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Effect of Urbanization on Communities of Small Mammals in Park-Forests in a Large Industrial Center

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Abstract—The irregular effect of urbanization in different districts of a large industrial center may result in the differentiation of landscaped areas within the city and in the suburbs. Consequently, certain associations of mammals develop in urban park-forests. The recreational load is considered a key factor of the effect of urbanization on associations of small mammals. Up to a certain level, the recreational load does not influence the species composition of the community, but only affects the total numbers of animals.

INTRODUCTION

The expansion of large cities, involving the annexation of natural suburban areas, breaks them up into sections of different size and shape. In the city and suburbs, such territories are often transformed into recreational areas. The atmosphere over large industrial centers is polluted by a great deal of industrial and vehicle *emissions. Due to* prevailing winds, pollutants that fall with precipitation and dust are nonuniformly distributed throughout the urban territory and its suburbs, thereby increasing the diversity of effects on plant communities and heavily polluting certain districts. Non-indigenous plants are often introduced into urban and suburban plantations, thus additionally altering the existing plant communities.

Despite significant alteration of natural complexes, favorable conditions for numerous species of plants, animals, and microorganisms still persist in places. The adaptation of animal populations to specific urban conditions is likely to favor the emergence of new regulator mechanisms; i.e., a process of synurbanization is under way, whereby species tend to live in the immediate vicinity of humans, although they traditionally dwell outside urban areas. According to Andrzejewski *et al.* (1978), populations of the same species inhabiting urbanized and natural ecosystems differ in many parameters characteristic of their structural organiza-. tion and intrapopulational processes that adapt them to their niche in the ecosystem. Among mammal species participating in synurbanization, nonsynanthropic ones are of primary interest.

The effect of urbanization on the species composition and ecology of small mammals has been investigated in studies carried out in cities with different degrees of industrial development and situated in different environmental-climatic zones, including studies by Polish zoologists (Andrzejewski, 1975; Andrzejewski *et al.,* 1978; Babinska-Werka *et al.,* 1979; Babinska-Wsrka, 1981), who studied nonsynanthropic rodents in park-forests of Warsaw. The Russian Lisin (1983, 1984, 1987) working in the city of Gorky and English zoologists working in Oxford (Dickman, 1987; Dickman and Doncaster, 1987, 1989) investigated all kinds of mammals. Although certain peculiarities were noted in each case, the general characteristics of the composition of communities of small mammals as *well* as their distribution in the cities were similar.

The city of Yekaterinburg is the largest industrial center in the Middle Urals, with a population of over 1.5 million people and well-developed heavy industry. The impact of such a city on natural communities is undoubtedly significant. All urban green tracts were based on coniferous pine forest with small-leaved species. The industrial enterprises are generally situated on the outskirts except for the southwestern part of the city. Consequently, not only are central parks exposed to various intensive impacts, but also suburban park-forests.

MATERIALS AND METHODS

To study the effect of urbanization on small mammals in Yekaterinburg, five large park-forests situated in different peripheral parts of the city were chosen (Fig. 1): (I) the Northern; (II) Northeastern; (III) Eastern; (IV) Southwestern, and (V) Southern park-forests. Two more areas in the city were examined: (VI) the Botanical Garden (about 50 ha) of the Institute of Forestry, Ural Division, Russian Academy of Sciences, and (VTJ) the arboretum (near the center, about 8.5 ha).

Animals were caught in midsummer (late June and July) in 1990. The total number of trap-days was 150 in the arboretum and 300 in all other sections.

