.005
LMLI	0.171 ± 0.004**	0.163 ± 0.006	0.178 ± 0.006	0.155 ± 0.004	0.149 ± 0.005	0.162 ± 0.007
MHI	0.294 ± 0.003	0.291 ± 0.004	0.297 ± 0.004	0.291 ± 0.004	0.290 ± 0.004	0.292 ± 0.008
MLI	0.528 ± 0.005	0.521 ± 0.009	0.534 ± 0.005	0.530 ± 0.008	0.527 ± 0.011	0.534 ± 0.011
NLI	0.386 ± 0.004	0.386 ± 0.006	0.387 ± 0.005	0.393 ± 0.005	0.395 ± 0.008	0.390 ± 0.007
RCCV	34.17 ± 0.726*	34.05 ± 0.867	34.28 ± 0.837	36.26 ± 0.723	36.26 ± 1.117	35.79 ± 0.995

Notes: The comparison is between the cranial indices of Tashkent and Saykhun populations: *between the general populations; +between males; **between females. One conventional sign means that the differences are significant at $P < 0.05$, two signs at $P < 0.01$, three signs at $P < 0.001$.

BHI = brain height index, BLI = brain length index, BWI = braincase width index, CBL = condylobasal length, DLI = diastema length index, FLI = facial length index, IWI = interorbital width index, LMLI = mandibular tooth-row length, MHI = mandible height index, MLI = mandible length index, NLI = nasals length index, RCCV = relative braincase volume, UMLI = maxillary tooth-row length, ZWI = zygomatic width index.

indices obtained from the reference site (R, H, D) were on average 34.3% lower than those in urban habitats, similar to natural ones.

Parameters of urban and wild house mouse populations

A comparative analysis of the sex and age structure and productivity of the synanthropic population and two wild populations of the house mouse showed no differences in the sex and age structure between urban and wild rodent populations. Nevertheless, the urban population's productivity was 1.7 times higher than that of the natural one (Saykhun), which is, probably, a compensatory response to a higher mortality in the urban environment.

All the populations showed a domination of males among subadult individuals and females among adults, which was a result of the higher mobility of spreading subadult males and the associated higher mortality, both in the urban and wild populations. The analysis of the distribution of sexes indoors and outdoors showed the same principle. In both types of habitats, males dominated subadults (65% indoors and 60% outdoors), while females were more numerous among juvenile and adult individuals (57.7% and 77.8% indoors, respectively, and 100% and 66.7% outdoors, respectively).

The comparative analysis of morphophysiological indices recorded in the urban and two reference populations of *Mus musculus* indicated a higher mobility and stress load and more intense metabolic processes in urban mice in comparison to wild ones. Hepato-suprarenal indices (HGSI) were reliably lower in the Tashkent population than in the natural ones, which is indicative of the reduction of energy potential in the urban population. The lower HGSI together with the smaller absolute

and relative body masses and higher adrenal index in the urban population suggest less favorable conditions and more stress load in urban biocoenosis.

A comparative analysis of morphophysiological indices and HGSI in rodents inhabiting various functional zones revealed a number of reliable distinctions (Tables 4, 5). This brings us to a conclusion that the situation in Tashkent is paradoxical: the city's inhabitants have abundant food, but are under a big stress load. The animals living in the limited spaces of multistory buildings are quite inactive, and their livers reserve minimum amounts of nutrients.

Woodland parks provided the most favorable conditions for the animals. They showed high body size indices and HGSI. However, their kidney and spleen indices were potentially high, which indicates increased metabolism and effects by toxic agents such as heavy metals (Bykova, 2010; Bykova, Gashev, 2014) and parasites (Bykova, Gashev, 2011). The most unfavorable situation was in urban wastelands. Lower body size indices were accompanied by higher mobility (higher heart index) and overall stress load (higher adrenal index and lower HGSI). The inhabitants of the private residential area had a more favorable environment. Although their body size indices were quite low, they were under a minimum stress load. A correlation analysis showed a negative correlation relationship between the mean HGSI nonlinear form ($r = -0.51 \pm 0.43$; $h = 0.67 \pm 0.37$) and anthropogenic load in various habitats. Low HGSI under a high anthropogenic load indicates that the animals in urban biocoenosis, despite living in good climatic conditions and having sufficient food, suffer a higher stress load than those in the reference sites.

