ISSN 1067-4136, Russian Journal of Ecology, 2014, Vol. 45, No. 6, pp. 490–497. © Pleiades Publishing, Ltd., 2014.
Original Russian Text © N.F. Chernousova, O.V. Tolkach, O.E. Dobrotvorskaya, 2014, published in Ekologiya, 2014, No. 6, pp. 439–447.

Small Mammal Communities in Forest Ecosystems Affected by Urbanization

N. F. Chernousova[a], O. V. Tolkach[b], and O. E. Dobrotvorskaya[b]

[a] *Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, ul. Vos'mogo Marta 202a, Yekaterinburg, 620144 Russia*
e-mail: nf_cher@mail.ru

[b] *Botanical Garden, Ural Branch, Russian Academy of Sciences, ul. Vos'mogo Marta 202b, Yekaterinburg, 620144 Russia*

Received October 23, 2013

Abstract—A set of characters has been used to evaluate transformations in forest phytocenoses and their small mammal communities affected by urbanization, compared to conditionally undisturbed phytocenoses (communities). In park forests of the city of Yekaterinburg, the understory and subordinate shrub and herb–dwarf shrub layers of phytocenosis are transformed to a greater extent. The undergrowth of conifer forest-forming species is as a rule sparse or absent, and that of deciduous trees often consists mainly of invasive species. Small mammal communities in pine forests transformed under the effect of urbanization also undergo changes leading to the formation of relatively stable (for an urbanized environment) zoocenoses differing both in species composition and in parameters characterizing community diversity.

Keywords: urbanization, forest phytocenosis, small mammals, community diversity

DOI: 10.1134/S106741361405004X

Species with close ecological niches, such as murine rodents, form a community that plays a certain role in the ecosystem. In particular, they serve as food for predators and in this respect murine rodents and shrews comprise a single small mammal community, which is an important structural unit of any biocenosis. A comprehensive analysis of its qualitative and quantitative characteristics (species compositions, abundance of individual species, and specific features of their relationships within the community) makes it possible to assess the responses of communities inhabiting the same landscape–geographic region that has undergone various kings of anthropogenic transformation. In particular, this concerns the process of urbanization, which gradually "removes" space from the natural environment and, on the other hand, transforms biocenoses adjoining the cities, thereby creating conditions for accelerated evolution of ecosystems.

The statuses of plant and small mammal communities are interconnected by cause–effect relationships. By assessing transformations of phyto- and zoocenoses within the city limits, it is possible to estimate to what extent urbanization-induced changes in plant communities affect small mammals inhabiting lower vegetation layers. Thus, a single time section may prove sufficient for revealing the possible dynamics of the responses of communities, small mammals in particular, to anthropogenic transformations in the plant component of natural biocenoses.

Analyzing published data and the results of his own studies, Litvinov (2004, 2010) has shown that a decrease in Shannon's diversity index provides evidence for disturbances in the structure of dominance and disappearance of some species from the community (i.e., for the loss of stability), while Simpson's index is more sensitive to changes in the structure of dominance, especially those related to anthropogenic impact. Therefore, using both indices of diversity, it is possible to more objectively describe the status of small mammal community under different conditions.

Yekaterinburg, a large industrial center with the fourth largest population in Russia (about 1.5 million), can serve as a convenient model city for analyzing the impact of urbanization on the natural environment. In the classification of urban areas by Tikhonova et al. (2012), Yekaterinburg falls into the category of "largest urban agglomerations." The vegetation of small green areas in the historical center of the city has nothing in common with the natural vegetation of the region. However, due to increasing housing development, the city has expanded and engulfed the Central Recreation and Entertainment Park (CREP), which previously was at its edge, and the Arboretum of the Botanical Garden (Ural Branch, Russian Academy of Sciences), with remains of pine forests in both areas. Other pine stands transformed into park forests are located along the city periphery, at different points of the compass. Disturbances in them are most conspic-

