ISSN 1995-4255, Contemporary Problems of Ecology, 2024, Vol. 17, No. 5, pp. 638–644. © Pleiades Publishing, Ltd., 2024.
Russian Text © The Author(s), 2024, published in Sibirskii Ekologicheskii Zhurnal, 2024, No. 5, pp. 731–738.

Reaction of Small Mammal Communities to Different Degrees of Urbanogenic Transformation of Forest Phytocenosis

N. F. Chernousova*

Institute Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, Ekaterinburg, 620144 Russia

**e-mail: nf_cher@mail.ru*

Received March 4, 2024; revised March 15, 2024; accepted March 19, 2024

Abstract—Ongoing urbanization around the world is leading to changes in ecosystems, and wildlife is forced to respond by adapting to them. First of all, disturbance concern plant communities, which are transformed in and around the city actively. Changes in phytocenosis along with the stress of the human presence also affects animals, what often leads to a decrease in small mammal community biodiversity in places subject to anthropogenic influence. However, for some mammalian species (especially small ones) that are more resistant to stress from human presence, urbanization has its advantages by creating modified habitats and reducing competition with native species that are more sensitive to urbanogenic effect. For several years, we have been studying the influence of the megalopolis (Ekaterinburg city) located in the forest zone on communities of small mammals in sites of pine forest transformed to different degrees depending on the proximity to urban development (two park-forests), as well as in the Central Culture and Recreation Park (in places with different attendance level). The forest phytocenoses were found have been altered throughout the entire park-forest sites due to weed vegetation and introduced plant species, as well as under the influence of recreation especially strongly in places adjacent to developments. The micromammal communities of all sites, in addition to forest rodents, are present hemisynanthropic species that are not characteristic of this zone forest (the small wood mouse and the striped field mouse). In outlying park-forest places where the anthropogenic load is much lower, forest mammal species are found in greater numbers, although the presence of hemisynanthropic species remains. In some cases, this might lead to an increase in community diversity indices. Naturally the conditions of the plant environment affect the ability of rodents and shrews to form steady micropopulations and communities in the forest sites of the city outskirts, although and the anxiety factor plays a significant role.

Keywords: urbanization, forest phytocenosis, small mammals, park-forest, park, gradient of community change

DOI: 10.1134/S1995425524700422

INTRODUCTION

The growth of large cities and their capture of ever-expanding areas of the natural environment leads to it being fragmented into separate areas. Inside and on the outskirts of cities, such areas are being transformed into recreational areas. Studies of the influence of the city on natural communities, which began in the middle of the 20th century, mainly by Polish ecologists and continued by Russians and others (Andrzejewski et al., 1978; Babinska-Verka et al., 1979; Babinska-Verka, 1981; Dickman and Doncaster, 1987, 1989; McDonnell and Pickett, 1990; Korneeva, Shpilkin, 1978; Lisin, 1983, 1984; Stepanova, 1978; and many others), have recently acquired a particularly large scale (Litvinov, 2004, 2010; Aronson et al., 2016; Norton et al., 2016; Andrade et al., 2020; Haight et al., 2023; Rega-Brodsky et al., 2023). These are just some examples of work in this field.

In the forest zone, where we have been conducting our research since 1990 (Chernousova, 1996, 2001, 2002, 2010, 2016, 2023; Chernousova et al., 2004, 2006, 2009, 2012, 2014; and many other publications), forest plantations in and around cities are introduced to plants unusual for local natural complexes; in addition to recreation, this changes preexisting plant communities. The forest adjacent to the city becomes a park-forest zone, limiting the city and, in some cases, merging with the natural forest planting. Forest areas are often preserved within the city, modified to varying degrees by pronounced urban impact. Such areas and park-forests are successful model objects for studying the influence of forest transformation on the phytocenoses of small mammals living in them.

MATERIAL AND METHODS

The objects of our research were the park and park-forests of Ekaterinburg, a metropolis with more than

Fig. 1. Survey localities: (1) Kalinovsky park-forest, (2) Lesovodov Rossii, and (3) Central Culture and Recreation Park.

one and a half million people who actively use forest areas for recreation. For several years (2006–2016), we caught small mammals (Fig. 1) in two park-forests located in the southeastern (Lesovodov Rossii) and northeastern (Kalinovsky) parts of the city, and in the Central Culture and Recreation Park (CP) located inside the city.