To estimate die numbers and species composition of mammals, three test areas were chosen in each park-forest, covering as many possible various landscape-floristic

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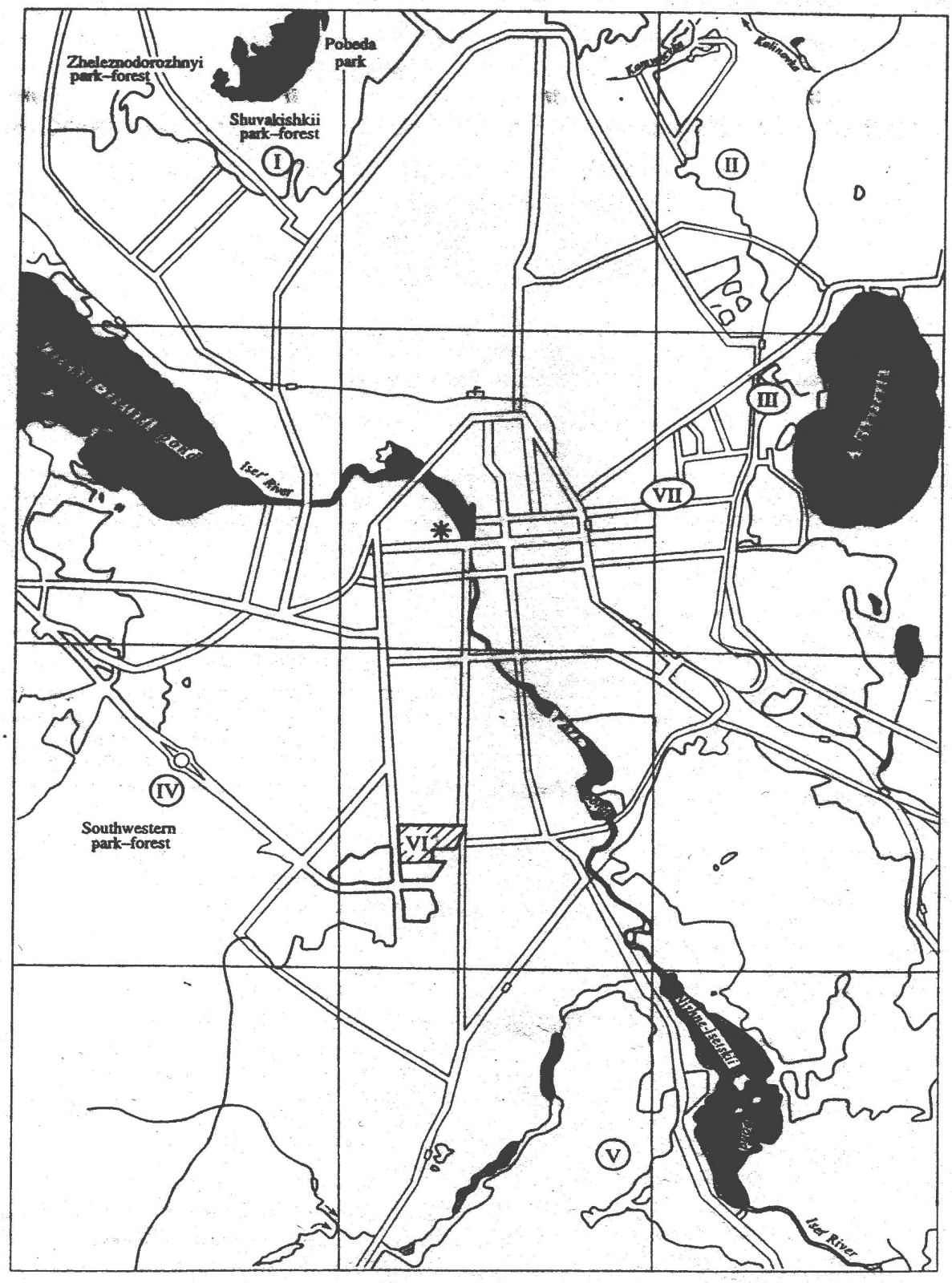

Fig. 1. Map of Yekaterinburg.
(I—VII) examined green areas (The designations are explained in "Materials and Methods"); "*" indicates the city center.