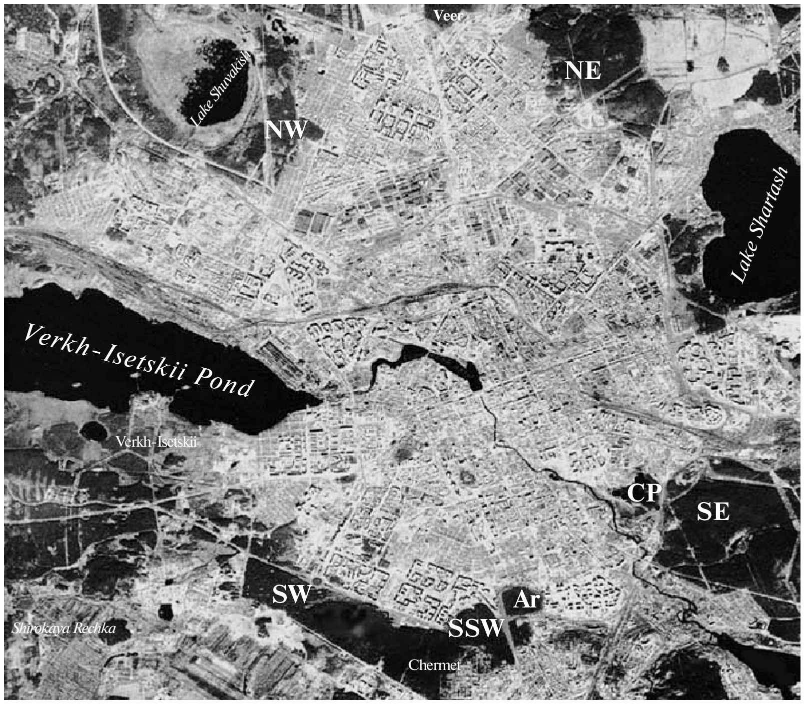

Fig. 1. Map of Yekaterinburg and locations of test plots. For designations (here and in Figs. 2–5), see Material and Methods.

uous in impact zones near built-up areas and the highway encircling the city. These park forests have slightly different topography, and their lower vegetation layers also differ from each other, although the edificator species—Scots pine, *Pínus sylvéstris* L.—is the same. In addition to recreational impact, phytocenoses of CREP and park forests have been transformed by planting of introduced shrub species, especially in zones adjoining built-up areas.

Park forests of Yekaterinburg represent forest ecotones in the broad sense of this term (Solov'eva and Rozenberg, 2006) that are exposed to the impact of airborne pollutants and recreational activities, which varies in strength in different zones of park forests depending on their proximity to built-up areas and land-use management. Recreational impact results in damage to the ground vegetation layer, forest litter, and soil, as well as in introduction of synanthropic plant species under the forest canopy (Chernousova and Tolkach, 2007). Transformation of phytocenoses in park forests should obviously affect their faunal assemblages, including small mammal communities (Chernousova, 2010).

The purpose of this study was to analyze the response of small mammal communities to disturbances in forest ecosystems caused by urbanization. To this end, we (1) made an integrated assessment of edaphic and plant components of forest cenoses altered under urbanizing influence from a large industrial center, (2) evaluated basic parameters of small mammal communities along the gradient of phytocenosis transformation, and (3) analyzed the effect of change in plant components of biogeocenosis on small mammal communities.

MATERIAL AND METHODS

Studies were performed in areas of pine forest transformed to different degrees in the city of Yekaterinburg (Fig. 1) and in two control forest plots. The former included five park forests located at different points of the compass and designated as shown in parentheses: Shuvakishskii in the northwest (NW), Kalinovskii in the northeast (NE), Lesovodov Rossii in the southeast (SE), Southwestern (SW), and South-southwestern (SSW). In addition, we included in the study two areas diametrically different in recreational load: the CREP (CP), where this load is especially high, and the Arboretum (Ar), where it is practically absent, since its territory is surrounded with a tall fence and separated from the SSW park forest by a collective orchard and a highway. Two control plots were in natural pine forests located 50 km southeast and 20 km west of Yekaterinburg (F-1 and F-2, respectively), where only slight signs of recreational impact could be detected.

Small mammals were sampled in the middle of the summer seasons of 2010–2012 using the standard trap-line method. In each urban locality, three trap lines were set so that the first line was in the area most affected by anthropogenic impact and the other two lines were in less disturbed areas. The positions of the lines remained unchanged from year to year. Sampling effort in each locality was 300 trap–days per year, and a total of 1305 animals were trapped and analyzed. Using average data on each locality, Shannon's and Simpson's diversity indices (H and D) and corresponding indices of species evenness (E_H and E_D) were calculated by standard formulas (Begon et al., 1989).

