

# Current diversity of small mammals of the «Sarykum Barkhans» of Dagestan Reserve

Marinat Gudova\*, Fatimat Tembotova, Marita Emkuzheva, Albina Amshokova, and Ekaterina Kuchinova

Tembotov Institute of Ecology of Mountain Territories of Russian Academy of Science, 360051 Nalchik, Russia

**Abstract.** We studied the species diversity and abundance of small terrestrial mammals in the spring and autumn period of 2016-2019 in four groups of habitats of the protected area "Sarykum barkhans" of the Dagestan Nature Reserve: barkhan, floodplain forest, ailant plantations, the territory of the cordon. During the study period, 10 species of terrestrial small mammals were recorded – *E. roumanicus*, *C. suaveolens*, *C. leucodon*, *M. musculus*, *M. macedonicus*, *A. fulvipectus*, *C. migratorius*, *M. socialis*, *D. sagitta*, *D. nitedula*. *Apodemus* and *Mus* mice are the dominant species in the studied area. Mice of *Apodemus* and *M. macedonicus* were registered for the first time in the territory of barchans. Indicator species of xerophilic ecosystems – *C. migratorius*, *M. socialis*, *D. sagitta*, were recorded locally, exclusively in the only biotope of barkhan. *H. auritus*, *S. pygmaeus*, *A. major*, *M. arvalis*, *A. terrestris*, *R. norvegicus*, *M. tamariscinus*, which were previously noted by several authors, were not registered (both traces of vital activity and animals themselves) in the studied area during the whole period of research (2016-2019). Seasonal and annual fluctuations of species diversity and abundance taking into account groups of biotopes and small mammal habitats were revealed.

## 1 Introduction

Protected areas are places where natural biota are preserved; they are least subject to anthropogenic transformation. In the North Caucasus there are not many such areas where natural ecosystems and their components are preserved. For example, there are seven federal nature reserves in the region. In this regard, under conditions of increasing anthropogenic pressure, as well as global climate change, it is extremely important to conduct regular monitoring of both the state of biodiversity in general and individual components of natural ecosystems in specially protected natural areas.

Sarykum barkhans is a unique natural complex, the only moving sands in Russia, for the conservation of which the Dagestan State Nature Reserve was established, along with the Kizlyar Bay area. At present Dagestansky reserve consists of 5 clusters, as it was joined by Agrakhsy and Tlyarotinsky wildlife sanctuaries and Samursky national park. Sarykum is located 18 km northwest of Makhachkala, at the base of the northeastern slopes of the Narath-Tyube Ridge, on the left bank of the Shura-Ozen River. Barkhan Sarykum is the only desert in Russia, which is the second highest point in the world – 245 m above sea level.

Micromammalia of the "Sarykum barkhans" are insufficiently studied, earlier studies were mainly limited to the inventory of the species composition [1-3]. Thus, according to literature data, 15 small mammals (Eulipotyphla, Rodentia) inhabit here. However, there are no data on monitoring of species diversity and population dynamics. There are also no data on ecological characteristics of communities and biotopic confinement of species [4].

The aim of the study is to lay the foundations for long-term monitoring of the state of natural ecosystems and their components of the Dagestan Reserve. To implement this goal, to study species diversity, population dynamics, biotopic confinement of species, to give ecological characteristics of communities of small mammals of the protected area "Sarykum barkhans" of Dagestan State Nature Reserve in inter-annual and seasonal aspects.

## 2 Materials and methods

Study area. The "Sarykum barkhans" protected area of the "Dagestan" Reserve (Fig. 1) and adjacent territories are arid areas on the border of lowlands and advanced ridges of the Eastern Caucasus, where, due to physical and geographical features, a variety of biotopes have been formed: a large sandy scattered barkhan, the appearance of which is gradually changing, tree and shrub thickets at its foot, the river valley with meadow vegetation and thinned strips of floodplain tree and shrub vegetation, rocky dry mountain slopes with xerophytic shrubs, Clay hilly submountain plain with sagebrush and cereals vegetation, fescue-grass steppes on placors and gentle mountain slopes, shrubby sandy steppe at the foot of barkhan, remains of pine forests and juniper woodlands on slopes of Narat-Tyube ridge, fragments of broad-leaved forests, stony slopes and cliff outcrops.

According to A.K. Tembotov's typification [5], the study area covers semi-deserts of the southeastern part of the Caspian lowlands of the Dagestan belt variant. The Dagestan variant belongs to the continental subtype of the East-North Caucasus (semi-desert) type of zonality, which differs sharply from the West-North

\* Corresponding author: [mpapieva@inbox.ru](mailto:mpapieva@inbox.ru)

Caucasus in the degree of xerophytization of landscapes. High-mountain axial ridges with eternal snows enhance the continentality of the climate here.