In each locality, trapping was carried out on three lines of 25 traps each for 4 days. The first line was located in the most recreationally exposed part of the park-forest, as close as possible to urban development. The second two are in its more remote parts, differing in biotopes. In CP, these were the least visited places by citizens, in remote areas of the park.

This paper presents data from catches for six separate years—periods when there was no depression in the number of rodents, which are the main component of the small mammal community.

The subcanopy layers of phytocenoses of the lines of park-forests and CP were studied. The undergrowth and undergrowth of all lines were counted on 25 counting plots measuring 2 × 2 m. The species composition and height of the undergrowth and undergrowth were determined according to the scale of A.V. Pobedinsky (1966). The grass and shrub cover was described on 25 plots of 1 × 1 m. The height of each tier and the projective cover of each species were recorded on them (Table 1).

The results of research on phyto- and zoocenoses were processed using the STATISTICA 8 and PAST 3.2 programs (Hammer Øyvind, 2022).

RESULTS

Analysis of Phytocenoses by Lines

A general description of the surveyed park-forests as forest ecotones represented by pine forest areas belonging to the southern taiga district of the Trans-Ural foothill forest vegetation province (Kolesnikov, 1973) was given by us in previous articles (Chernousova, 2023; Chernousova et al., 2014). Indicators of

Table 1. Phytocenotic indicators determined on all lines

Pine regrowth (individuals/ha)	Occurrence (pine undergrowth), %
Young deciduous trees (individuals/ha)	Number of types of undergrowth of deciduous trees, pcs.
Occurrence of undergrowth of deciduous trees, %	Undergrowth (individuals/ha)
Number of species of shrubs (without raspberries and rowan), pcs.	Occurrence of shrubs (without raspberries and rowan), %
Occurrence of mountain ash (*Sorbus aucuparia*), %	Occurrence of raspberries (*Rubus idaeus*), %
Total number of species of herb–shrub layer, pcs.	Average projective cover of the herb–shrub layer, %
Number of types of cereals, pcs.	Projective coverage by cereals, %
Number of synanthropic plant species (without cereals), pcs.	Projective coverage of synanthropic species (without cereals), %

vegetation of tiers located below forest-forming species the studied phytocenoses are given in Table 1.

Based on the parameters indicated in Table 1, we built a dendrogram of the similarity of plant communities in PAST 3.2 for individual lines and localities under study (Fig. 2).

The dendrogram shows that individual lines were united mainly in accordance with the degree of their anthropogenic and recreational disturbance. The first line of the CP is located separately from the other two, and the entire cluster of the park is the next level of connection with the first line of the Lesovodov Rossii park-forest.

Analysis of Small Mammal Communities

The results of catching small mammals by line, combined over several years, are presented in Table 2.

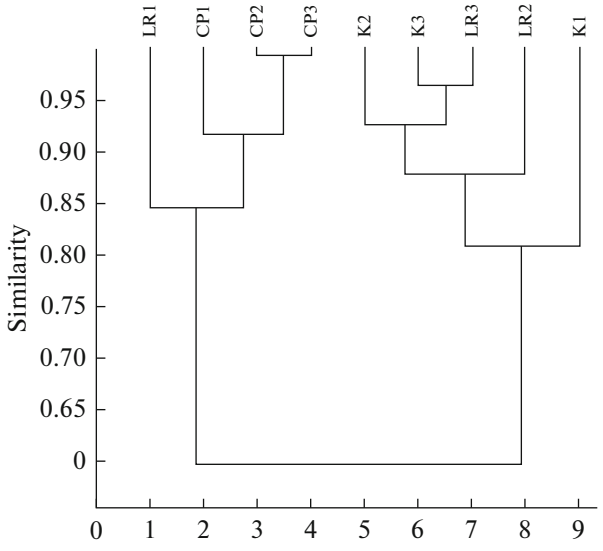

Fig. 2. Dendrogram of cluster analysis of the levels of similarity of individual lines of phytocenoses, constructed by the single accession (nearest neighbor) method. CP, Central Culture and Recreation Park; K, Kalinovsky park-forest; and LR, Lesovodov Rossii. Numbers next to the names are line numbers.

