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Long-Term Dynamics of Small-Mammal Communities in Anthropogenically Disturbed Territories in the South-East of West Siberia

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Abstract. The paper summarizes the unique 40-year experience (1978-2018) of studying the dynamics of communities caused by total deforestation and subsequent restoration in the Kuznetsk Basin of Kemerovo Region. The analysis of extensive material (more than 100,000 specimens) shows that small mammals are valid indicators of a variety of succession processes evoked by the transformation of habitats, which primarily involves the renewal of taiga forests on extensive clear felling. General long-term trends are superimposed on by natural cyclical fluctuations of population as well as by disturbances in the structure of communities, caused by weather and climatic anomalies, by rapid increases in population and changes in the spatial and ethological structure of individual species.

1. Introduction

Small mammals are one of the main objects of research in eco-faunistic studies. They form the basis of teriofauna of any terrain, and the number of species, structure and spatial heterogeneity of their communities are the indicators that allow one to assess ecological features and the current state of the territories by means of zoological methods. The study of the dynamics of small mammal communities makes it possible to evaluate the effects of anthropogenic impact of various duration and intensity on natural complexes [1].

Small mammals are found in a variety of habitats and among the first to inhabit disturbed lands [1, 2]. Of particular interest are the small mammals' responsiveness to changes in living conditions, manifested primarily in abundance fluctuations and transformation of hierarchical structures in their communities [3, 4]. There are a number of scientific papers concerned with changes in the communities of small mammals caused by various anthropogenic factors [4, 5, 6], including deforestation[7], but the overwhelming majority of these studies cover only a short time period and do not consider how the population reverts back to its original state as the impact of unfavorable factors decreases.

As such, of the greatest interest is the situation that has developed in the valley of the river Tom during the construction of the Krapivinsky reservoir. Beginning in 1976, floodplain forests, including massifs of the black taiga, were cut down in the floor of the future reservoir. The floor was cleared of forest vegetation and prepared for flooding. In total, 42 thousand ha of forests were cleared. However, the flooding of the territory did not take place, since the construction of the reservoir ceased due to environmental concerns. The natural communities of the anthropogenically disturbed territory entered the stage of restorative succession.

Currently, the territory is under limited nature resource use, which has led to the natural renewal of



forests. The available 40-year series of stationary observations makes it possible to trace the main stages of succession on mass material (more than 102,000 specimens of small mammals). The first studies were carried out before deforestation (the initial state of communities of small mammals), which was followed by a study of several intermediate stages, occurred during disturbance of natural habitats and their almost complete restoration.

2. Methodology

The studies were conducted in the Krapivinsky district of the Kemerovo region, near the biology station of the Kemerovo State University “*Azhendarovo*”, where the forest-steppe of the Kuznetsk Basin transitions to the black taiga of the foothills and low mountains of the Kuznetsk Alatau (Fig. 1). The territory features a variety of habitats, from coniferous forests to dry steppe meadows. Particular attention was paid to the anthropogenically disturbed areas that took up considerable space at the time of preparation of the reservoir floor. These include overgrown cleared forests of various types.

