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DYNAMICS OF MOUSE-LIKE RODENT COMMUNITIES IN ANTHROPOGENICALLY DISTURBED TERRITORIES OF THE SOUTHEAST OF WESTERN SIBERIA (KEMEROVO REGION, RUSSIA)

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Dynamics of Mouse-Like Rodent Communities in Anthropogenically Disturbed Territories of the Southeast of Western Siberia (Kemerovo Region, Russia). Ilyashenko, V. B., Luchnikova, E. M., Danilov, V. N., Kovalevsky, A. V., Zubko, K. S. — We studied the dynamics of mouse-like rodent communities in the area of self-growing vegetation, which had undergone deforestation. The research is based on the results of continuous monitoring conducted from 1978 to 2019. Pitfall traps was the method of catching small mammals during the monitoring period. We used Simpson's Diversity Index to quantify species diversity. The community similarity was evaluated by the percentage of species through Czekanowski-Sørensen Index. The studies were carried out near the "Azhendarovo" Biological Station (54°45' N, 87°01' E). The results of the studies showed that natural primeval communities of the taiga zone before deforestation were characterized by a multidominant structure. The dominant group included the *Alexandromys oeconomus* Pallas, 1776, and codominant species are represented by the genus *Clethrionomys*. A characteristic feature of the small mammals' population of taiga forests is the preponderance of the *Apodemus peninsulae* (Thomas, 1907) over the *Apodemus agrarius* Pallas, 1771. On meadowlands, the genus *Microtus* voles prevailed. These were largely the *Al. oeconomus*, which accounted for 43 % of all mouse-like rodents. After the deforestation, the structure changed. In the early stage of deforestation, the dominant species among rodents was the *Al. oeconomus*. The composition of dominant species in the recovering areas of cut-down taiga began to approach to the original state 40 years after the deforestation. Meadow communities followed the path of transformation, having no analogs in the initial period and were characterized by a significant amount of ruderal vegetation.
Key words: small mammals' communities, rodents, long-term dynamics, deforestation, succession.

Introduction

Mouse-like rodents form the basis of fauna of any locality, and the number of species, structure and spatial heterogeneity of their communities are the markers that allow us to evaluate the effects of anthropogenic impact on natural complexes through zoological methods (Ilyashenko et al., 2015; Ilyashenko & Luchnikova, 2017; Luchnikova et al., 2020). Rodent responses to the changes in living conditions, manifested particularly in fluctuations in their population and transformation of the communities' hierarchical structure are of particular interest. There are many scientific papers devoted to changes in small mammal communities under the influence of various anthropogenic factors (Ravkin et al., 2009; Chernousova et al., 2014, etc.), including deforestation (Bogdziewicz & Zwolak, 2014). However, the vast majority of these studies are short-term and do not consider the processes of recovery of populations of small mammals as the impact of adverse factors decreases.

From this point of view, the situation in the Tom River Valley during the construction of the Krapivinsky Reservoir represents the interest, as starting from 1976 floodplain forests were being cut-down in the bed of the future reservoir. In total, 420 km^2 of forests, including massifs of dark coniferous taiga, had been cut down. However, the area was not flooded. The construction of the reservoir was stopped due to some environmental considerations and social and economic crisis. Natural communities of anthropogenically disturbed territory entered the stage of restorative succession. Moreover, the movement of 20 rural settlements out of the floodable zone, and at the same time an almost complete cessation of agricultural activity (cultivation of fields and gardens, grazing, haying), led to a sharp decrease in the anthropogenic impact on meadow ecosystems. Currently, this is a territory with restricted environmental management, which led to the natural reforestation, overgrowing of arable land, hayfields, and pastures. The results of series of 40-year-long stationary observations (more than 102 thousand specimens of small mammals) that are at our disposal allow us to observe the main stages of succession from the initial community (before deforestation) through some natural succession series to the current state (a recovery stage).

Material and methods

The studies were carried out in the Krapivinsky District of Kemerovo Region, in the vicinity of the Biological Stations of the Kemerovo State University "Azhendarovo" (54°45' N, 87°01' E) and "Lachinovo" (54°50' N, 87°00' E), where forest-steppe of Kuznetsk Depression changes to the dark coniferous taiga of the foothills and low mountains of the Kuznetsk Alatau. The territory is characterized by various habitats for small mammals, from coniferous forests to upland steppe meadows. We paid special attention to the vast anthropogenically disturbed areas that were formed during the preparation of the reservoir bed: overgrowing deforested zones in the place of forests of various types, uncultivated lands covered with nettles in the place of former settlements, sparse willows that appeared in place of meadows.