It can be seen that in all communities there are species of the genus uncharacteristic for forests of the type under study *Apodemus* (Kaup, 1829), which is an indicator of anthropogenic disturbance of phytocenoses. Moreover, in most cases, on the first lines the number of these species is higher, and only the Kalinovsky park-forest is an exception. All three species of forest voles (genus *Clethrionomys* Tilesius, 1850) live in the park-forests and, in the CP, only the northern red-backed vole, which is the most numerous in the Lesovodov Rossii park-forest. Gray voles (genus *Microtus*, Shrank, 1798) constitute an insignificant part in all communities (Table 2).

There are three species of shrews (genus *Sorex* L., 1768) in the park-forests; it is clear that the common shrew predominates significantly (Table 2), while in the Central Culture and Recreation Park it is small in number and was present only on two remote lines; on one of them we also caught two Laxmann's shrews throughout the entire period.

The dominance index (due to the high number of small wood mice) was the highest on the lines in the CP and in park-forests on the first lines (Table 2). The Shannon–Wiener diversity index, on the contrary, is higher in park-forests of the second and third lines. Community evenness indices do not have a clear pattern, which is understandable due to the composition and number of species along the lines. Only in the CP is the Pielou index slightly lower.

Based on the composition and number of communities of zoocenoses of lines, as well as for phytocenoses, we constructed a dendrogram (Fig. 3) in PAST 3.2.

The dendrogram for micromammal communities shows that, as for phytocenoses, the Central Culture and Recreation Park lines together with LR1 form one cluster. However, the grouping of other lines of animal communities is somewhat different from that for phytocenoses. A separate cluster is formed by the lines of the Kalinovsky park-forest, and two remote lines of the Lesovodov Rossii park-forest (LR2 and LR3) occupy an intermediate position between the two previous clusters, although they are connected to the first group.

Table 2. Composition of micromammal communities according to the lines of forest plantation capture

View	Line								
	K1	K2	K3	LR1	LR2	LR3	CP1	CP2	CP3
Apodemus agrarius Pallas, 1771 (striped field mouse)	0	3	1	0	1	0	50	5	9
A. (*Sylvemus*) *uralensis* Pallas, 1811 (small field mouse)	34	39	40	97	92	56	150	122	98
Clethrionomys glareolus Schreber, 1780 (bank vole)	52	60	46	1	0	0	0	0	0
C. rutilus Pallas, 1779 (northern red-backed volume)	1	0	0	11	76	62	0	17	19
C. rufocanus Sundevall, 1846 (gray-sided vole)	0	1	0	0	1	3	0	0	0
Microtus arvalis Pallas, 1778 (common vole)	14	10	3	4	1	7	2	0	0
M. oeconomus Pallas, 1776 (root vole)	0	0	0	5	1	2	0	0	0
M. agrestis Linnaeus, 1761 (short-tailed vole)	0	2	0	0	0	0	0	0	0
Sicista betulina Pallas, 1779 (northern birch mouse)	0	4	1	0	1	0	0	0	0
Sorex araneus Linnaeus, 1758 (common shrew)	5	15	17	23	37	22	0	7	6
S. caecutiens Laxmann, 1788 (Laxmann's shrew)	0	4	6	0	0	2	0	0	2
S. minutus Linnaeus, 1766 (pygmy shrew)	1	4	0	0	12	11	0	0	0
Number of species	***6***	***10***	***7***	***6***	***9***	***8***	***3***	***4***	***5***
Number of individuals	**107**	**142**	**114**	**141**	**222**	**165**	**202**	**151**	**134**
Dominance Index	0.36	0.27	0.31	0.51	0.32	0.28	0.61	0.67	0.56
Shannon–Weaver index	1.21	1.62	1.35	1.01	1.31	1.50	0.61	0.67	0.89
Evenness Index (Pielow)	0.68	0.70	0.69	0.56	0.60	0.72	0.56	0.49	0.51

See Fig. 2 for line designations.