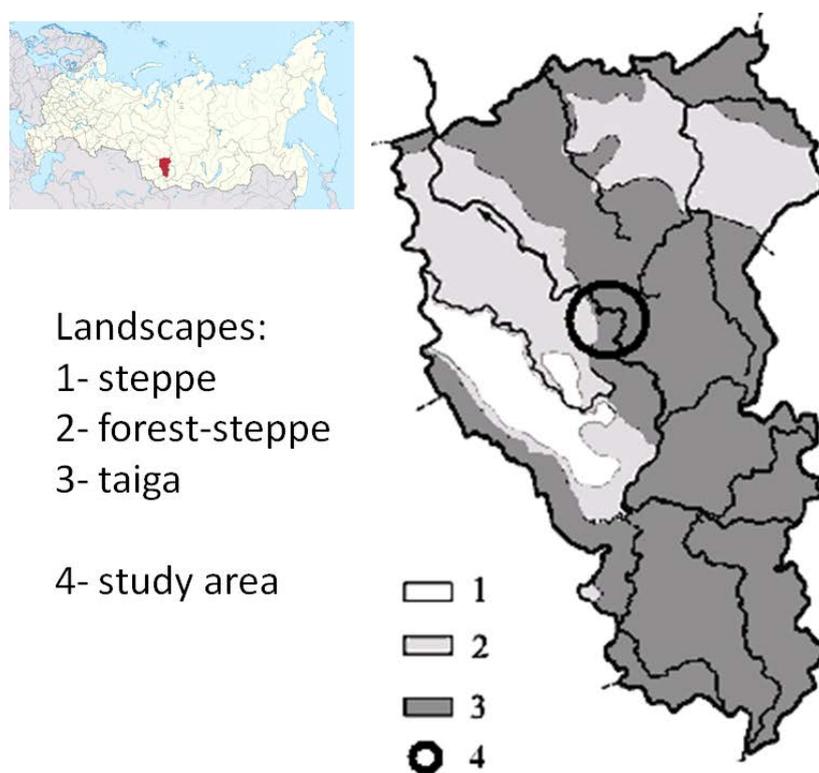


Figure 1. Map of the study area

For monitoring research of the environment, we used methods of relative survey of small mammals by means of trapping grooves.

Species composition and the number of captured small mammals between 1978 and 2018 are presented in Table 1.

Table 1. The number of small mammals captured near the “Azhendarovo” biology station between 1978 and 2018

Species	Number
1. Siberian White-toothed Shrew <i>Crocidura sibirica</i> Dukelsky, 1930	1019
2. Eurasian Water Shrew <i>Neomys fodiens</i> (Pennant, 1771)	2668
3. Common Shrew <i>Sorex araneus</i> Linnaeus, 1758	23785
4. Tundra Shrew <i>Sorex tundrensis</i> Merriam, 1900	1772
5. Laxmann's Shrew <i>Sorex caecutiens</i> Laxmann, 1788	6138
6. Taiga Shrew <i>Sorex isodon</i> Turov, 1924	14462
7. Flat-skulled Shrew <i>Sorex roboratus</i> Hollister, 1913	2361
8. Least Shrew <i>Sorex minutissimus</i> Zimmermann, 1780	127
9. Pygmy Shrew <i>Sorex minutus</i> Linnaeus, 1766	5766
10. Northern Birch Mouse <i>Sicista betulina</i> (Pallas, 1779)	4205
11. Gray Red-backed Vole <i>Myodes rufocanus</i> (Sundevall, 1846)	2783
12. Bank Vole <i>Myodes glareolus</i> (Schreber, 1780)	4008
13. Northern Red-backed Vole <i>Myodes rutilus</i> (Pallas, 1779)	5304
14. Water Vole <i>Arvicola amphibius</i> (Linnaeus, 1758)	1113
15. Narrow-headed Vole <i>Microtus gregalis</i> (Pallas, 1779)	563
16. Root Vole <i>Microtus oeconomus</i> (Pallas, 1776)	18551
17. Common Vole <i>Microtus arvalis</i> (Pallas, 1778)	1300
18. Field Vole <i>Microtus agrestis</i> (Linnaeus, 1761)	1741
19. Harvest Mouse <i>Micromys minutus</i> (Pallas, 1771)	1521
20. Korean Field Mouse <i>Apodemus peninsulae</i> (Thomas, 1907)	3160
21. Striped Field Mouse <i>Apodemus agrarius</i> (Pallas, 1771)	3432
22. Total small mammals ,	105779

Relative numbers of animals were calculated as the number of captured animals in terms of 100 cylinder-days. To determine the ecological-topological affiliation of the species, we estimated the coefficients of biotope fidelity. To assess species diversity, we used the Simpson polydominality index, and community similarity was estimated by species proportion with the help of the Czekanowski-Sørensen index.