All names of animals are given according to The Mammalia of Russia: A Taxonomic and Geographic Reference (Pavlinov & Lissovsky, 2012), with changes according to the paper of Kryštufek et al. (2020).

To carry out monitoring studies of the state of the environment, we used the methods of relative accounting of captured small mammals with standard pitfall traps (50-meter grooves with five pitfall traps every 10 meters) in zones of meadows and taiga, mixed forests, nettle, and ecotone areas. Monitoring was being carried out from 1978 to 2019. Small mammals were captured on the left and right banks and islands of the Tom River. A total of 88 thousand mammals of 20 species were caught (Ilyashenko et al., 2020).

The abundance of animals was calculated as the number of captured animals equivalent to 100 "trap-nights". To determine the ecological and topological affiliation of the species, the coefficients of habitats allegiance were calculated according to the formula proposed by Yu. A. Pesenko (Pesenko, 1982): $F_{ij} = (n_{ij} \times N - n_i \times N_j)/(n_{ij} \times N + n_j \times N_j - 2n_{ij} \times N_j)$, where n_{ij} is the number of individuals of the i species in the j sample (habitat) of N_j volume, n_i is the number of individuals of this species in all captures with a total volume of N. To quantify species diversity, we used the Simpson's Diversity Index. The community similarity was evaluated by species percentage using the Czekanowski-Sørensen Index (Pesenko, 1982).

Results

The communities of small mammals found in the studied area belong to the environmental and faunal association of mammals living in highland dark coniferous taiga forests that dominate in the region. They differ from the communities of the adjacent forest-steppe and steppe territories, first of all, in the richness of the species composition of small mammals; in the combination of species that diverge in terms of ecological and topological requirements (forest, forest-meadow, meadow, eurytopic, near-water, etc.), and in the originality of the hierarchical structure of the community in whole, and of habitat groups, in particular (Ilyashenko, 2015). As forest species, we categorize *Apodemus peninsulae*,

Table 1. The coefficients of biotopic preference based on the results of multi-year research at Biological Station (Bungarap-Azhendarovsky Reserve)

Species	Habitats					
	Taiga	Mixed Woodland	Deforested areas	Ecotone	Ruderal Vegetation	Meadows
Sicista betulina	–0.02	0.16	–0.05	0.04	0.09	–0.15
Clethrionomys glareolus	0.56	0.06	–0.08	–0.41	–0.72	–0.27
Clethrionomys rufocanus	–0.10	0.18	–0.08	0.14	0.12	–0.20
Clethrionomys rutilus	0.37	–0.12	0.07	0.12	–0.67	–0.42
Arvicola amphibius (Linnaeus, 1758)	–0.24	–0.02	0.04	–0.21	–0.22	0.45
Microtus gregalis	–0.61	–0.35	–0.55	–0.36	–0.39	0.78
Alexandromys oeconomus	–0.05	–0.12	0.11	–0.07	–0.01	0.12
Microtus arvalis	–0.42	0.27	–0.42	–0.02	0.10	0.36
Microtus agrestis	–0.09	0.31	–0.28	0.17	–0.12	0.04
Micromys minutus	–0.26	–0.14	–0.13	0.18	0.32	–0.14
Apodemus peninsulae	0.04	0.18	–0.08	–0.06	0.10	–0.36
Apodemus agrarius	–0.55	–0.20	–0.22	0.20	0.49	–0.05

N o t e. The preference ranges from –1 to 1, where –1 characterizes the complete absence of the species in the abitat, and 1 means the absolute confinement of the species to the habitat.

Microtus arvalis (Pallas, 1778), *Microtus agrestis* (Linnaeus, 1761), *Clethrionomys rutilus*, and *Clethrionomys rufocanus*. The representatives of meadow species are *Apodemus agrarius*, *Micromys minutus* (Pallas, 1771), *Microtus gregalis* (Pallas, 1779), and *Microtus arvalis* (table 1). As eurytopic species, we categorize *Sicista betulina* (Pallas, 1779), and *Alexandromys oeconomus*. In the studied area, *Clethrionomys glareolus* (Schreber, 1780) lives on the periphery of its area of distribution. In undisturbed habitats, it prefers deciduous and mixed forests and ecotone areas (Moshkin et al., 2000).