Study of species diversity of small mammals was conducted in 9 different biotopes: 1. southeastern part (h=90 m, 43.00364°N, 047.23314°E) – sparse woody vegetation, plantings of *Robinia pseudoacacia* with admixture of *Populus hybrida*, *Tamarix ramosissima*; 2. Southwestern part (h=118 m a.s.l. 43°00.148'N, 047°13.533'E) – poplar-forest community of *Elaeagnus caspica*, *P. hybrida*, *Eremosparton aphyllum*, *Euphorbia seguieriana*, *Artemisia annua*; 3. Northwestern part (h=162 m a.s.l, 43°00'38.31"N, 47°12'46.81"E) – herb-grass community of *Leymus ramosus*, *Leymus racemosus* with *E. aphyllum*, psammophytic herbaceous vegetation (*Lactuca serriola*, *Asparagus officinalis*); 4. northeast part (h=82 m asl, 43.01141° 047.24692°) – tamarix-grass with mixed grass with *Calligonum aphyllum*, *Bromus tectorum*, *L. racemosus*, *Senecio*

*jacobaea*, *Euphorbia seguieriana*, rare bushes of *T. ramosissima*; 5. left bank of Shura-Ozen River (h = 84 m asl, 43°00.134N, 047°12.777'E) – floodplain forest, oak-tamarix-grass community; 6. Left bank of Shura-Ozen River (h=78 m a.s.l, 42°99.9 14' N, 047°22.8 94' E) – floodplain forest, oleaster-tamarix-grass; 7. right bank of the Shura-Ozen River (h = 72 m, 42°59.920' N, 047°14.294'E) – floodplain forest, oleaster-tamarix-grass; 8, 9. ailanthus plantations (h = 61 m, 43°00.718' N, 047° 24. 914' E) – artificial plantings of *Ailanthus altissima* with an admixture of *Crataegus* sp. (well-defined undergrowth).

For ecological characterization and comparative analysis of communities of small mammals, similar biotopes of the "Sarykum barkhans" site were combined into 4 groups of biotopes: barkhan (biotopes 1-4), floodplain forest (5-7), cordon area (8), ailanthus plantations (9).



**Fig. 1.** Map of the study area in the eastern part of the North Caucasus: 1 – Sarykum barchans (geographical coordinates 43°00.472' N, 47°13.808' E). The red line indicate the Republic of Dagestan border. Open access Caucasus map used in the paper ("© OpenStreetMap contributors". <https://www.openstreetmap.org/copyright>)

The climate of Sarykum is moderately continental [6]. The average annual temperature at an altitude of 100 m a.s.l. – 12.3°C, the average monthly January temperature is 1.0°C, July temperature is 25.6°C, the highest average temperature both for Dagestan and for Russia as a whole. At the foot of the barkhan an absolute maximum temperature of 42.5°C was recorded for Dagestan. In summer on the slopes of the southern exposition, the temperature of the surface of the barkhan reaches 55-60°C. In April the temperature of the sand

during the day exceeds 30°C. The average monthly precipitation is 350-400 mm [7].

**Material.** The total number of small mammals studied was 164 specimens.

To specify species diversity of mice of genera *Apodemus* and *Mus*, we carried out genotyping of 12 specimens of *Apodemus* Kaup, 1829 and 10 specimens of *Mus* Linnaeus, 1758.

**Methods.** Species diversity of small mammals was studied by the standard method of trap-lines; there were 25 cranes in each line placed every 5 m. Trap-lines were

set up in the same biotope for three days. Bread crust moistened with unrefined sunflower oil was used as bait. In total, 3922 trap-nights were worked. Numbers were graded according to A.K. Kuz'yakin [8] and A.K. Tembotov [9].

As material for molecular genetic studies we used samples of muscle tissue of forest and house mice (*Apodemus*, *Mus*) fixed in 96% ethyl alcohol. For molecular genetic analysis we used a 549-bp-long segment of the cytochrome b mtDNA gene, which corresponds to positions 70-619 of the full gene sequence. DNA was manually isolated using a Diatom™ DNA Prep100 kit (Isogen, Moscow). Amplification of DNA fragments was performed using MasterMix X5 kit (Dialat, Moscow). The primers for forest mice L-14724: CGAAGCTTGATGAAAACCATCGTTG and H-15573: AATAGGAAGTATCATTCGGGTTGATG used in this work and PCR parameters were taken from the article by A.E. Balakirev et al [10]. For house mice, primers L14115: GACATGAAAATCATCGTTG and H15300: GTTTACAAGACCAGAGTAAT, and PCR parameters from the article by Yasuda et al. [11] were used.