3. Results and discussion

Communities of small mammals in the study area refers to the ecological and faunistic complex of mammals that inhabit the mountain-taiga dark coniferous forests prevalent in the Kuznetsk Alatau and its spurs. These communities differs from its counterpart the adjacent forest-steppe and steppe territories, first of all, by the richness of the small mammals species composition, by the combination of species (forest, forest-meadow, meadow, eurytopic, near-water, etc.) varying in their eco-topological requirements, by the peculiarity of the hierarchical structure of the community in general and in biotopic groups in particular [8].

On the basis of estimated coefficients of biotope fidelity the following species are referred to as forest species: taiga shrew (*Sorex isodon*), Laxmann's shrew (*Sorex caecutiens*), flat-skulled shrew (*Sorex roboratus*) and least shrew (*Sorex minutissimus*); Korean field mouse (*Apodemus peninsulae*), field vole (*Microtus agrestis*), northern red-backed vole (*Myodes rutilus*) and gray red-backed vole (*Myodes rufocanus*); the meadow species are: tundra shrew (*Sorex tundrensis*) and pygmy shrew (*Sorex minutus*), striped field mouse (*Apodemus agrarius*), harvest mouse (*Micromys minutus*), narrow-headed vole (*Microtus gregalis*) and common vole (*Microtus arvalis*). As eurytopic species we categorize common shrew (*Sorex araneus*), Siberian white-toothed shrew (*Crocidura sibirica*), northern birch mouse (*Sicista betulina*) and root vole (*Microtus oeconomus*). Eurasian water shrew (*Neomys fodiens*) and water vole (*Arvicola amphibius*) live in biotopes adjacent to water bodies, and can be considered as semi-aquatic. The bank vole (*Myodes glareolus*) lives on the periphery of its range in the study area; in

undisturbed biotopes it prefers deciduous and mixed forests and ecotone patches [6].

Prior to mass felling, the community of small mammals in the taiga forests was polydominant, with the taiga shrew being the dominant insectivorous mammal, and the common shrew the codominant one (Fig. 2). Among the secondary species, the Laxmann's shrew and pygmy shrew, as well as Eurasian water shrew predominated stably. Siberian white-toothed shrew, flat-skulled shrew, tundra shrew and least shrews were inconsiderable in number.

Among mouselike rodents, the dominant one was the root vole, typical to floodplain habitats, and the codominant ones were the representatives of the genus *Myodes*: the northern red-backed vole and the gray red-backed vole. A characteristic feature of the population of small mammals in the taiga forests is the predominance of the Korean Field Mouse over the Striped Field Mouse (Fig. 3).

Continuous felling of floodplain-valley forests in 1975-1978 led to the formation of a mosaic of open, forest-covered and untouched forest areas, which caused a change in the spatial-biopic structure of the population of small mammals.

Deforestation at the early stage of restorative succession created favorable conditions for flat-skulled and tundra shrews between 1979 and 1987, and for the former – until the year 2000, when its share in the catch reached the maximum values for the entire study period. Although both species gravitate towards open biotopes, their high concentration was observed in young and very dense "fencing" aspen forest stands, which appeared on the site of the destroyed taiga.

Among rodents on early felling, the root vole was dominant, being here almost the only representative of the genus *Microtus*. The share of the *Myodes* voles decreased by several times, except for the bank vole, whose numbers increased in the disturbed areas. The ratio of the striped field and Korean field mice at the early stage of felling were approximately equal, but as the reforestation process continues, the share of the latter begins to increase gradually. The ability of the common shrew and bank voles to populate anthropogenically disturbed areas, including areas of deforestation, has already been noted [9, 10, 11], so the increase in the proportion of these species in communities might be regarded as an indicator of environmental disturbance.

