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SYSTEMATIC STUDY OF ARID TERRITORIES

Spatial Structure of Steppe Marmot Populations under Protection Regime in the Southern CIS-Urals

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Abstract—This article presents data on the distribution of the steppe marmot *Marmota bobak* Müll, 1776 in the Burtinskaya Steppe Site of the Orenburg State Nature Reserve (Orenburg Region, Belyaevsky District), from its inception to the present. The research was carried out by the author in 1998–2001 and 2021–2022; information on the number of steppe marmots from the archive of the reserve was also used. Mapping of all residential colonies of the steppe marmot and families in them was carried out, and the area of family plots was calculated. Statistical processing of the results of observations was carried out using the STATISTICA 10.0.1011 computer program. The spatial structure of the population, which had developed even before the establishment of the reserve, has been preserved with minor changes for more than 30 years. In the first years (1989–1990), eight relatively small settlements were noted on the territory of the site. Since 1996, ten colonies have been identified, and in 1999, 75 residential family plots were noted on them. By 2003, the territories of the colonies were completely developed, the marmots occupied old abandoned burrows within the colonies, and the number of families on the site increased to 106. Over the next 9 years, the number of families remained stable, after which their number began to decline: by 2017, only 55 families remained. Currently, there is a gradual increase in the number of families in the Burtinskaya Steppe Site; according to the results of mapping in 2022, 74 families were noted.

Keywords: steppe marmot, Burtinskaya Steppe Site, Orenburg State Nature Reserve, spatial structure, colony, family, family plot

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INTRODUCTION

The range of the steppe marmot *Marmota bobak* Müll, 1776 covers the belt of plain and mountain steppes of Northern Eurasia, including the territory of the Orenburg region, where it inhabits to a limited extent the hilly-ridged plains of the Obschy Syrt, steppe river valleys and treeless slopes of the low mountains of the Ural Mountains, as well as the steppes of the Burtinsky and Ural-Tobolsk plateaus, the Orskaya and Turgai plains. The mosaic distribution is associated with plowing, anthropogenic transformation of landscapes, and poaching (Rudi, 1997). The conservation of this species in the region was facilitated by the prohibition of hunting in the 1960s–1970s, work on reacclimatization, the creation of reserves, and the organization in 1989 of the Orenburg State Nature Reserve, in which the steppe marmot inhabits all areas.

According to many researchers, habitats without grazing are unsuitable for this species (Abelentsev et al., 1961; Nikolsky and Savchenko, 2002; Tokarsky et al., 2011; Kharchenko and Lezhenin, 2012; Zhalilov and Andreichev, 2015; Ronkin et al., 2017; 2020). The presence of grazing of large ungulates improves the feeding quality of the vegetation cover for the steppe marmot, the proportion and availability of prey species increases, and continuous vegetation of plants is provided throughout the entire period of marmot activity (Ronkin, 2003). On the other hand, marmots themselves can have an impact on the vegetation cover over a large area around the burrows, from minimal (thinning of the cover) to significant (change in species composition, complete failure of the entire vegetation cover around nesting burrows; Shatalin et al., 2020).

In the first years of the existence of the reserve (1989–1990), two relatively small foci were distinguished on the territory of the Burtinskaya Steppe Site, and the rest of the local settlements, which were smaller in size, were scattered over the territory of the site (Geide, 1991). Later (1998–2001), we described the territorial distribution of marmots on the territory of the site, and counted the number (Soroka, 2001). It was shown that the number of the steppe marmot in the territory withdrawn from economic use increased by almost 4 times over 10 years.

Since the steppe marmot is one of the characteristic representatives of the steppe fauna, monitoring the

state of its populations is an important area of monitoring research, especially in protected areas. The dynamics of the spatial distribution of the steppe marmot can be an indicator of the dynamic processes in steppe ecosystems.

The main purpose of the work was to study the long-term dynamics and current distribution of the steppe marmot on the territory of the Burtinskaya Steppe Site of the Orenburg State Nature Reserve.

MATERIALS AND METHODS

This article is based on data obtained by the author in 1998–2001 and 2021–2022, as well as information on the registration of the steppe marmot from the archive of the Orenburg Reserve. Observations of steppe marmots were carried out in the Belyaevsky district of the Orenburg region on the territory of the Burtinskaya Steppe Site of the Orenburg State Nature Reserve.