Table 1. Distribution of small mammals in green areas of Yekaterinburg

Place of capture and number on the map	% of the total number of animals	Total number of species	Index of species diversity	Portion of rare species
I Northern park-forest	16.5	5	2.8 ±0.29	0.29 ± 0.07
II Northeastern park-forest	13.6	3	1.5±0.16	0.24 ±0.08
III Eastern park-forest	15.5	3	1.8 ±0.14	0.11 ±0.07
IV Southwestern park-forest	13.3	4	2.9 ± 0.09	0.03 ± 0.03
V Southern park-forest	11.1	5	3.3 ±0.33	0.17 ±0.08
VI Botanical Garden	29.7	4	1.9 + 0.16	0.36 ± 0.05
VII Arboretum (the city center)	0.3	1		

complexes characterized by different degrees of trampling (due to frequenting by the local public). The census of animals was carried out by a standard method, i.e., lines of 25 traps were set for four days. Synanthropic species (grey rats and house mice) were ignored. In the most abundant mammal, the field mouse, the state of the reproductive system was studied, and the demographic characteristics of the population were analyzed. For this purpose, all trapped animals were divided according to their age and sex. The senior group *(adultus + subadultus)* was composed of animals that had reproduced and had a developed reproductive system; the junior group *(juvenis)* included nonbreeders with an infantile reproductive system. To estimate a female's fertility, the number of embryos and placenta spots were summed up, thus arbitrarily determining its total fertility per season.

RESULTS AND DISCUSSION

In park-forests and city parks, four species of shrews (the Eurasian common, masked, East Siberian, and lesser shrews, which were united into one group for analysis—So rex sp.) and seven species of rodents (the field mouse *(Apodemus agrarius),* the common vole *(Microtus arvalis),* the root vole (M. *oeconomus),* the short-tailed vole *(M. agrestis),* the bank vole *(Clethrionomys glareolus),* and the ruddy vole *(C. rutilus),* plus one specimen of the northern birch mouse *(Sicista betulina)* were discovered.

Due to the diversity of plant communities and some other external factors, small mammals were nonuniformly distributed throughout the green zones (Table 1 and Fig. 2). The most species were found in the northern park-forest, while the fewest species occurred in the arboretum (in fact, only one species - *M. arvalis).* In suburban park-forests, shrews constituted a considerable portion of captured animals (about 25%) and even 57% in the Western park-forest, with *S. araneus* as the dominant species (90% of all shrews).

Apart from estimating the number of species of small mammals inhabiting particular park-forests, an index of species diversity was used to characterize their communities (Table 1). This was calculated from the formula suggested by Zhivotovsky (1980):

$$\mu = (\sqrt{p_1} + ... + \sqrt{p_m})^2$$

where $p_1, \ldots, p_m$ are the frequencies of species, and m is the number of species in the park-forest.

The index of the portion of rare species in a community, similar to the equitability of the feature, was calculated from the formula (Zhivotovsky, 1980)

$$h = 1 - \mu / m.$$

The highest indices of species diversity were recorded in the Southern, Southwestern, and Northern recreational parks (Table 1). Though the number of captured species was the same in the Botanical Garden and the Southwestern park-forest, and the numbers of animals in the Botanical Garden were twice as great, the index of species diversity in the garden was reliably lower than in the Southwestern park, and the portion of rare species was greater, which influenced the diversity index. However, the diversity index and the portion of rare species were equally high in the Northern park-forest.

In all green tracts of the city, except the Southwestern and Northeastern recreational parks, the field mouse dominated among rodents. Only in the Northeastern recreational park and the arboretum was it completely absent: the population of small mammals in the latter was represented by one species—the common vole (the arboretum is intensively used by the local public for recreation and walking dogs). In the North - eastern park-forest, red-backed voles made up 67.9% of all trapped rodents, (Fig. 2b) occupying the same ecological niche as *A. agrarius* does in other park-forests. Despite these exceptions, it is reasonably safe to attribute the field mouse to the principal urban species: its part in the total catch made up 41.8% (Table 2).