In all areas with trap lines (except for the SSW park forest), botanical surveys were conducted to determine the following parameters: stocking density and composition of tree stand in circular plots (in five replications); forest type according to Kolesnikov's (1973) classification; the abundance of understory and undergrowth (in 25 2 × 2 m plots), indicating species composition and plant height on Pobedinskii's (1966) scale; parameters of herb–dwarf shrub layer (in 25 1 × 1 m plots), including plant height, coverage of individual species, and the presence and coverage of mosses; the total depth of plant debris and forest litter; and relative area (%) under the network of paths (estimated visually). The occurrence frequency of each species in the understory, shrub layer, and herb–dwarf shrub layer in the plots was calculated to estimate the degree of vegetation degradation under recreational load.

The data from three trap lines in each locality were averaged, and the corresponding sets of phytocenotic conditions (including the depth of plant debris and forest litter) and parameters of small mammal communities were compared using diagrams plotted with the PAST2 program (Hammer et al., 2008).

RESULTS AND DISCUSSION

Park forests are mainly represented by pine stands (quality class 1–2) characteristic of the southern taiga district of Transural piedmont forest province (Kolesnikov, 1973).

In the Shuvakishskii and Lesovodov Rossii park forests and the Arboretum, trap lines were set in stands with similar site conditions (the herbaceous group of forest types, herbaceous forest type). Stocking density in the Lesovodov Rossii park forest (0.3–0.4) and the Arboretum (0.4) is lower than in the Shuvakishskii park forest (0.5–0.6). The age of tree stand is 100–110 years in the Arboretum and 150 years in Shuvakishskii and Lesovodov Rossii park forests. Despite the absence of serious recreational load, the regeneration capacity of tree stands in the Arboretum is low. The understory and undergrowth include considerable proportions of adventive species introduced by zoochory. Three undergrowth in the Lesovodov Rossii park forest are extremely sparse, and in the Shuvakishskii park forest it consists only of birch (Table 1).

Tree stands in the Southwestern park forest, CREP, and control forest plots belong to the ericaceous dwarf-shrub group of forest types (ericaceous dwarf-shrub pine forest and true moss–ericaceous dwarf-shrub pine forest types). They have similar stocking density (0.6) but slightly differ in tree age: in the Southwestern park forest, trees of older generations (150–170 years) alternate with younger trees (80 years), and the same is observed in the control (132 and 53 years), while all trees in the CREP are 103 to 178 years old. Unlike in park forests and CREP, the understory in the control forest is dense, and neither understory nor undergrowth contains synanthropic species.

Table 1 show data on vegetation layers under the tree canopy and forest litter. It can be seen that urbanization has affected lower vegetation layers of phytocenoses. This is manifested primarily in the sparse growth of young trees of the main forest-forming species, enrichment of the species composition of undergrowth with self-sown adventive plants, and increase in its density due to active growth and eventual dominance of typical forest species (raspberry and rowan), which has been directly or indirectly stimulated by proximity to urban areas. Thickets of raspberry, a eutrophic nitrophile, develop in park forests owing to soil enrichment with decaying waste and human and domestic animal excrement. Raspberry seedlings usually emerge in sites where soil has been damaged during recreational activities. Numerous populations of rowan appear due to the dispersal of its seeds by flocks of fieldfares, which actively colonize cultivated landscapes and nest in park forests and around orchards and garden plots (Mal'chevskii and Pukinskii, 1983). The development of undergrowth has an effect on growing conditions for herbaceous and dwarf shrub species, favoring the growth of some plant groups and suppressing the others. Thus, raspberry together with stinging nettle often forms thickets that suppress the growth of forest plants comprising the ground vegetation layer. Conditions for the dominance of raspberry in such cases are probably created by ground fires and subsequent dispersal of its seeds by birds from nearby garden plots.

The relative area under the network of paths in park forests generally varies from 3 to 8%, which corresponds to degradation stages 1 and 2, except for the most frequented areas of park forests and CREP, where it reaches 11–20% (degradation stage 4) (*OST* (Industrial Standard) *56-100-95...*, 2006). The control plots and Arboretum are practically free from recreational load.

To generalize the results of assessment of plant communities and edaphic conditions for the set of parameters shown in Table 1, they were processed by cluster analysis and presented as a dendrogram (Fig. 2). It can be seen that the control plots (located away from the city) and all plots within the city limits form two separate clusters, which is evidence for the impact of urbanization on the species richness, coverage, and occurrence frequency of young plants of the main forest forming species, shrubs, and herb–dwarf shrub layer.