Before large-scale deforestation, the community of small mammals of taiga forests was multi-dominant. *Alexandromys oeconomus* dominated among the mouse-like rodents and representatives of *Clethrionomys*, *Clethrionomys rutilus,* and *Clethrionomys rufocanus* acted as co-dominants. A characteristic feature of the population of small mammals of taiga forests is the predominance of *Apodemus peninsulae* over *Apodemus agrarius*. The voles of the genus *Microtus* prevailed in the meadow areas. These were mainly the *Alexandromys oeconomus*, which accounted for 43 % of all mouse-like rodents. The abundance of *Clethrionomys* voles here was significantly lower than in taiga forests, and *Apodemus agrarius* prevailed over *Apodemus peninsulae*.

Clear-cutting of floodplain and valley forests in 1975–1978 led to the formation of a mosaic area consisting of open, forested and untouched forest areas, which led to a change in the spatial and habitat structure of the small mammals populations (Ilyashenko et al., 2019). During the early stage of deforestation, the dominant voles among rodents was *Alexandromys oeconomus*, being almost the only representative of the genus *Microtus*. The share of *Clethrionomys* voles decreased by several times, with the exception of *Clethrionomys glareolus*, the population of which in the disturbed areas was increasing. The ratio of *Apodemus agrarius* and *Apodemus peninsulae* in the early stage of deforestation was approximately equal, but in the course of reforestation, the proportion of the latter began to gradually increase. The ability of *Clethrionomys glareolus* to populate anthropogenically disturbed areas, including deforestated ones, has already been noted in some studies (Moshkin et al., 2000). Therefore, an increase in its share in communities can be considered as an indicator of environmental disturbance. The disappearance of settlements and

agricultural activity led to the transformation of habitats. Extensive nettles were formed instead, and their high-mosaic phytocenosis is formed mainly by tall-growing weedage. Rodent communities, characterized by a very unstable hierarchical structure, were formed here. In the early and middle stages of transformation, here just like in the area of early-stage felling, *Alexandromys oeconomus* was clearly dominating and the number of *Clethrionomys glareolus* was increasing.

The cessation of livestock grazing in meadow habitats led to some natural succession processes, the early stages of which were characterized by an increase in the height of the grass stand and a decrease in the proportion of cereals. These processes did not affect the meadow communities of small mammals in a significant way. However, the next stage of transformation — massive overgrowing of meadows with shrubs and their gradual transformation into willow woodlands — resulted in the fact that these habitats became unsuitable for typical meadow species: *Microtus gregalis,* and *Microtus arvalis*. The decrease in abundance or even complete absence of these species in the pitfall traps is come along with an increase in the number of *Apodemus peninsulae* (a forest species), gradually forcing *Apodemus agrarius* out of the meadows.

Gradual self-reduction of aspens, an increase in the share of fir and birch trees, and a change in the structure of soil litter characterized further reforestation processes that took place in 25–30-year-old deforested zones in 1996–2003. During this period, the rodent community is gradually acquiring the features of the original — generally taiga type although the proportion of *Clethrionomys glareolus*, acting here as an indicator of environmental disturbance, reaches 20% in some years. It should be noted that middle-aged (25–35-year-old) deforested zones was generally the least preferred habitat for most species. The population of small mammals, in comparison with other habitats, was the smallest.

In recent years, reforestation continues, and the rodent community of 40-year-old forests can be referred to as almost completely restored, although the phytocenosis has not reached its initial state yet. The growth of species diversity, an increase in the similarity index of the studied community with the original taiga community, restoration of the abundance of forest species (*Clethrionomys* voles, *Apodemus peninsulae*) is the evidence of this process (fig. 1). A steady decrease in the abundance of *Clethrionomys glareolus* in deforested zones in the last 10 years also indicates recovery processes. As for nettles, their expected transformation into typical floodplain meadows of the taiga zone never happened. Mosaic ruderal tallgrass still dominates here. Nettles turned out to be the only habitat in the studied area, where mice of the genus *Apodemus* and not *Alexandromys oeconomus* dominate among rodents. Moreover, there is still a high abundance of *Clethrionomys glareolus*, an indicator of the disturbed environment in the southeast Western Siberia.

Thus, the decrease in anthropogenic impact led to the recovery-type succession process in the deforested zones while in meadows and nettles it has taken a form of transformation into other habitats, which are unique in many respects, with no analogs in the initial period of the research.