If united into one group, species with close ecological niches—*A. agrarius* and *C. glareolus* — appear to make up the majority of the population of small mammals and the greater part of rodents in all green tracts of the city (except the arboretum).

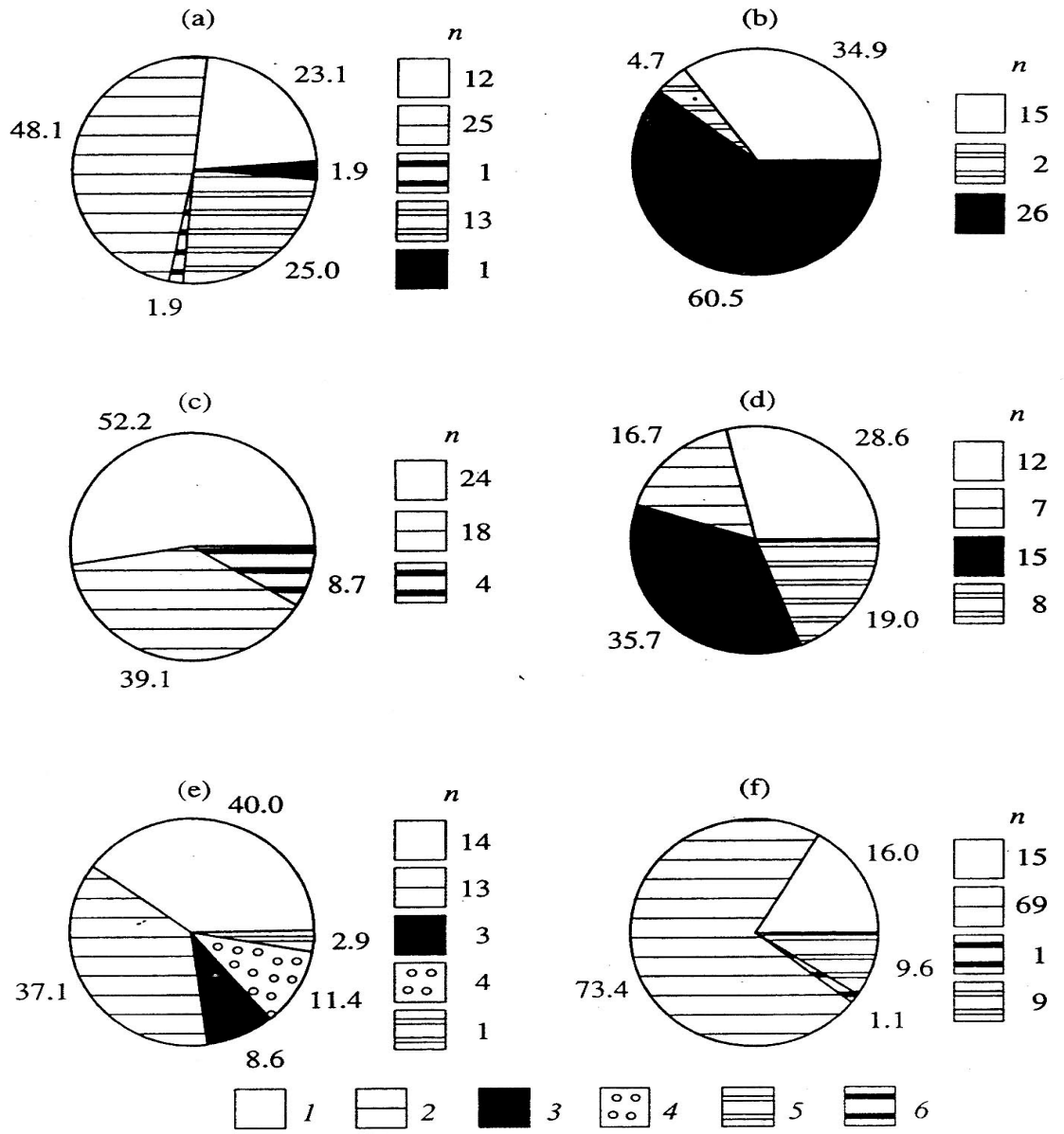

Fig. 2. Quantitative distribution of small mammals in green areas of Yekaterinburg (figures on the diagram represent *%).* The (a) Northern, (b) Northeastern, (c) Eastern, (d) Southwestern, and (e) Southern park-forests (0 and the Botanical Garden; *n* - number of trapped animals of the species (i) *Sorex* sp., (2) A. *agrarius, (3) C. glareolus, (4) C. rutilus,* (5) *M. arvalis,* and (6) *M. oeconomus.*

Although voles of the genus *Microtus* were trapped in all examined areas, their numbers in the catches greatly differed (Fig. 2). While they amounted to 100% of the population in the city center (the arboretum), they averaged between 3.8 and 30.4% in suburban park-forests. The most numerous species of this genus was the common vole (Table 2). The root vole was less represented, and only two individuals of the short-tailed vole were trapped in the Northern park-forest, which is natural for this species, exhibiting only temporary surges in numbers.

Ten species of mouselike rodents inhabit natural forests of the southern Urals free from strong anthropogenic pressure (Bol'shakov, 1977). The most numerous species is the red-backed vole; voles of the genus *Microtus* and the wood mouse are frequent. The field mouse avoids coniferous forests and is thus rather rare.

The species ratios in urbanized tracts are fairly different (Table 2 and Fig. 2). All the park-forests are basically formed of modified pine forest with the addition of small-leaved tree species, a shrub layer, and pine regrowth. These parks are frequented by people.

Table 2. Species composition of small mammals in Yekaterinburg

Species	n*	Proportion of each species in the total catch, %
Sorex sp,	95	30.1
A. agrarius	132	41.8
M .arvalis	34	10.8
M. oeconomus	6	1.9
C glareolus	45	14.2
C. rutilus	4	1.3
Total	316	100

* Total number of individuals of each species trapped in all examined areas.