In turn, the cluster comprising all plots within the city limits is divided into two smaller clusters, with

Table 1. Basic phytocenotic parameters of test plots

Parameter		Plot*							
		F-1	F-2	SW	NE	NW	SE	CP	Ar
Understory, 1000 ind./ha	pine	4950	1778	400	900	1200	1506	0	0
	deciduous species	1750	3388	1933	733	1800	11361	22633	4733
Undergrowth, 1000 ind./ha		7275	14000	24633	12367	22333	49960	34667	22333
Occurrence frequency, %	young pine trees	46.0	30.0	16.0	14.7	6.7	18.3	0.0	0.0
	young deciduous trees	29.0	58.9	16.0	17.3	24.0	22.6	27.7	84.3
	shrubs (without raspberry and row-an)	53.0	77.8	13.5	44.0	37.3	16.3	13.7	50.7
	rowan	13.0	34.4	38.7	44.0	36.0	63.7	37.3	41.3
	raspberry	7.0	1.0	57.3	24.0	61.3	69.0	68.0	46.3
	moss cover	10.7	3.3	0.5	0.1	13.7	4.3	2.2	2.9
Coverage, %	herbs–dwarf shrubs	94.6	83.9	68.9	105.7	86.7	80.0	53.5	64.5
	grasses	10.5	6.0	11.5	13.5	9.1	8.8	5.3	2.4
	synanthropic species (without grasses)	9.2	1.3	10.4	9.3	18.4	12.9	18.3	13.8
Total depth of plant debris and litter, cm		4.9	5.6	1.8	3.1	1.7	1.9	3.9	1.7
Number of species	deciduous tree undergrowth	2	2	3	1	2	6	5	5
	shrubs	6	7	8	10	10	12	9	7
	herb–dwarf shrub layer	50	42	40	56	37	50	27	27
	synanthropic plants (without grasses)	9	6	11	12	8	11	7	5

* For designations of plots (here and in Table 2), see Material and Methods.

CREP and Arboretum being segregated from park forests. This segregation is accounted for not so much by specificity of growing conditions or recreational impact as by the presence or absence of sources for contamination of forest phytocenosis with adventive plants. Among park forests, Southwestern and Lesovodov Rossii are similar to each other in the pattern of vegetation under the tree canopy, although they belong to different forest types, while Kalinovskii and Shuvakishskii are segregated from them and from each other because of distinctive features of lower vegetation layers. Thus, phytocenotic parameters of the lower vegetation layers, which are of primary significance for small mammals, differ between the plots depending on the degree of urbanizing influence. In park forests, the understory and subordinate shrub and herb–dwarf shrub layers of phytocenosis are transformed to a greater extent. The undergrowth of conifer forest-forming species is as a rule sparse or absent, and that of deciduous trees often consists mainly of invasive species. The spread of self-sown adventive trees and shrubs along with suppression of seedlings from the maternal tree stand are also observed in the absence of recreational impact on the forest plot (in the Arboretum).

According to Mirkin et al. (2008, p. 51), *successions in which individual stages are represented by synanthropic plant communities develop as stochastic processes, rather than as regular, sequential replacements of the "arrays" of species corresponding to discrete stages. In individual successional series of the same type, the same species can enter succession and leave it at different*

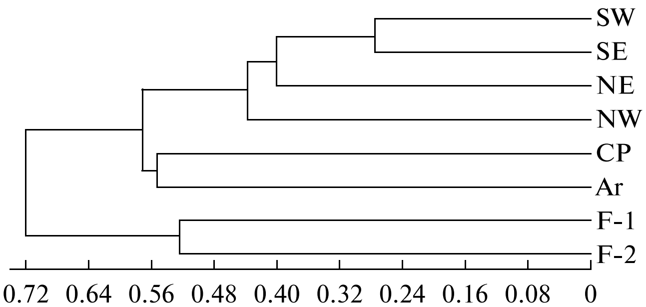

Fig. 2. Dendrogram of similarity in basic parameters between phytocenoses of test plots.

times and, hence, remain within synanthropic communities for different periods of time.

Typical allogenic serial succession with a constant pattern is also observed in small mammal communities of the zone affected by urbanization. Therefore, taking into account the results of our studies over a 10-year period (Chernousova, 1996, 2001, 2010), it can be concluded that fairly stable communities of small mammals have developed in areas exposed to approximately equal anthropogenic impact. Communities formed under the effect of allogenic succession in park forests structurally differ from typical forest communities of small mammals: they are characterized by dominance or codominance of pigmy wood mouse (*Apodemus uralensis*) and smaller proportions of species characteristic of conifer forests.

Small mammals trapped over 3 years belonged to 13 species, but their composition and abundance differed between the plots (Table 2).