DNA nucleotide sequencing was performed on an ABI 3130 sequencer (Applied Biosystems, USA) using the BigDye Terminator Kit 3.1 (Applied Biosystems, USA) at Syntol (Moscow).

Due to the fact that genotyping was not performed for all studied mice of two genera *Apodemus* and *Mus*, represented in the North Caucasus by twin species that are not morphologically differentiated, general information for each genus is given in the text below.

Margalef, Shannon, Pielu, and Simpson indices are used as measures of diversity, community evenness, and dominance. The Margalef and Shannon indices reflect relative species richness. The Shannon index is most admissible because it is based on relative species abundance. The Pielu index characterizes evenness, i.e., the uniformity of species distribution in catches. The Simpson index shows the degree of domination of the most abundant species. The degree of community similarity was assessed according to Czekanowsky-Sjerenzen [12].

The data were statistically processed using the PAST v.3.12 program [13]. The dominance structure [14] was described according to the % of species in the catch.

Species richness, species diversity, and abundance were studied during the following time periods: 1. total species diversity – spring 2016-2019 and fall 2016; 2. inter-annual variability in species diversity - spring 2016-2019; 3. population dynamics – spring 2016-2019, 4. seasonal variability – fall 2016 and spring 2017.

### 3 Results

Species diversity. Small mammals of the Sarykum barchans and adjacent territories are represented by 10

taxa (Table 1), 3 representatives of the order Eulipotyphla Waddell et al, 1999, and 7 taxa of the order Rodentia Bowdich, 1821: *Erinaceus roumanicus* Waggett-Hamilton, 1900, *Crocidura suaveolens* Pallas, 1811, *Crocidura leucodon* Hermann, 1780, *Mus musculus* Linnaeus, 1758, *Mus macedonicus* Petrov and Ruzic, 1983, *Apodemus fulvipectus* Ognev, 1924, *Cricetulus migratorius* Pallas, 1773, *Microtus socialis* Pallas, 1773, *Dipus sagitta* Pallas, 1773, *Dryomys nitedula* Pallas, 1778 (tab. 1).

All genotyped 12 specimens of mice of the genus *Apodemus* were assigned to *A. fulvipectus*. Of the 10 genetically dated members of the genus *Mus* - 3 specimens of mice were identified as *M. musculus* and 7 specimens as *M. macedonicus*.

The complex of small mammals includes 3 ecological groups. The first group consists of widespread taxa – these are mice of the genera *Apodemus* and *Mus*. The second group consists of desert and semi-desert-steppe species: *D. sagitta*, *M. socialis*, *C. migratorius*, and *C. suaveolens*. The third group is formed by steppe forest-steppe species: *C. leucodon*. The fourth group consists of forest, forest-steppe species: *D. nitedula* and *E. roumanicus*.

*Inter-annual variability in species diversity* (Table 2). At the "barchan" site, *C. leucodon*, *Apodemus* and *Mus* mice, *M. socialis*, *C. migratorius*, *D. sagitta*. Only mice of the genus *Apodemus* were found stably. *C. migratorius* and *D. sagitta* were not found only in 2016, *C. leucodon* and *M. socialis* were registered only one year each. Mice of the genus *Mus* were consistently present in the floodplain forest; mice of the genus *Apodemus* were not recorded in 2018. In 2019, a small white-toothed mouse, *C. suaveolens*, was detected. In the ailanthus plantations, the situation with the species richness is approximately the same as in the floodplain forest. The diversity of the cordon area is poor, here in the autumn of 2016 was found *E.* mice of the genera *Apodemus* and *Mus*, in 2017 mice of the genera *Apodemus* and *D. nitedula* (Table 1). Small mammals were not recorded in the other two years.

Throughout the study period, barchans were characterized by high species richness and species diversity with low dominance (Table 2). Ailanthus plantings in 2016 and 2019 were characterized by species richness that was slightly higher than the average for all habitat groups, but lower than on barchans. This site was characterized by significant fluctuations in diversity indices throughout the study period. The floodplain forest was characterized by average species richness and diversity and higher leveling values due to stable dominance of *Mus* mice. This area is also characterized by stability throughout the study period, except for 2018, when only *Mus* mice were recorded. The poorest was the cordon area, where only 2017 showed average species richness and diversity with low equilibrium. In other years, small mammals were not recorded in this area, as noted above.