RESULTS AND DISCUSSION

The formation of phytocenoses of forest and park areas consists of preserved forest plantations that previously existed in their place and introduced and weedy plant species. Therefore, the state of forest plant communities in park-forests is influenced by all these components, and the recreational impact naturally varies in different parts and is most pronounced in those adjacent to urban areas. As we mentioned earlier (Chernousova, 2023; Chernousova et al., 2014), the Central Culture and Recreation Park and the Lesovodov Rossii were previously united forest area, so they belong to the same type of forest. As a result, the first line of the park-forest, the most transformed by recreation, ended up in the same cluster with the phytocenoses of areas of the CP, although it is separated by a highway and small buildings (Figs. 1, 2). The less disturbed sites of the Lesovodov Rossii and all sites of Kalinovsky park-forests form another large cluster. These park-forests have a similar type of forest plantings, and apparently, as a result, they formed a common cluster. However, the first line of the Kalinovsky park-forest, as the closest to the development and subject to significant recreational load, is located in this cluster separately from the other lines of park-forest localities. Such a grouping of clusters indicates that forest areas within the city limits respond with similar reactions of phytocenoses to a comparable degree of urbanogenic load.

Like for phytocenoses, for micromammal communities (Fig. 3), the position of the lines on the dendrogram is quite consistent with the logic, depending on the transformation of the forest phytocenosis and recreational load. We previously noted an analogous arrangement of clusters of small mammal communities for park-forests in general between those that are most transformed and those that are most similar to natural forest localities (Chernousova, 2023).

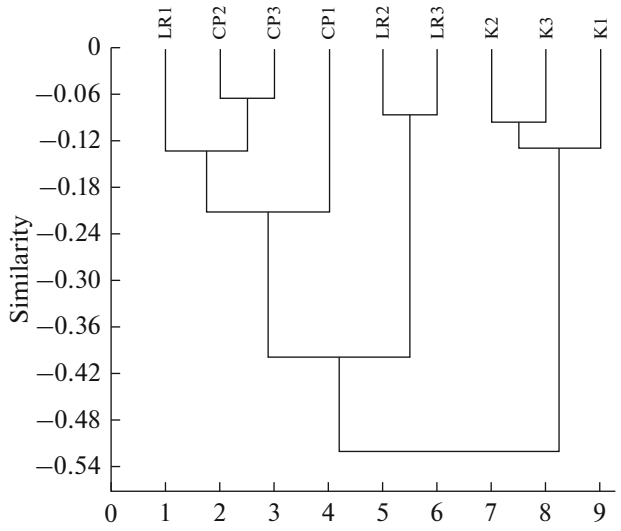

Fig. 3. Levels of similarity of micromammal communities of individual lineages of urban forest areas. See abbreviations in Fig. 2.

When comparing the dendrograms of phyto- and zoocenoses (combined Fig. 4), it is clear that both for the vegetation of the layers located below forest-forming tree species and for micromammals, all lines of the CP and the first line of the Lesovodov Rossii park-forest as the most exposed to recreational transformation, form one cluster. However, within these clusters, individual lineages for animals and plants are grouped differently. The levels of similarity between the lines of less disturbed areas of park-forests for phyto- and zoocenoses are somewhat different.

Thus, although there is some general pattern in the formation of large associations of clusters of phyto- and zoocenoses, there is no complete coincidence between them, which is quite natural, since on mammals, in addition to the plant environment, are affected by a number of other factors, and one of them is the influence of anxiety associated with the level of recreation, which affects different animals species different way.

CONCLUSIONS

Forest areas within the city are subject to changes due to the presence of weeds and introduced plants and due to the high level of recreation, which is naturally strongest in areas adjacent to or close to development. These areas have the largest path network and the presence of more numerous weeds and introduced plant species. Obviously, in such places, unfavorable conditions are created for the habitat of forest mammals, and their communities are replenished with species that are more resistant to human presence and uncharacteristic for the natural forest cenoses of the area we are studying. In remote forest areas of park-forests, where the anthropogenic load is much lower,