Judging from the principles of calculating diversity indices, Shannon's index is the most informative (Magurran, 1992; Litvinov, 2004; Litvinov et al., 2007): it does not change when the number and proportions of species remain constant, and therefore changes (especially decrease) in its value are indicative of disturbances in the structure of dominance and disappearance of certain species from the community (i.e., the loss of community stability). Simpson's index is more sensitive to changes in the structure of dominance, especially those caused by anthropogenic factors (Litvinov, 2004). The pictograms based on the two diversity indices and the corresponding indices of evenness (Fig. 3) were plotted with Statistica 8 program. According to Litvinov (2004, 2010) and Shchipanov et al. (2012), the level of symmetry of such pictograms may be regarded as an indicator of community stability. In can be seen in Fig. 3 that the small mammal community of control forest plot F-1 has the most congruous pattern of species diversity and evenness, even though the relative abundance of small mammals in this habitat is lower than in most of park forests, where it is largely accounted for by *A. uralensis.* This agrees well with the state of vegetation, which is typical for undisturbed pine forests of the southern taiga zone. Therefore, plot F-1 satisfies the requirements for a control plot.

The diversity and evenness of small mammal community in the second control plot (F-2) are obviously inferior to those in park forests, regardless of high proportion of forest species. Apparently, the influence of its proximity to the city and collective orchards was sufficiently strong to affect the structure of this com-

Table 2. Species composition of small mammal communities in test plots

Species	Plot								
	F-1	F-2	SW	NE	NW	SE	SSW	CP	Ar
A.agrarius	0	0	++	++	++	++	++	+	++
A. uralensis	+	++	+++	+++	+++	+++	+++	+++	+++
C. glareolus	++	+++	+++	+++	+++	0	++	0	0
C. rutilus	+	++	0	+	0	+++	+	++	0
C. rufocanus	0	+	0	0	0	+	0	0	0
M. arvalis	++	+	++	++	0	0	+++	0	++
M. oeconomus	+	0	0	0	0	0	0	0	+
M. agrestis	++	0	+	0	0	0	0	0	0
Sicista betulina	+	0	+	+	++	+	0	0	0
Micromys minutus	0	0	+	0	0	0	0	0	0
S. araneus	++	+	++	++	+	+	++	0	+
S. caecutiens	+	+	0	+	+	0	0	0	0
S.minutus	+	+	0	0	0	+	0	0	0
Total catch over 3 years, ind.	82	56	145	137	205	198	178	132	119

Indices of abundance: (+) ≤1 ind., (++) 1 ≤ 10 ind, (+++) >10 ind. per 300 trap–days.

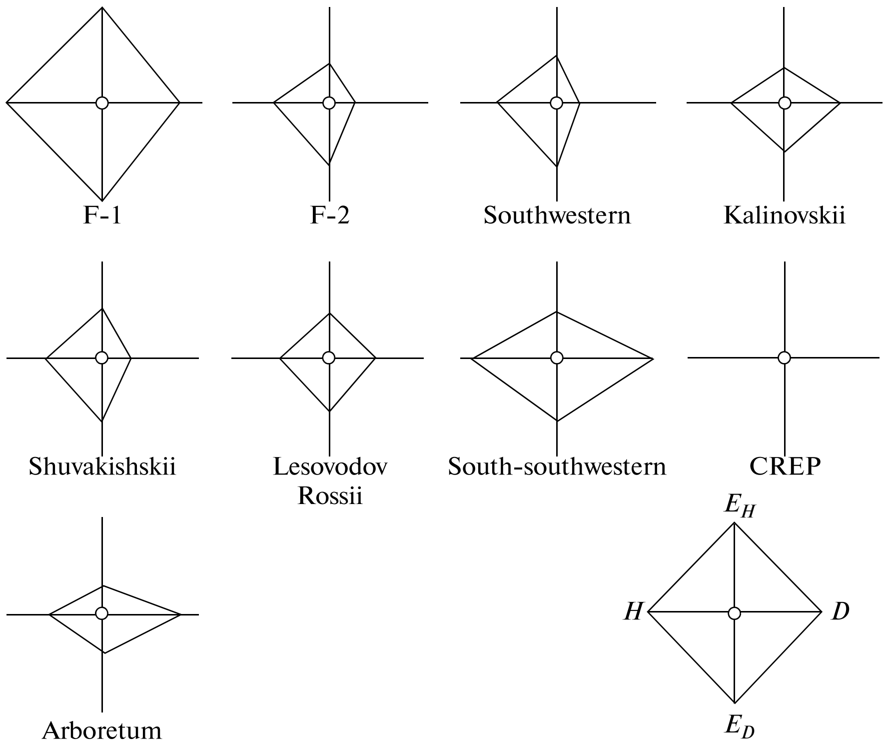

Fig. 3. Pictograms of 4-year average indices of species diversity and species evenness of small mammal communities in park forests and parks of Yekaterinburg and in control forests.

munity. Therefore, F-2 can only conditionally be accepted as a control plot.