**Table 1.** Species structure, biotopic distribution and population dynamics of small mammals of the "Sarykum barkhans" protected area (Eastern Caucasus) in the annual aspect (spring, autumn 2016-2019)

Taxa	Station	Barkhan				Floodplain forest				Ayllanthus plantations				Cordon area			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
<i>E. roumanicus</i>		–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
<i>C. leucodon</i>		+	–	–	–	++	–	–	–	++	–	–	–	–	–	–	–
<i>C. suaveolens</i>		–	–	–	–	+	–	–	–	–	–	–	+	–	–	–	–
<i>Apodemus</i>		++	++	++	++	++	++	–	++	++	++	–	++	++	+	–	–
<i>Mus</i>		–	–	++	++	++	+++	++	++	++	–	+	++	+	–	–	–
<i>D. nitedula</i>		–	–	–	–	–	–	–	–	+	++	–	–	–	+	–	–
<i>M. socialis</i>		–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
<i>C. migratorius</i>		–	++	++	+	–	–	–	–	–	–	–	–	–	–	–	–
<i>D. sagitta</i>		–	++	++	+	–	–	–	–	–	–	–	–	–	–	–	–
Total number of species		2	5	4	4	4	2	1	2	4	2	1	3	3	2	0	0

Note: + – species is rare, numbers less than 1%, ++ – species is common, numbers 1.1-9.9%, +++ – species is numerous, numbers over 10%; 1 – 2016, 2 – 2017, 3 – 2018, 4 – 2019.

**Table 2.** Diversity indices of micromammalia of the Sarykum barkhans protected area in the annual aspect (spring 2016-2019)

Biotope group		Barkhan				Floodplain forest			
year		2016	2017	2018	2019	2016	2017	2018	2019
index		–	5	4	4	2	2	1	2
Taxa		–	5	4	4	2	2	1	2
Shannon		–	1,157	1,142	0,983	0,637	0,487	–	0,693
Margalef		–	1,17	1,274	1,207	0,455	0,329	–	0,481
Simpson		–	0,373	0,333	0,486	0,556	0,692	1	0,5
Pielou		–	0,835	0,896	0,709	0,918	0,703	–	1
Biotope group		Ayllanthus plantations				Cordon area			
year		2016	2017	2018	2019	2016*	2017	2018*	2019*
index		3	2	1	3	0	2	0	0
Taxa		3	2	1	3	0	2	0	0
Shannon		0,898	0,611	0	0,974	–	0,642	–	–
Margalef		0,869	0,432	0	0,962	–	0,913	–	–
Simpson		0,46	0,531	1	0,406	–	0,331	–	–
Pielou		0,817	0,881	–	0,887	–	0,924	–	–

Note: \*No counts were conducted on barchans in 2016; no small mammals were recorded on the ranger station in spring 2016, 2018, 2019

Seasonal variability of species diversity. Autumn. Six taxa were recorded in the studied area in autumn

2016: *C. leucodon* and *C. suaveolens*, *E. roumanicus*, *D. nitedula*, mice of *Mus* and *Apodemus* genera.

On the barchan in autumn, relatively low species richness and species diversity are observed with minimum leveling index and maximum Simpson dominance (Table 3). Only 2 taxa are registered here: *C. leucodon* and mice of *Apodemus* genus. 3 species each were detected in the floodplain forest and in the cordon. In the floodplain forest *C. leucodon*, *C. suaveolens* and mice of the genus *Mus*. This community is characterized by a high index of diversity and the maximum index of uniformity. On the territory of the cordon – mice of *Mus* and *Apodemus* genera, and also *E. roumanicus* were

registered. This complex of small mammals is characterized by low uniformity and high dominance index.

The maximum indicators of species richness and species diversity were noted in ailanthus plantations, here 4 taxa were registered: mice of genera *Mus* and *Apodemus*, *D. nitedula* and *C. leucodon*. The complex of small ailanthus plantations is characterized by minimal index of dominance and high index of equalization.

**Table 3.** Seasonal dynamics of ecological structure of small mammals' theriocomplex (autumn 2016, spring 2017) of "Sarykum barchans" reserve site (East Caucasus)

Biotope group	Barkhan			Floodplain forest		
	autumn	spring	p*	autumn	spring	P
Season Index						
Taxa	2	5		3	2	
Shannon	0,451	1,157	0,0001	1,041	0,487	0,002
Margalef	0,558	1,17	0,0001	0,647	0,329	0,005
Dominance	0,722	0,373	0,0001	0,368	0,692	0,013
Pielou	0,65	0,835	0,0001	0,948	0,703	0,13

Biotope group	Ayllanthus plantations			Cordon area		
	autumn	spring	p	autumn	spring	P
Season Index						
Taxa	4	2		3	2	
Shannon	1,237	0,611	0,0001	0,956	0,637	0,701
Margalef	1,207	0,434	0,0001	1,028	0,910	1
Dominance	0,319	0,580	0,0001	0,429	0,556	0,701
Pielou	0,892	0,881	0,0001	0,870	0,918	0,507