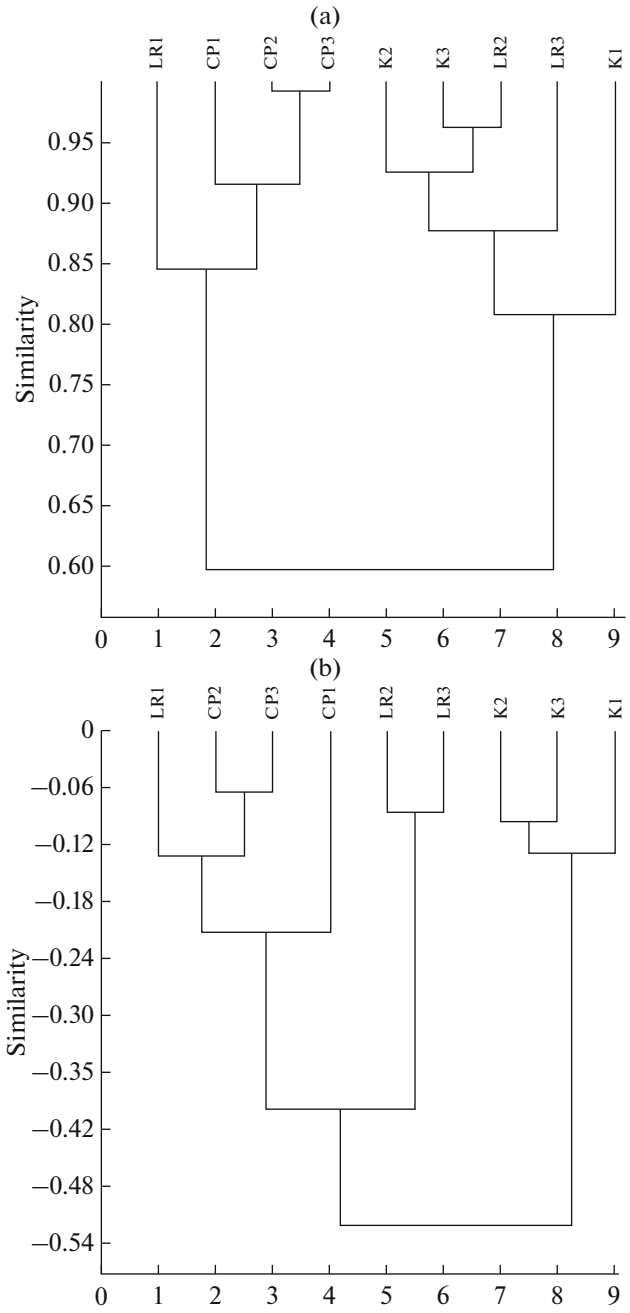

Fig. 4. Dendrograms of individual lines of phytocenoses (a) and micromammal communities (b). See abbreviations in Fig. 2.

forest species are found in greater numbers, although the presence of hemisynanthropic species remains, which in our case include the small wood mouse and striped field mouse. Of course, in addition to the level of high anxiety in park-forests and parks, the vegetation environment also affects the ability of rodents and shrews to form stable micropopulations and communities in forest areas of the city.

Therefore, in park-forests, on the one hand, conditions are created that are unfavorable for forest species

of micromammals. On the other hand, urbanization has its advantages for some species of mammals that are not typical for the pine forests of a given province, due to the appearance in phytocenoses of characteristics that make it easier for these animals to exploit landscapes disturbed by the active presence of humans, as well as due to reduced competition with forest species, for which such environmental changes are unfavorable. Due to the presence of hemisynanthropus species, the diversity of micromammalian communities increases, although where they reach especialy high numbers, practically replacing forest species (as for example in Central Culture and Recreation Park), the diversity decreases.

Patterns have been revealed in the similarities and differences in the grouping of individual lines of dendrograms for phytocenoses and micromammal communities in park-forests and Central Culture and Recreation Park, depending on the degree of their urban transformation (primarily recreational).

ACKNOWLEDGMENTS

I thank Dr. Sci. (Agric.) O.V. Tolkach and engineer O.E. Dobrotvorskaya at the Forest Department of the Botanical Garden of the Ural Branch, Russian Academy of Sciences, for help in describing the forest conditions of the communities.

FUNDING

This work was carried out as part of State Task no. 122021000082-0 "Mechanisms of the Homeostasis of Living Systems at the Level of Individual, Population, Taxocene, and Biogeocenosis in the Conditions of Natural and Anthropogenic Environmental Gradients of the Landscapes of the Urals."

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

CONFLICT OF INTEREST

The author of this work declares that she has no conflicts of interest.

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