Mammal communities different than those in natural forests must have formed. No wood mice were caught in the park-forests over two years. Surprisingly, wood mice were always found among small mammals in other cities investigated. In park-forests of Moscow, this species is common, the red-backed vole is dominant, but the field mouse is rare (Komeeva and Shilkin, 1978; Stepanova, 1978). Only in central parks of Moscow surrounded by housing developments was the field mouse the predominant species, characterized by low variation in numbers (Stepanova, 1978). The complete absence of wood mice in green tracts of Yekaterinburg over two years must be due to profound depression of its numbers during this period.

Some researchers believe that *C. glareolus* and A. *agrarius* compete for food and habitats. However, Geuse and Bauchau (1985) observed no relationship between the presence and density of one species and those of the other. Therefore, the absence of A. *agrarius* in the Northeastern park-forest cannot be due to the great numbers of *C. glareolus* or competition. This park-forest must have preserved largely undisturbed conditions, as it is situated apart from the main flow of urban waste, and the recreation practices there are somewhat fewer compared to those in other park-forests. These data suggest that urbanization mostly affects the typical aborigine of Ural forests—the red-backed vole, which is more sensitive to disturbance caused by people and domestic animals.

The Botanical Garden is surrounded by housing and industrial buildings, but it is closed to people. Therefore, there is almost no recreational load there. Animals were trapped in sections with well-preserved natural vegetation. Thus, the Botanical Garden may serve as a model area to reveal the effect of urbanization without the trampling of vegetation. It is precisely there that *A. agrarius* was the most numerous (Fig. 2f) - Its predominance in this area is likely to be constant, as is corroborated by Ivanov (1983), who kept records in 1981 and 1982. The number of species in the Botanical Garden was not great, regardless of the diverse biotopes there; however, the total quantity of small mammals was the greatest: 29.7% of the total number of animals caught in Yekaterinburg during the season (Table 1). Apart from the arboretum, the smallest number of animals were trapped in the Southern recreational park, while the number of species there was the highest. The Southern park-forest occupies vast territory, and its plant communities are rather diverse. However, it is frequented by the local population because of nearby private gardens, sport fields, and an orchard, which might influence the number of mammals. The results obtained suggest that recreation is not the key factor in determining the composition of urbanized animal communities, but markedly affects their total numbers.