The area of the Burtinskaya Steppe Site is 45 km^2. The geographical position of the territory determines the continentality of its climate with dry hot summers (*t* July: +22.0°C), cold severe winter (January *t*: −15.8°C), a significant number of average daily temperatures over +10°C (+2600°) and an average annual rainfall of 327 mm. The territory is a complex of the Muyuldy and Karmen erosion-remnant massifs and vast hilly-ridged spaces that separate them with a difference in absolute heights from 230 to 420.9 m a.s.l. The relative heights of the ridges range from 10 to 160 m. The predominant rocks are variegated and red conglomerates with interlayers of sandstones, which belong to the Lower Triassic and younger Middle Jurassic pebbles and clays; Quaternary eluvial-deluvial, deluvial and spoon deposits 0.5 to 5.0-m thick are widely developed (*Stepnoi zapovednik* ..., 1996). The soils of the site are southern (ordinary) chernozems, carbonate, and underdeveloped. All of them are characterized by a shortened soil profile and the presence of gravel (pebbles) from the surface and along the entire profile (*Krasnaya kniga pochv* ..., 2001).

Botanically and geographically, the Burtinskaya Steppe Site is located in the subzone of forb-turf-cereal Zavolzhsko-Kazakhstan steppes (*Zony i tipy* ..., 1999; Safronova, Kalmykova, 2012). The vegetation cover of the Burtinskaya steppe is quite diverse; steppes dominate. The most common steppes in this area are from Stipeta zalesskii formation. Steppes with shrubs, shrub steppes, and thickets of shrubs are not uncommon. Phytocenoses that develop in relief depressions are characteristic: in shallow logs there are steppe communities with abundant xeromesophytic and mesophytic forbs, and in ravines and gullies there are meadows, aspen and birch-aspen groves. Meadows and black alder forests form along the banks of streams and in places where groundwater is close (Kalmykova, 2012).

The Burtinskaya Steppe Site was singled out from the lands of three state farms. The main part of the territory was used for hayfields and pastures. Significant amounts of rubble on the soil surface did not allow the use of the area for arable land. The pasture load was significant, up to eight herds of sheep and cattle. Cattle grazed mainly on the slopes of watersheds and in hollows. There was significant slaughter at summer camps and watering places.

We recorded all residential colonies of the steppe marmot and individual families and plotted them on a map-scheme at a scale of 1 : 2000. On each colony, the location of all encountered burrows and the paths connecting them were mapped, and the nature of the burrows was noted. The location of winter holes was specified in 1999 using the GPS-12 satellite navigator, and in 2022 using the NextGIS Mobile application.

We calculated the areas of family plots according to maps, limiting them to a network of paths and extreme protective holes, taking into account the maximum distance at which marmots move away from them. The family plot was depicted as a polygon, drawing boundaries along the outer sides of the peripheral squares. As a result, the area of the family plot consisted of the sum of the areas of all squares of the coordinate grid. The area of the colony was considered equal to the sum of the areas of family plots, minus the territory unsuitable and unused by marmots. Statistical processing of the results of observations was carried out using the STATISTICA 10.0.1011 computer program.

RESULTS AND DISCUSSION

In 1990, two relatively small settlements of the steppe marmot were identified on the territory of the Burtinskaya Steppe Site, and six others, smaller in size, were scattered throughout the site. The total number of marmots living here was estimated at 100–120 individuals (Geyde, 1991). In 1996, ten residential colonies were identified on the territory of the site, which remained practically without significant changes throughout all subsequent years (Fig. 1). The colonies occupy small areas and are rather strongly separated territorially, which indicates that not all of the territory satisfies the ecological needs of animals. According to the accepted classification (Bibikov, 1989; Mashkin, 1997), this type of settlement is classified as focal or mosaic. The main biotopes inhabited by marmots on the site are gently undulating ridged slopes of ravines with forb-feather grass-fescue and stony steppes on thin southern chernozems.