The small mammal community of the South-southeastern park forest, where recreational impact is very strong (second to that in CREP), is similar in diversity to the community of plot F-1. This may be primarily to increased diversity of this phytocenosis, which includes a large proportion of introduced shrub species, and its contamination with various refuse, including food waste (note that such contamination is practically absent in CREP). However, the indices of species evenness in this community are similar to those in small mammal communities of other park forests.

No relationship has been revealed between the shape of pictograms and the positions of park forests relative to the points of the compass. The degree of recreational impact is approximately the same in all park forests, and this may explain a relatively similar, almost symmetrical shape of their pictograms. However, their size is significantly smaller, compared to the pictogram for F-1, indicating that small mammal communities formed in the park forests are stable but differ from that of the control forest area. All indices of the community exposed to the strongest recreational impact (CREP) proved to be the lowest, providing additional evidence of recreational load in shaping the communities of small mammals (Chernousova, 1996, 2010).

Taking into account that Simpson's index is considered to be more responsive to the impact of anthropogenic factors (Magurran, 1992; Litvinov, 2004; etc.), we used program Statistica-8 to plot the distribution of pictograms in the plane of axes D; E_D and, for comparison, axes H; E_H (Fig. 4). It can be seen that the distribution of pictograms along the E_D axis of evenness is random, not related to the degree of recreational and technogenic disturbance, with the South-southwestern park forest being segregated from other plots (Fig. 4a).

The distribution of pictograms along the D axis has a different pattern: all park forests concentrate in a narrow zone, which also includes control plot F-2. The Arboretum is located slightly below this zone, while F-1 (control community) and CREP (strongly disturbed community) are far displaced from it to the top and bottom of the diagram, respectively. Such data presentation makes it possible to reveal changes in faunal assemblages prior to manifestation of floristic changes, as in the case of control F-2. Faunal assemblages of park forests distinctly affected by urbanization slightly differ in species composition but are approximately equal in their biocenotic role.

The distribution of pictograms along the H axis in the H; E_H plane (Fig. 4b) is similar to that along the D axis (Fig. 4a), but that along the E_H axis of evenness has a different pattern: F-1 and CREP occupy diametrically opposite positions, while those of F-2 and all

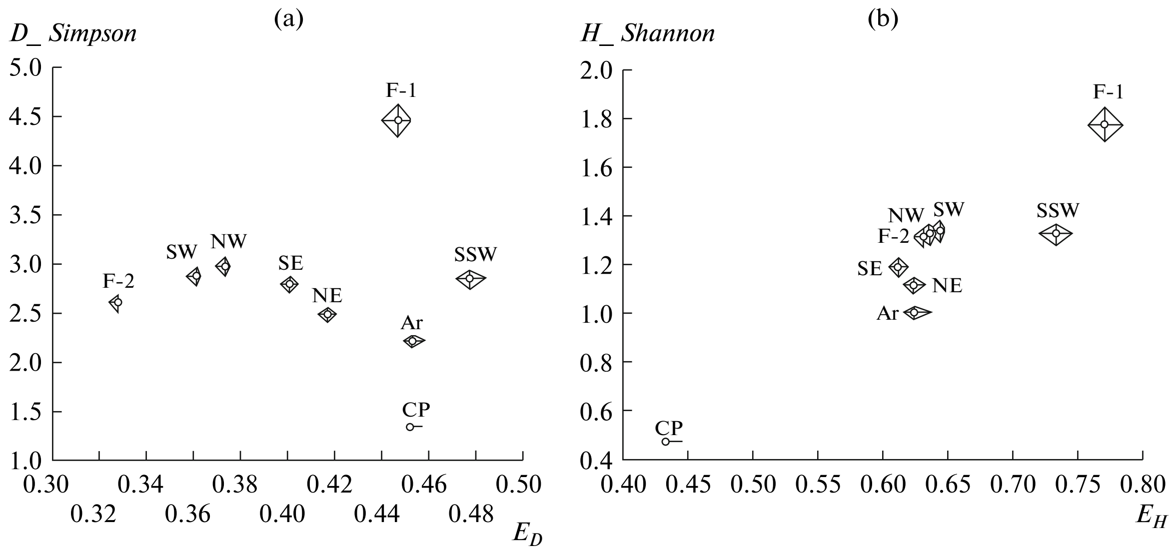

Fig. 4. Distribution of pictograms in the planes of axes (a) D; E_D and (b) H; E_H.

other plots within the city (except the South-south-western park forest) practically coincide. Thus, our data show that the distribution of pictograms along the Shannon–Pielou axes reflects only the extreme degree of recreation-induced changes, in agreement with Litvinov's (2004) opinion that Simpson's index is more responsive to anthropogenic changes.