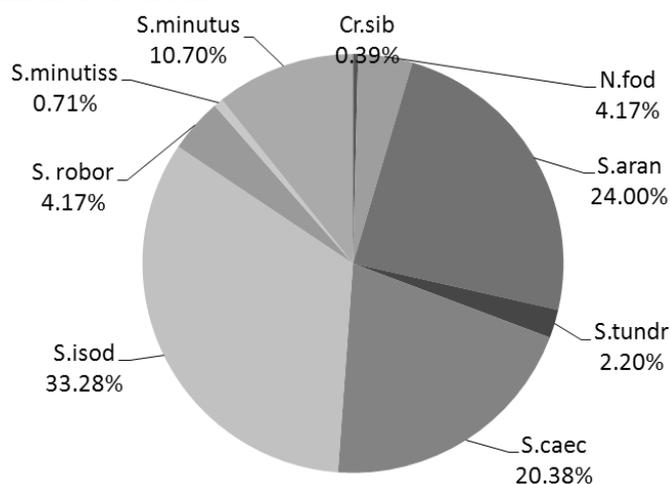


Figure 2. Insectivorous mammals community dominance structure in non-disturbed taiga forests (1979) (Polydominancy index = 4.417) Legend: Cr.sib - Siberian White-toothed Shrew; N.fod - Eurasian Water Shrew; S.aran - Common Shrew; S.tundr - Tundra Shrew; S.caec - Laxmann's Shrew; S.isod - Taiga Shrew; S.robob - Flat-skulled Shrew; S.minutiss - Least Shrew; S.minutus - Pygmy Shrew.

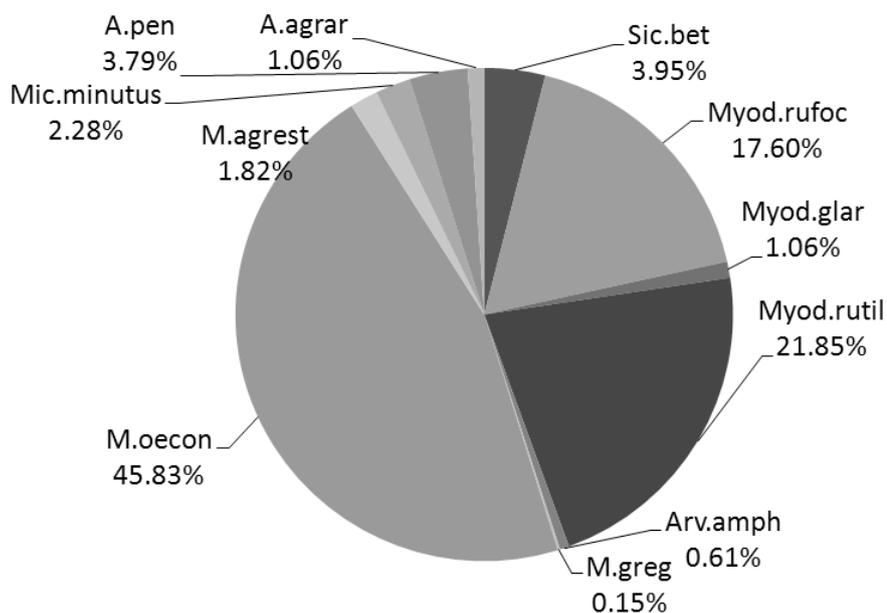


Figure 3. Rodents community dominance structure in non-disturbed taiga forests (1979) (Polydominancy index = 7.468) Legend: Sic.bet - Northern Birch Mouse; Myod.rufoc - Gray Red-backed Vole; Myod.glar - Bank Vole; Myod.rutil - Northern Red-backed Vole; Arv.amph - Water Vole; M.greg - Narrow-headed Vole; M.oecon - Root Vole; M.agrest - Field Vole; Mic.minutus - Harvest Mouse; A.pen - Korean Field Mouse; A.agrar - Striped Field Mouse.

Among rodents on early felling, the root vole was dominant, being here almost the only representative of the genus *Microtus*. The share of the *Myodes* voles decreased by several times, except for the bank vole. Thus, a peculiar community of small mammals was formed in the young secondary forests at the site of felling. At the same time, as overgrowth of the felled areas with young stock of deciduous conifers and changes in the hydrometric regime of individual sections of the terraces above floodplain took place, the species of small mammals were redistributed along the ecotone sites, wastelands and bordering forests unaffected by felling.