Abbreviation: p\* – diversity permutation test

*Spring.* The species composition of small mammals is represented by 6 taxons: mice of *Mus* and *Apodemus* genera, *M. socialis*, *C. migratorius*, *D. sagitta*, *D. nitedula* throughout the protected area "Sarykum barchans" and the adjacent territory. Shannon and Margalef indices, characterizing species diversity and species richness, have high values on the barchan, the most xerophytic of all studied, in spring. Five taxa are registered here: *A. fulvipectus*, *M. macedonicus*, *M. socialis*, *C. migratorius*, *D. sagitta*. The Simpson dominance index has low values, but at the same time the average equalization (Pielou index) was revealed here (Table 3). In all other sites 2 taxa, in particular mice of *Mus* and *Apodemus* genera, were registered. The community of rodents of the cordon area is characterized by the maximum index of equalization and the minimum index of Simpson dominance. The community of mice of the floodplain forest is characterized by the lowest Shannon and Margalef indices, along with the highest dominance index and the lowest Pielou index, indicating low leveling. Ailanthus planting community occupies an intermediate position relative to all biotope groups.

It should be said that seasonal variability of the studied indices is manifested differently at different sites (Table 3). Maximum indices of species diversity and species richness were recorded in autumn in ailanthus plantations and in spring on barchan. Minimal values, on the contrary, in ailanthus plantations in spring and in barkhan – in autumn.

No less interesting is the fact that in the spring period *Mus* mice were recorded in all natural biotopes of the Sarykum barchans and adjacent territories, except for anthropogenic ones – the cordon area with household outbuildings. In autumn period of researches, mice of *Mus* genus were registered both in natural and anthropogenic environment. *M. musculus* and *M. macedonicus* cohabit in two habitats – floodplain forest of the Shura-Ozen River and in ailanthus plantations.

Although seasonal fluctuations of indices were revealed in all groups of biotopes, nevertheless, differences are significant in all four indices only on barchan and ailanth plantations (Table 3), in floodplain forest differences are unreliable only in the index of flatness. As reflected above, the differences are insignificant in all indices in the territory of cordon.

Comparative analysis of information indices of diversity of communities of therio population as a whole for the protected area "Sarykum barchans" and adjacent territories in the seasonal aspect revealed greater species diversity of small mammals in spring compared to autumn, at the same time the minimum values of the dominance index and the maximum values of the levelness index were registered (Table 4).

**Table 4.** Indices of species diversity of small mammals for the entire territory of the Sarykum barchans (fall 2016, spring 2017)

Index \ Season	autumn	spring	p*
Shannon	1,361	1,513	0.0001
Margalef	1,329	1,265	0.0001
Dominance	0,314	0,258	0.0001
Pielou	0,760	0,845	0.0001

Abbreviation: p\* – diversity permutation test

However, due to the fact that only two years were studied and the data are aggregated for all sites, these results can be considered only as preliminary, requiring verification in the future. And also, it will be necessary to investigate seasonality for separate sites.

When assessing the similarity of complexes of small mammals of the described groups of sites the Czekanowsky-Sjerenzen index was used. The highest similarity index (0.633) was noted between the communities of the cordon and ailanthus plantations in the spring period: both groups of biotopes represented mice of the genus *Apodemus* and *D. nitedula*. However, in the autumn season there is minimal similarity between these communities (0.167).

In pairwise comparison of the small mammal community of the barchan with other groupings in the spring season, sharp differences are observed. Characteristic of barkhans, the mossy ground squirrel, the gray hamster and the common vole are recorded in spring only on the barkhans, which increases the differences with other communities, while in the autumn season these differences are smoothed out.

**Numbers and their dynamics.** In 2016, the total catchability of small mammals was 8.1 individuals per 100 trap-days. In 2017-2018, a decline was found (down to 2.9 individuals per 100 trap-days). In 2019, the total catchability rose (6.0 individuals per 100 trap-days), but not to the previous level (Fig. 2).

Mice of the genus *Apodemus* were not recorded in individual years at three sites: floodplain forest in 2016, ailanthus plantings in 2018, and the cordon area in 2018-2019. *Mus* genus mice were also not recorded in individual years, but more frequently and in all sites: barchan in 2016-2017, floodplain forest in 2018, ailanthus plantings in 2018, and cordon area in 2017-2019 (Figure 2).