To further evaluate similarity between small mammal communities of test plots and their relationships in comparison with those of corresponding phytocenoses, we plotted a dendrogram based on a set of parameters including the indices of community diversity and evenness, relative abundance of species, and their number and composition (Fig. 5). Unlike in plots

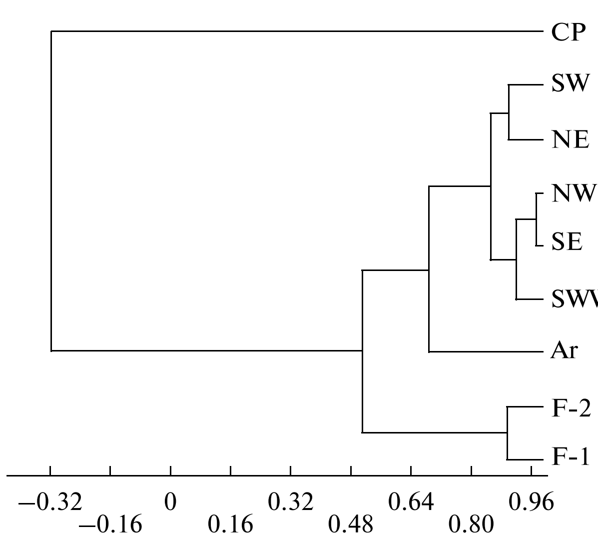

Fig. 5. Dendrogram of similarity between small mammal communities of test plots.

of pictogram distribution, the two control plots proved to be closely similar, forming an individual cluster in the dendrogram. Although the phytocenosis of CREP (exposed to increased recreational pressure) clustered together with phytocenoses of park forests (see Fig. 2), its small mammal community also forms an individual cluster, separate from those comprising park forest and control communities. This is additional evidence that mammals, small mammals in particular, are especially sensitive not so much to phytocenotic components as to the factor of anxiety, which for obvious reasons reaches a peak level in the CREP.

Thus, phytocenotic parameters of lower vegetation layers, which are of primary importance for small mammals, differ between the plots depending on the degree of urbanizing influence. As noted above, the understory and subordinate shrub and herb–dwarf shrub layers in phytocenosis of part forests are transformed to a greater extent, the undergrowth of conifer forest-forming species is as a rule sparse or absent, and that of deciduous trees often consists mainly of invasive species.

Small mammal communities in pine forests transformed under the effect of urbanization undergo changes leading to the formation of relatively stable (for an urbanized environment) zoocenoses differing both in species composition (Chernousova, 2010) and in parameters characterizing community diversity (Chernousova et al., 2012).

Although the status of small mammal communities is related to the degree of phytocenosis transformation, it depends mainly on the frequency of human visits per unit area of transformed forest plot, and this dependence is even stronger than that on the level of its disturbance from recreational impact. This is confirmed by the shape of pictograms and their distribution in the coordinates of indices characterizing the composition of communities.

REFERENCES

Begon, M., Harper, J.L., and Townsend, C.R., *Ecology: Individuals, Populations, and Communities*, Oxford: Blackwell, 1986. Translated under the title *Ekologiya: Osobi, populyatsii i soobshchestva*, Moscow: Mir, 1989.

Chernousova, N.F., Effect of urbanization on communities of small mammals in park forests in a large industrial center, *Russ. J. Ecol.,* 1996, no. 4, pp. 278–283.

Chernousova, N.F., Specific features of the dynamics of murine rodent communities under the effects of urbanization: 1. Dynamics of species composition and abundance, *Russ. J. Ecol.*, 2001, no. 2, pp. 122–125.

Chernousova, N.F. and Tolkach, O.V., Dynamics of small mammal communities in urbanized areas, in *Sinantropizatsiya rastenii i zhivotnykh* (Synanthropization of Plants and Animals), Irkutsk, 2007, pp. 163–155.