Identified trends in the qualitative and quantitative changes of the communities' state come along with natural processes of long-term fluctuations in the number of small mammals. Firstly, these are population cycles of 3–4 years, which include stages of population growth, sharp increase in numbers, decline, and depression. The cycles are most clearly traced during periods of stable climatic conditions (1978–1993), in years characterized by atypical weather conditions (1999–2003), we observed cyclic disturbance. Secondly, a set of adverse weather factors (snowless frosts, prolonged drought, etc.) has an uneven effect on different types of small rodents. For instance, *Clethrionomys* voles inhabiting "closed" habitats are less affected by climatic factors, because of which the dynamics in their numbers is more even than that of *Microtus* voles that prefer "open" habitats (meadows). Thirdly, in some years, the structure of small mammals' community dominance can change under

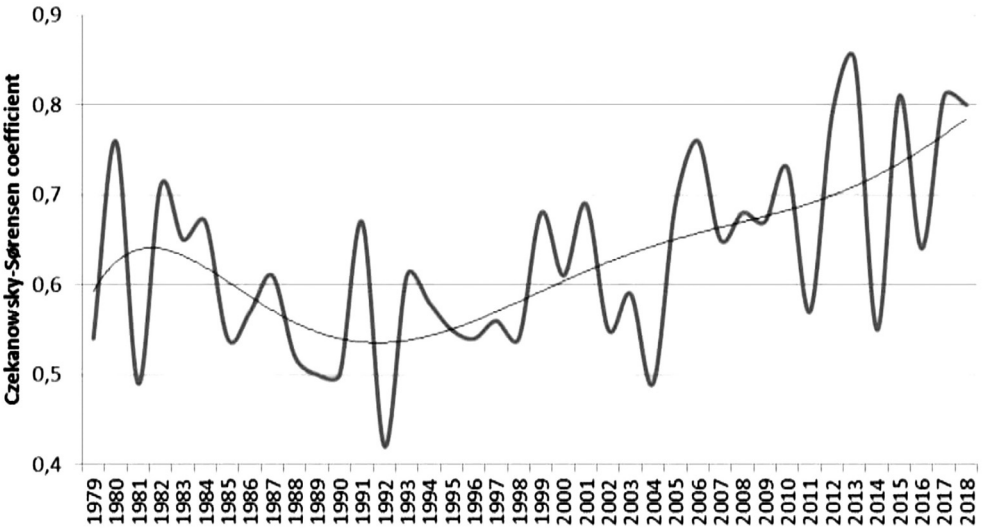

Fig. 1. The dynamics of similarity of small mammal populations in deforested zones compared to the initial population in taiga (using the Czekanowsky-Sørensen coefficient calculated for species' percentage in the community).

the influence of sharp increase in number of a certain species. An example is the increase in number of the *Arvicola amphibius*, a species generally uncharacteristic for the study area, which we described (Ilyashenko & Luchnikova, 2017). Similar short-term sharp increase in number were observed among other species — *Microtus arvalis* in 1988, 1997 and 2007, and *Microtus agrestis* in 1990, 2003, and 2015.

Conclusion

Our studies have shown that in the structure of small rodents' communities on anthropogenically disturbed and recovering territories, there are significant changes caused by the habitat transformations, and, first of all, by such processes as reforestation of deforested zones and overgrowing of meadows. In southern taiga forests of the southeast Western Siberia, with the reduction of anthropogenic pressure, the change in vegetation and animal communities in deforested zones is taking the path of returning to the original taiga type. With no agricultural activity, meadows and nettles have transformed into qualitatively different habitats inhabited by specific rodent communities that had no analogs in the studied area before. *Clethrionomys glareolus* is an indicator of intermediate recovery stages in disturbed communities. In general, in the floodable zone of the Krapivinsky Reservoir, there is a steady increase in the share of forest species, their penetration into meadow areas, and a decrease in the abundance of species that prefer steppe meadows. These processes can be considered as the main long-term trends. The responses of small mammals' communities both to disturbances in environmental conditions and to decrease in anthropogenic impact have long-lasting nature and may be slow in coming for several years or even decades. The common long-term trends are superimposed by natural cyclic fluctuations in the number, as well as disturbances in the structure of communities caused by weather-climatic anomalies, sharp increase in number, and changes in the spatial and ethological structure of certain species. Given such a complex system of factors affecting mouse-like rodents, it can be argued that scientific data obtained in short-term studies cannot fully reflect the diversity of dynamic processes occurring in communities of small mammals. To study the processes of anthropogenic and restorative successions, long-term monitoring observations are needed.

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