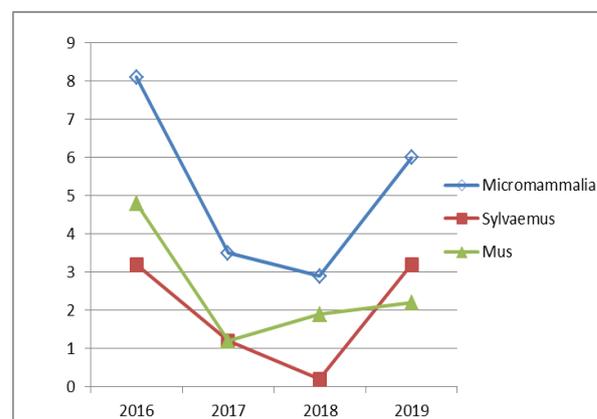
Numbers of mice of the genus *Apodemus* vary depending on season, year, and site from 0.2 to 8.3 individuals per 100 trap-days. Forest mice are observed synchronous with the general dynamics of small mammal catches (from 3.2 to 0.2 individuals per 100

trap-days, then 3.2 individuals per 100 trap-days). The maximum abundance (8.3 individuals per 100 trap-days) was registered in biotopes of the south-eastern part of the barchan, the minimum values – for the north-western part of the barchan with psammophilous vegetation (site 3).

For *Mus* representatives the dynamics of abundance in the territory of Sarykum barchans is somewhat different: the number decreases in the second year of the study, then there is a slight increase (from 4.8 individuals per 100 trap-days to 1.2 individuals per 100 trap-days, then – 1.9 and 2.2 individuals per 100 trap-days). But, at the same time, high abundance is noted in separate biotopes that meet the requirements of the species. In the floodplain forest, the number of house mice in the second year (2017) of the study reached 14.2 individuals per 100 trap-days. In the studied territory of the barchan, *M. macedonicus* dominates among genetically dated material of mice of the genus *Mus*, accounting for 70%.

Summarizing the data on the number of mice of the two genera, it should be noted that, on the whole, eurytopic mice of the genus *Mus* were dominant throughout the study period, and eurytopic mice of the genus *Apodemus* were subdominant (Fig. 1).

Typical representatives of deserts and semi-deserts, in fact, indicator species, *D. sagitta* and *C. migratorius* showed attachment exclusively to barkhan in all years of studies (Table 1). These species have a small proportion (0.3; 0.4, respectively) in the terion population of the protected area and adjacent territories, but in their characteristic habitat group, on the barkhan, where they are common in terms of numbers. *D. sagitta* was relatively stable in all years of surveys (2.9; 3.1; 2.8 individuals per 100 trap-days); *C. migratorius* was characterized by some fluctuations in numbers, so, in the second year – an increase in numbers from 2.2 individuals per 100 trap-days to 7.4 individuals per 100 trap-days, then decrease to 2.8 individuals per 100 trap-days.



**Fig. 2.** Dynamics of catchability of micromammalia and population dynamics of *Mus* and *Apodemus* mice in the "Sarykum barchans" area of Dagestan zapovednik (spring 2016-2019)

*M. socialis* was recorded once during the entire study period in 2017, in the southeastern part of the barchan, as a rare species. *D. nitedula*, recorded both in spring and autumn 2016 in ailanthus plantations and in spring 2017 in the territory of the cordon, where fruit trees are growing, was not recorded in other years. *C. suaveolens* was recorded on the territory in fall 2016 in floodplain forest and spring 2019 in ailanthus plantings. *C. leucodon* was recorded only in the fall period, and it was noted in almost all habitat groups, except in the cordon area, the species was more often common.

*E. roumanicus* and *C. suaveolens* are extremely rare, while *C. leucodon* was common in some years in the floodplain forest and ailanthus plantations (Table 1).

## 4 Discussion

Species richness. According to the literature (Sokolov, Syroechkovsky, 1989; Yarovenko, Murtazaliev, 2009; Dzhamirzoev, Yarovenko, Bukreev, 2011) the complex of small mammals (Eulipotyphla, Rodentia) in the "Sarykum barchans" is represented by 15 species: *Hemiechinus auritus* Gmelin, 1770, *E. concolor* Martin, 1838, *C. leucodon*, *C. suaveolens*, *Spermophilus pygmaeus* Pallas, 1778, *Allactaga major* Kerr, 1792, *D. sagitta*, *Microtus arvalis* Pallas, 1778, *M. socialis*, *M. musculus*, *Arvicola terrestris* Linnaeus, 1758, *Rattus norvegicus* Berkenhout, 1769, *Meriones tamariscinus* Pallas, 1773, *C. migratorius*, *D. nitedula*.