Many parameters of the cranial indices of the urban population (condylobasal, diastema, mandible, mandibular tooth-row

and nasals lengths indices, BH index, and IW index) were higher than those of wild ones, which indicates a more rapid growth of the skulls of synanthropic animals. The more representative differences were those between the Tashkent and Saykhun populations (Table 6). Earlier, we reported that animals inhabiting urban areas show lower body dimensions than those in wild populations (Bykova, 2010, 2013). This means that in urban conditions, relative body dimensions diminish, while relative cranial dimensions grow, which is, probably, a sign of adaptation associated with growth speed. According to Schwartz (1980), rapidly growing animals feature a higher and wider skull with a less-developed facial portion, which is more characteristic of young individuals. Slowly growing animals have a flattened and elongated skull, which is more typical of adults. A comparison between the animals from Tashkent and those from Saykhun shows that the CL index and the indices of the facial and cerebral parts of the skull, as well as the ML are smaller in urban animals than in wild populations, while the interorbital and occipital widths and the heights of the brain and mandibles are higher in urban animals. When the Tashkent population was compared with the one from Aydar Lake, adult individuals from the wild population demonstrated lower cranial values. Thus, changes in the house mouse's skull proportions in the urban environment are similar to those in rapidly growing animals (the juvenile type). As is known, the stress caused by negative anthropogenic impacts intensifies metabolism and accelerates the growth and aging of the organism. Probably, the high overall stress load present in all the functional zones of Tashkent, which was proved by the authors of this article, triggers the rapid growth of synanthropic animals.

When comparing the intensity of brain activity in animals from urban and natural populations by measuring their relative braincase volume (RCCV), we discovered that this index was higher in both natural populations, and this effect was most pronounced in the one from Lake Aydar. This suggests a larger brain volume and, as a result, a greater brain activity in free-living house mice, which, most likely, is associated with the animals' more complex behavior in the wild. When we compared the cranial indices of synanthropic house mice from the residential and woodland park zones, we discovered that the outdoor individuals demonstrated higher BH, ZW, IW, MH, and NBL indices than the animals living outdoors, which indicates a higher skull growth rate in outdoor animals compared to indoor ones and indirectly suggests a larger brain volume. The RCCV index showed the same tendency of a higher relative braincase volume in outdoor animals and in indoor ones. The more intensive cerebral activity in outdoor animals is, probably, associated with the high level of disturbance. Most of the skull parameters (10 of 13) of the animals living in private houses were greater than those of individuals inhabiting multistory buildings. Thus, the inhabitants of multistory buildings demonstrated the smallest RCCV values; then came the dwellers of the private houses and woodland park zone in an ascending order. The animals from the Aydar and Saykhun areas showed the highest RCCV indices. Thus, the complexity of house mice's behavior increases as the level of urbanization drops. The correlation analysis indicated a reliable (at $P < 0.01$) high-degree negative curvilinear correlation relationship ($r = -0.76 \pm 0.37$; $h = 0.97 \pm 0.13$) between the brain volume of the house mouse from various habitats and the degree of anthropogenic load. RCCV indices drop as the anthropogenic load grows, which

means that house mice in natural and less-impacted populations demonstrate a more complex behavior.

To summarize, the comparative analysis of the parameters of synanthropic and natural house mouse populations demonstrates that urban environment does not have any significant impact on the sex and age structure of the house mouse population. The male-to-female ratio varies according to age and habitat type, but there is a tendency throughout the populations toward male domination in subadult animals and female domination in adult ones. We have not recorded variations in age structure between urban and wild populations. Subadult animals predominate in all populations. The urban population differs from both natural ones in productivity and embryo mortality, where it occupies the mean position between the population inhabiting shrub thickets on the shore of the Aydar Lake (the highest productivity and embryo mortality) and that in the riparian forest on the left bank of the Syrdarya (low productivity, zero embryo resorbing). A number of differences were identified in the morphological and cranial parameters between the synanthropic and both natural populations, which may be a response to environmental variations caused, alongside other factors, by anthropogenic impacts. These include more rapid growth, higher metabolism and energy exchange, as well as signs of overall stress load upon rodents in urban biocoenosis.

Conclusion

Thus, the current mammalian fauna of Tashkent is represented by 32 species; during the city's development, 9 of them have abandoned the area through anthropogenic impact or have been forced out by alien species, while 5 new invasive species have come. In various urban habitats, growing urbanization is accompanied by a reduction in the number of small mammalian species, increase in their abundance, simplification of structure, and a decrease in biodiversity of urban communities of small mammals.

It was also established that urbanization did not have any significant impact on the sex and age structure of house mouse populations. The productivity of the urban population is 1.7 times higher than that of the natural ones, which is a compensatory response to high embryo mortality in the urban population, while in the wild populations, the rate is near zero.

We think we can make an important conclusion that the differences between the morphophysiological parameters of the synanthropic population and those of the natural ones are an adaptive response to anthropogenic impacts, which shows up as more rapid growth, higher metabolism, and energy exchange, as well as signifies an overall stress load upon rodents in urban biocoenosis. The comparative analysis of urban and wild house mouse populations shows that the skull of urban animals grows faster than that of wild ones, while its proportions change following the development pattern of juvenile individuals, which suggests that the individuals from the Tashkent population can be referred to as rapidly growing animals with a tendency to show increase in relative cranial parameters in outdoor individuals.

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