Further reforestation processes that took place at 25-30 years old felling sites between 1996 and 2003 were characterized by gradual self-thinning of the aspen tree stand, increase in the proportion of fir and birch trees, and change in the soil litter composition, to which the rodents and insectivores reacted differently. During this period, the rodent community gradually acquires the features of its original, mostly taiga state. However, the share of the bank vole, which acts here as an indicator of the environmental disturbance, reaches 20% in some years. Simultaneously, the community of insectivorous mammals on felling within the described period features low species diversity against the background of the obvious dominance of the common shrew. It should be noted that 25-35 years old felling in general was the least preferred habitat for most species. The number of small mammals there, in comparison with other biotopes, was the smallest.

Over the past decade, reforestation of the felling has not stopped, and the community of small mammals of 40-year-old stands might be considered as almost completely restored, although phytocenosis has not yet returned to its original state. Proof of this is the increase in species diversity and in the similarity index of the community in question with its original taiga state, as well as restoration of the forest species abundance (voles of the genus *Myodes*, the taiga shrew and the Laxmann's shrew, the Korean field mouse) (Fig. 4 - 6).

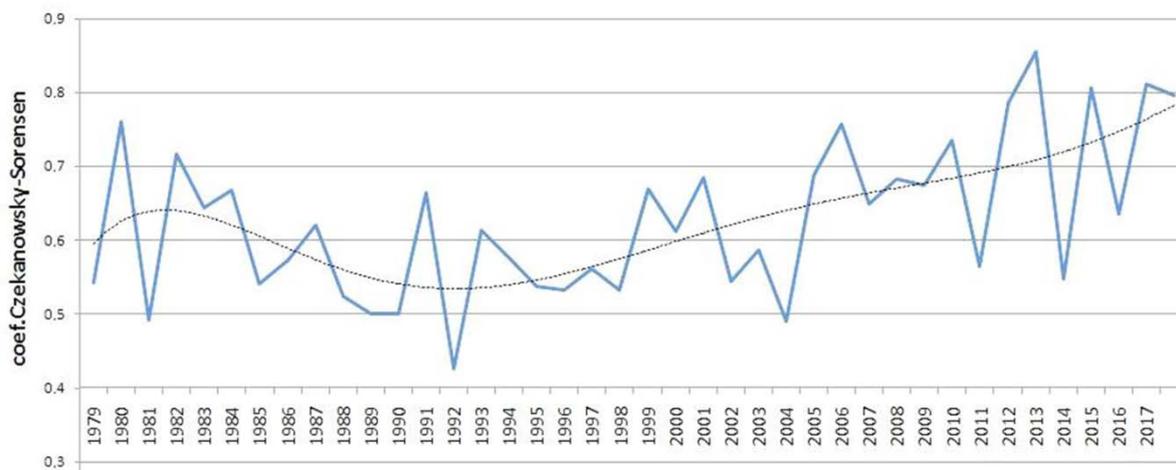


Figure 4. Dynamics of similarity of the small mammals population on felling to the initial population of the taiga (using the Czekanowski-Sørensen coefficient calculated for the share of species in the community)

The steady decrease in the abundance of bank voles on felling for the last 10 years is also indicative of the restoration process.

The responses of small-mammal communities, both to environmental disturbances and to the reduction of anthropogenic load, are long lasting and may occur several years or even decades late (Fig. 4). General long-term trends are superimposed on by natural cyclical fluctuations of population as well as by disturbances in the structure of communities, caused by weather and climatic anomalies, by rapid increases in population and changes in the spatial and ethological structure of individual species [12, 13]. Thus, recovering of small-mammals communities living in conditions of total felling are a complex process that runs in several stages, differing in the nature of response reactions. In order to evaluate them it is necessary to summarize the material that covers a series of population cycles.