Polish zoologists (Babinska-Werka *et al,* 1979) worked out a ten-point scale to estimate the habitats of small mammals according to five parameters: (1) the size of the area; (2) the size of the green zone; (3) the distance from the city center; (4) available shelter; and (5) the severity of disturbance, i.e., the human press. The authors noted that only the latter two are significant for rodent numbers, and they must be interrelated. This assumption is supported by investigations by Lisin (1983, 1987) and the conclusion above regarding the effect of recreation on mammal numbers. The present results indicate that species diversity is determined not by disturbance, but some other factors, probably the greater diversification of the biotopes.

The demographic characteristics of populations were analyzed for *A. agrarius,* the most abundant species (Table 3). A prevalence of males over females was observed in all populations, but, in different regions, this ratio varied. Ivanov (1983), who studied rodents in the Botanical Garden for three years, also noted the constant prevalence of males in populations of field mice. This provides support for a nonaccidental origin of such a disproportionate sex ratio in favor of males, at least in mice in the Botanical Garden. Only among juvenile *A. agrarius* did the sex ratio vary in different park-forests: in some (I and VII), males prevailed over females, whereas the opposite was observed in others (III and V). However, as the number of the trapped *juvenis* in most park-forests was not great; the real sex ratio in young animals can only be approximately estimated.

In all populations of field mice surveyed in midsummer of 1990, adult animals constituted the majority. In the Botanical Garden and the Northern park-forest, the quantity of *adultus* + *subadultus* was about twice as great as that of *juvenis,* and, in other park-forests, there were extremely few young animals. This might suggest high mortality of juveniles in the heavily frequented green zones.

In areas with higher recreation loads, populations are stressed. This causes a reduction of animal numbers (for instance, due to a decrease in individual lifespans). To keep up minimum population numbers, the fecundity of females must be higher, which was indeed

Table 3. Demographic characteristics of populations of A. *agrarius*

Park-forest	*n**	Ratio of males to females			Ratio of adults to subadults	Fecundity
		total	adults	subadults		
Botanical Garden (VII)	69	1 : 1.8	1 : 1.2	1 : 3.5	1.6: 1	8.1+0.4
Northern (I)	25	1 : 1.3	1 : 1.3	1 : 1.2	1.8 : 1	8.25 ± 0.8
Eastern (III)	18	1 :2	1 :2.4	1 :0	17: 1	8.5 ±0.6
Southwestern (IV)	7	0:7	0:7	-	7:0	-
Southern (V)	13	1 : 1.2	1 : 1.75	2:0	5.5: 1	8.25+0.6

* Total number of field mice caught in the area.
** Average number of embryos and placental spots per female.

revealed while analyzing the quantity of embryos and placental spots per female (Table 3). Despite the greatest numbers of *A. agrarius* in the Botanical Garden, there were fewer embryos per female there (which is indicative of lower fecundity) than in frequented parks. Although the mice from park-forests with recreation loads have higher reproductive potential, the number of juveniles is fewer; consequently, the numbers in such populations are lower.

Thus, recreational processes are the primary factor influencing the formation of communities of small mammals under intensive urbanization, providing they do not cause nearly total destruction of animal shelters (as was the case in the arboretum). Recreation, being a significant impact on total numbers, does not inhibit the diversity of species. However, the quantitative ratio of different animal species varies: species abundant in nonurbanized areas become rare and vice versa. In biocenoses, new dominants take up the ecological niches of their predecessors, which become rare. However, this only occurs up to certain limits of the destruction of biological communities. Beyond these limits, animal communities become drastically impoverished in both species diversity and numbers at crucial moments of the degradation of vegetation (primarily due to trampling) and are replaced by synanthropic mammals.