The fact that in the Sarykum barchans and adjacent territories we recorded mice of the genus *Apodemus* for the first time, in particular *A. fulvipectus*, which were dominant in all years, except 2016, and in all study areas, deserves special attention. In the literature known to us [1-3, 10], as well as in the annals of nature of the Dagestan Reserve the inhabitation of mice of the genus *Apodemus* has not been recorded here. As it is reflected by us (on the basis of cytochrome b studies) in the territory of barchan only *A. fulvipectus* was established, however, further researches can show presence of other species of the genus *Apodemus*. This assumption is possible because according to a number of authors [15-18], 3 species of *A. uralensis*, *A. fulvipectus* and *A. ponticus* inhabit other areas of Dagestan.

We also recorded *M. macedonicus* for the first time for this territory based on cytochrome b studies [19], whose distribution in the Caucasus, according to literature [20-23], covers only Transcaucasia.

During the whole period of research (2016-2019), we did not record (both traces of life and animals themselves) *H. auritus*, *S. pygmaeus*, *A. major*, *M. arvalis*, *A. terrestris*, *R. norvegicus*, *M. tamariscinus*, which were previously noted by the above-mentioned authors in the protected area "Sarykum barchans" and the protected zone. *S. pygmaeus* was found in the vicinity of Humtok, 2 km northeast of the protected area.

Preliminary data indicate significant seasonal variations in species richness and species diversity at three sites: on the barchan, in ailanthus plantations and floodplain forest, but only in the last two sites they decrease in spring, in these sites in both seasons low or

medium levels of dominance and high levels of uniformity are observed. On the barchan, on the contrary, the species diversity is higher in spring than in autumn. It is more likely that the three sites have favorable conditions for shelter and with a good forage base. In the territory of the cordon, the fluctuations are not so significant, nevertheless, the diversity indices are higher in autumn than in spring.

## 5 Conclusion

The modern diversity of small mammals (Eulipotyphla, Rodentia) in semi-desert landscapes of the southwestern Caspian lowland in the protected area "Sarykum barchans" of the State Nature Reserve "Dagestan" was studied.

During the study period (2016-2019), 10 taxa of small mammals were recorded – *E. roumanicus*, *C. suaveolens*, *C. leucodon*, *M. musculus*, *M. macedonicus*, *A. fulvipectus*, *C. migratorius*, *M. socialis*, *D. sagitta*, *D. nitedula*. Terion populations of the Sary-Kum barchans site are formed of three faunal complexes. The first group consists of widespread taxa – mice of the genera *Apodemus* and *Mus*. The second group consists of desert and semi-desert-steppe species: *D. sagitta*, *M. socialis*, *C. migratorius*, and *C. suaveolens*. The third group is formed by steppe-forest-steppe species: *C. leucodon*. The fourth group consists of forest-forest-steppe species: *D. nitedula* and *E. roumanicus*.

Eurytopic mice of the genus *Apodemus* dominate – representatives of the forest faunistic complex, occupying all surveyed biotopes of the Sarykum barchan and its surroundings and even sands. Mice of the genus *Apodemus* have not been registered earlier in the territory of the Sarykum barchan. Mice of the genus *Mus* in the floodplain forest are dominant or co-dominant forest mice. They inhabit biotopes of both natural and anthropogenic character.

*H. auritus*, *S. pygmaeus*, *A. major*, *M. arvalis*, *A. terrestris*, *R. norvegicus*, *M. tamariscinus* were not recorded in the studied area during the entire study period (both traces of vital activity and animals themselves, according to literature data, inhabiting barchans.

Annual monitoring of small mammals of the study area, conducted in the spring season for the four-year period from 2016 to 2019, showed maximum catchability values (8.1 individuals per 100 trap-days) in 2016, then in the next two years it was found to decrease, with a rise in 2019 to 6.0 individuals per 100 trap-days.

In 2016 and 2018, mice of the genus *Mus* were the dominant species in the Sarykum barchans; in 2019, mice of the genus *Apodemus* were the dominant species.

In spring, the species composition of the terion population of the Sarykum barchans and adjacent territories is represented by the following taxa: *C. suaveolens*, mice of *Mus* and *Apodemus* genera, *M. socialis*, *C. migratorius*, *D. sagitta*, *D. nitedula*. In autumn, the complex of small mammals included: *C. suaveolens*, *C. leucodon*, *E. roumanicus*, mice of the genera *Mus* and *Apodemus*, and *D. nitedula*.

Preliminary data on seasonal variability of species richness and species diversity in the study area suggest that maximum species richness and species diversity are characteristic of ailanthus plantings in autumn and spring on the barchan. The minimum values, on the contrary, in ailanthus plantings in spring and on barkhan in autumn. Seasonal fluctuations of species richness and species diversity are significant at three sites: on the barchan, in ailanthus plantations and floodplain forest, but only in the last two they decrease in spring, on the barchan, on the contrary, in spring it is higher than in autumn. In the cordon area, the fluctuations are not so significant, nevertheless, the species richness and species diversity are higher in autumn than in spring.