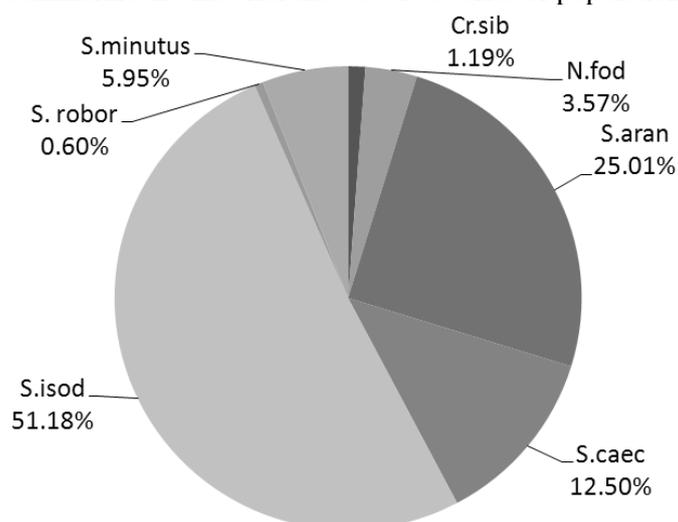


Figure 5. Insectivorous mammals community dominance structure after restoration of forests on felling in current time (2017) (Polydominativity index =2,898); Legend: Cr.sib - Siberian White-toothed Shrew; N.fod - Eurasian Water Shrew; S.aran - Common Shrew; S.caec - Laxmann's Shrew; S.isod - Taiga Shrew; S. robor - Flat-skulled Shrew; S.minutus - Pygmy Shrew.

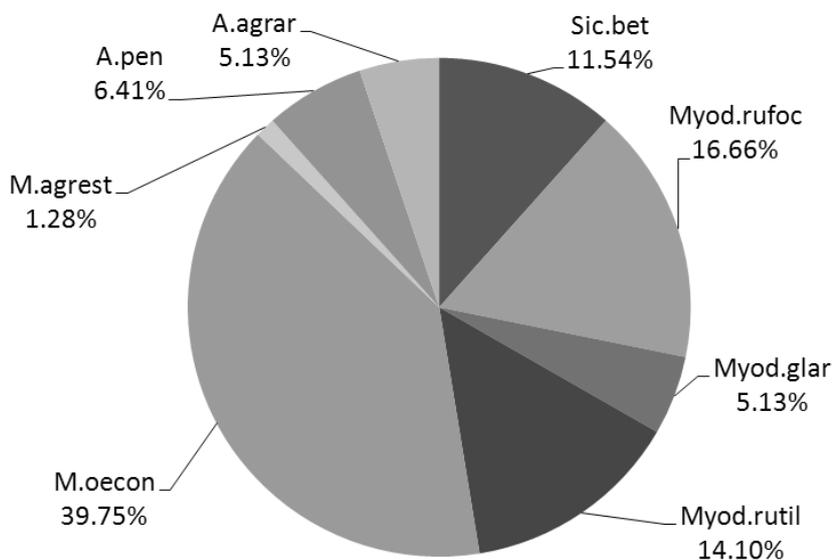


Figure 6. Rodents community dominance structure after restoration of forests on felling in current time (2017). (Polydominancy index = 4,3765) Legend: Sic.bet - Northern Birch Mouse; Myod.rufoc - Gray Red-backed Vole; Myod.glar - Bank Vole; Myod.rutil - Northern Red-backed Vole; M.oecon - Root Vole; M.agrest - Field Vole; A.pen - Korean Field Mouse; A.agrar - Striped Field Mouse.

4. Conclusions

Studies conducted between 1978 and 2018 show that significant changes take place in the structure of small mammal communities in anthropogenically disturbed and regenerating territories. Such changes are primarily caused by restoration of forests on felling and overgrowing of meadows, as well as transformation of habitats.

In the southern taiga forests in the southeast of Western Siberia, the decreased anthropogenic load causes the plant and animal communities on felling revert to their original taiga state.

Given such a complex system of factors affecting insectivorous and mouse-like rodents, it can be argued that the scientific data obtained as a result of short-term studies cannot fully reflect the diversity of the dynamic processes taking place in the communities of small mammals. Further long-term monitoring observations are needed to better understand the processes of anthropogenic and restorative succession.

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