REFERENCES

Andrzejewski, R., Ecological Problems of Environment Management in Town, *Wiad. EcoL,* 1975, vol. 21, pp. 175-186.

Andrzejewski, R., Babinska-Werka, J., Gliwicz, L, and Goszczynski, J., Synurbization Processes in Population of *Apodemus agrarius:* I. Characteristics of Populations in an Urbanization Gradient, *Acta TherioL,* 1978, vol. 23, pp. 341-358.

Babinska-Werka, J., Food of the Striped Field Mouse in Different Types of Urban Green Areas, *Acta Therioi,* 1981, vol. 26, p. 285.

Babinska-Werka, J., Gliwicz, J., and Goszczynski, J., Synurbization Processes in Population of *Apodemus agrarius:* II. Habitats of the Striped Field Mouse in Town, *Acta TherioL,* 1979, vol. 24, p. 405.

Bol'shakov, V.N., *Zveri Urala* (Animals of the Urals), Sverdlovsk: Nauka, 1977.

Dickman, C.R., Habitat Fragmentation and Vertebrate Species in an Urban Environment, *J. Appl. EcoL,* 1987, vol. 24, pp. 337-351.

Dickman, C.R. and Doncaster, C.P., The Ecology of Small Mammals in Urban Habitats: I. Populations in a Patchy Environment, /. *Anim. EcoL,* 1987, vol. 56, pp. 629-640.

Dickman, C.R. and Doncaster, C.P., The Ecology of Small Mammals in Urban Habitats: II. Demography and Dispersal, /. *Anim. EcoL,* 1989, vol. 58, pp. 119-127.

Geuse, Ph. and Bauchau, V, *Apodemus sylvaticus* (Rodenta: Muridae) et *Clethrionomys glareolus* (Rodenta: Microtidae): Competition ou coexistence?, Ann. *Soc. R. Zool. Belg.,* 1985, vol. 2, pp. 211-220.

Ivanov, K.I., The Field Mouse in Green Areas of Sverdlovsk, in *Issledovanie aktual'nykh problem teriologii* (Study of Current Problems in Theriology), Sverdlovsk, 1983, pp. 36-38.

Koraeeva, T.M. and Shpilkin, A.Z., Distribution of Small Mammals Depending on Human Frequenting, in *Rastitel'nost' i zhivotnoe naselenie Moskvy i Podmoskov'ya* (Plants and Animals of the City of Moscow and the Moscow Region), Moscow: Nauka, 1978, pp. 57-68. Lisin, S.R., Nonsynanthropic Rodents in a Large City (Population Analysis), *Cand. Set (Biol.) Dissertation,* Sverdlovsk, 1983.

Lisin, S.R., Relative Numbers of Populations of Field and Wood Mice and Their Status in Rodent Communities in the City of Gorky, in *Nazemnye i vodnye ekosistemy* (Aquatic and Terrestrial Ecosystems), Gorky, 1984, pp. 36-43. Lisin, S.R., Age and Sex Composition of Populations of Field and Wood Mice in Gorky, in *Nazemnye i vodnye ekosistemy* (Aquatic and Terrestrial Ecosystems), Gorky, 1987, pp. 69-74.

Lisin, S.R. and Petrov, VS., Nonsynanthropic Rodents in a Large City, in *Nazemnye i vodnye ekosistemy* (Aquatic and Terrestrial Ecosystems), Gorky, 1984, pp. 3-10.

Stepanova, N.V., Distribution of Small Mammals in Green Zones of Moscow, in *RastiteVnost' i zhivotnoe naselenie Moskvy i Podmoskov 'ya* (Plants and Animals of the City of Moscow and the Moscow Region), Moscow: Nauka, 1978, pp. 30-32.

Zhivotovsky, L.A., Index of Intrapopulation Diversity, /. *Obshck Biol.,* 1980, vol. 41, no. 6, pp. 828-836.