However, the conclusion about seasonal variability of species richness and species diversity is preliminary and requires confirmation by further studies.

Thus, during the studied period in the conditions of the Sarykum barchans and the adjacent territory, the widely distributed mice of the genera *Apodemus* and *Mus* are the background. The relative proportion of desert and desert-steppe species (*D. sagitta*, *C. migratorius*, *M. so-cialis*, and *C. suaveolens*), which are indicators of xerophilic ecosystems, is about 16% of the total catchability.

## Gratitudes

We express our sincere gratitude to the management of the State Nature Reserve "Dagestan", its director K.M. Kuniev and deputy director for scientific work G.S. Dzhmirzoev for the opportunity to work in the reserve. We thank the leading researcher of the Institute of Geography of the Russian Academy of Sciences, Dr. A.Yu. Puzachenko for valuable comments and recommendations for the article.

## References

1. V.E. Sokolov, E.E. Syroechkovsky, *Zapovedniks SSSR* (1989)
2. A.Y. Yarovenko, R.A. Murtazalieva, *The unique world of flora and fauna of Dagestan* (Epocha, 2009)
3. G.S. Dzhmirzoev, Y.A. Yarovenko, S.A. Boukreev, *Trudy of State Nature Reserve "Dagestan"*, 172-179 (2011)
4. F.A. Tembotova, M.S. Gudova, L.S. Dyshekova, E.A. Kuchinova, Z.Kh. Bottaeva, A.Kh. Chapaev, *Proceedings of Dagestan State Pedagogical University*. **11** (4), 62-69 (2017)
5. V.E. Sokolov, A.K. Tembotov, *Vertebrates of the Caucasus. Mammals. Insectivores* (1989)
6. *Physical Geography of Dagestan. School* (1996)
7. <http://dagzapoved.ru>
8. A.P. Kuzyakin, *Zoogeography of the USSR*, **109** (1962)
9. A.K. Tembotov, *Geography of mammals of North Caucasus* (Moscow 1972)
10. A.E. Balakirev, A.P. Gmyl, N.M. Okulova, T.A. Andreeva, O.V. Sokolenko, V.M. Malygin, L.A. Khlyap, M.L. Oparin, V.N. Orlov, *Genetics*, **43** (12), 1651-1666 (2007)
11. S.P. Yasuda, P. Vogel, K. Tsuchiya, S.-H. Han, L.-K. Lin, H. Suzuki, *Canadian Journal of Zoology*, **83**: 1411-1420 (2005)
12. E. Megarran, *Ecological diversity and its measurement* (Mir Publishing House. 1992)
13. Ø. Hammer, D.A.T. Harper, P.D. Ryan, *Paleontologia Electronica*. **1** (4), (2001)
14. V.V. Kucheruk, N.V. Tupikova, B.P. Dobrohotov, N.P. Lebedeva, B.P. Baranovsky, *Modern problems of zoogeography*, 115-151 (1980)
15. N.N. Vorontsov, G.G. Boeskorov, S.V. Mezherin, E.A. Lyapunova, A.S. Kandaurov, *Zhool. Zh.* **71**(3), 119-131 (1992)
16. L.A. Lavrenchenko, O.P. Likhnova, *Zhool. Zh.* **74**(5), 107-119 (1995)
17. G.G. Boeskorov, I.V. Kartavtseva, I.V. Zagorodnyuk, A.N. Belyanin, E.A. Lyapunova, *Russ. J. Genet.* **31**(2), 185-192 (1995)
18. M.I. Baskevich, *Biological Diversity of the Caucasus: Proc. II Regional Conf.* (Sukhum, 2002)
19. F.A. Tembotova, *Materials of the VII All-Russian Conference* (2019)
20. M. Macholán, V. Vohralik, *Acta Societatis Zoologicae Bohemoslovacaе*, 219-226 (1997)
21. M. Macholán, M. Vyskocilová, I.I. Bonhomme, A.N. Milishnikov, L.A. Lavrenchenko, V.S. Lebedev, *Russian Journal of Genetics*, **9**, 1011-1026 (2004)
22. H. Rajabi-Maham, A. Orth, R. Siah sarvie, P. Boursot, J. Darvish, Bonhomme, *Biological Journal of Linnaeus Society*, **107** (2), 295-306 (2012)
23. H. Suzuki, M. Nunome, G. Kinoshita, K.P. Aplin, P. Vogel, A.P. Kryukov, M.-L. Jin, S.-H. Han, I. Maryanto, K. K. Tsuchiya, H. Ikeda, T. Shiroishi, H. Yonekawa, K. Moriwaki, *Heredity*, **111**, 375-390 (2013)