Chernousova, N.F., Population dynamics of small mammal species in urbanized areas, *Contemp. Probl. Ecol.*, 2010, vol. 3, no. 1, pp. 108–113.

Chernousova, N.F., Tolkach, O.V., and Tolkachev, O.V., Small mammals in forest ecosystems affected by urbanization, *Usp. Sovrem. Estestvozn.*, 2012, no. 9, pp. 410–46.

Hammer, Ø., Harper, D.A.T., and Ryan, P.D., http://folk.uio.no/ohammer/past

Kolesnikov, B.P., *Lesorastitel'nye usloviya i tipy lesov Sverdlovskoi oblasti. Prakticheskoe rukovodstvo* (Site Conditions and Forest Types in Sverdlovsk Oblast: A Practical Manual), Sverdlovsk: Ural. Nauch. Tsentr Akad. Nauk SSSR, 1973.

Litvinov, Yu.N., *Soobshchestva i populyatsii melkikh mlekopitayushchikh v ekosistemakh Sibiri* (Communities and Populations of Small Mammals in Siberian Ecosystems), Novosibirsk: TsERIS, 2001.

Litvinov, Yu.N., Effects of factors of different nature on parameters of diversity in small mammal communities, *Usp. Sovrem. Biol.,* 2004, no. 6, pp. 612–621.

Litvinov, Yu.N., Spatiotemporal patterns in organization of small mammal communities, in *Soobshchestva i populyatsii zhivotnykh: ekologicheskii i morfologicheskii analiz* (Animal Communities and Populations: Ecological and Morphological Analysis), *Tr. Inst. System. Ekol. Zhiv. Sib. Otd. Ross. Akad. Nauk*, 2010, no. 46, pp. 17–48.

Litvinov, Yu.N., Abramov, S.A., Kovaleva, V.Yu., Krivopalov, A.V., Novikov, E.A., and Chechulin, A.I., Structural–temporal organization of a rodent community in the Teletskaya taiga, Altai Mountains, *Russ. J. Ecol.*, 2007, no. 6, pp. 413–418.

Mal'chevskii, A.S. and Pukinskii, Yu.B., *Ptitsy Leningradskoi oblasti i sopredel'nykh territorii* (Birds of Leningrad Oblast and Neighboring Regions), Leningrad: Leningr. Gos. Univ., 1983.

Magurran, A.E., *Ecological Diversity and Its Measurement,* London: Croom Helm, 1988. Translated under the title *Ekologicheskoe raznoobrazie i ego izmerenie*, Moscow: Mir, 1992.

Mirkin, B.M., Yamalov, S.M., Naumova, L.G., et al., Specific features of synanthropic communities as objects for classification: Role of deductive method, *Byull. Mosk. O–va Ispyt Prir., Otd. Biol.*, 2008, vol. 113, no. 4, pp. 51–59.

OST (Industrial Standard) *56-100-95: Methods and Units for Measuring Recreational Load on Natural Forest Complexes*, Moscow, 2006.

Pobedinskii, A.V., *Izuchenie lesovosstanovitel'nykh protsessov* (Analysis of Forest Regeneration Processes), Moscow: Nauka, 1966.

Shchipanov, N.A., Kouptsov, A.V., Kalinin, A.A., et al., Small mammals at the southeast of Tver oblast: 2. Diversity, population density and biomass, *Contemp. Probl. Ecol.*, 2012, vol. 5, no. 1, pp. 92–96.

Solov'eva, V.V. and Rozenberg, G.S., Modern views on ecotones, or ecotone theory, *Usp. Sovrem. Biol.*, 2006, no. 6, 531–549.

Thompson, C.M. and Gese, E.M., Influence of vegetation structure on the small mammal community in a shortgrass prairie ecosystem, *Acta Theriol.,* 2013, vol. 58, pp. 55–61.

Tikhonova, G.N., Tikhonov, I.A., Surov, A.V., et al., *Ekologicheskie aspekty formirovaniya fauny melkikh mlekopitayushchikh urbanisticheskikh territorii Srednei polosy Rossii* (Ecological Aspects of Small Mammal Fauna Formation in Urban Areas of Central Russia), Moscow: KMK, 2012.

Whittaker, R.H., New concepts of kingdoms of organisms, *Science,* 1969, vol. 147, pp. 250–260.

Whittaker, R.H., *Communities and Ecosystems*, 2nd ed., New York: Macmillan, 1975. Translated under the title *Soobshchestva i ekosistemy*, Moscow: Progress, 1980.

Translated by N. Gorgolyuk