In 1999, 75 steppe marmot families were recorded, by 2003 their number increased to 106. During this period, the maximum number of marmots on the site reached 400 individuals; they occupied old previously abandoned burrows within the selected colonies. Over the next 9 years, the number of families remained sta-

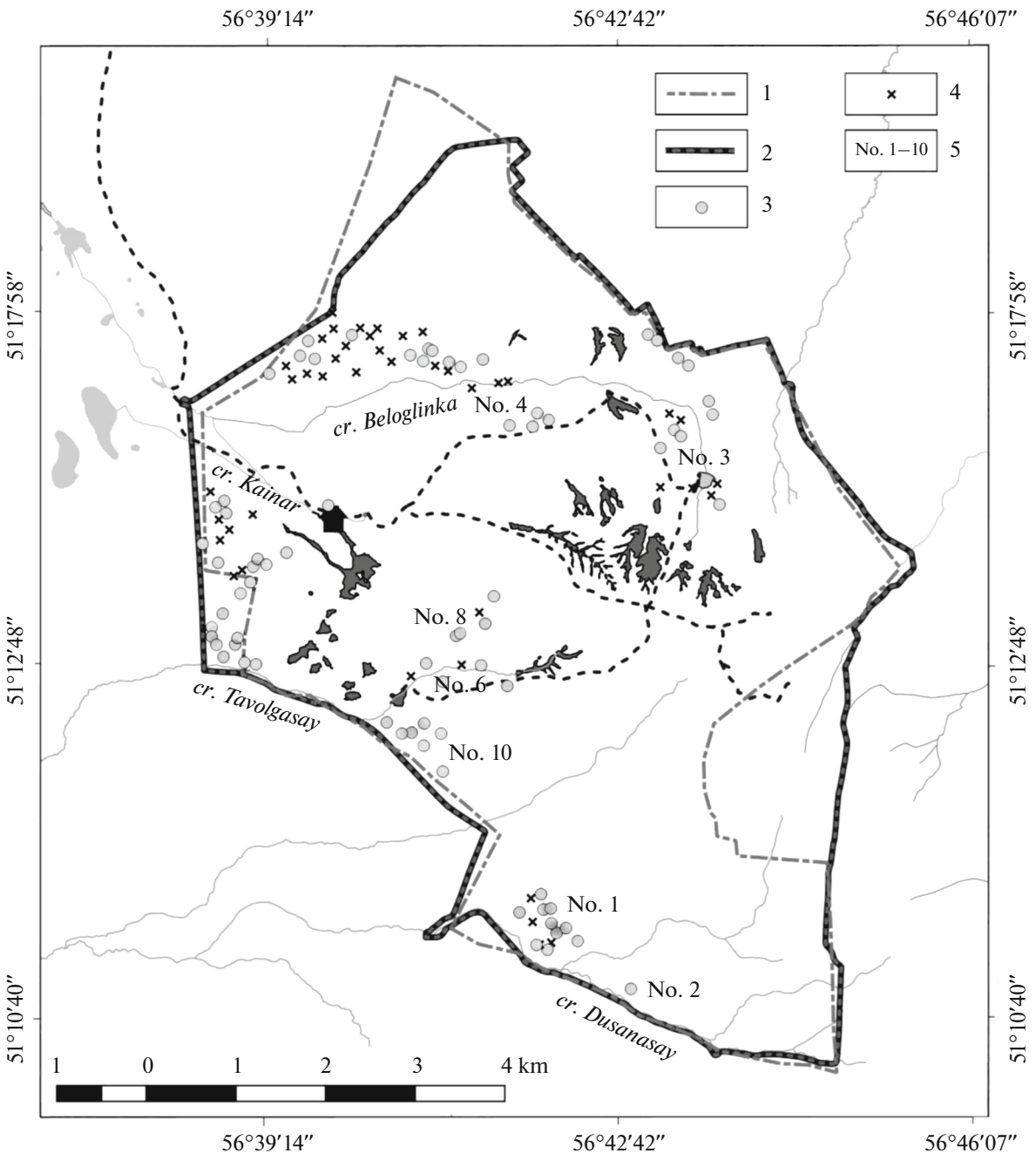

Fig 1. The scheme of the location of residential colonies of the steppe marmot on the Burtinskaya Steppe Site. *Conventions*: (1), boundary of the Burtinskaya Steppe Site; (2), mineralized strip; (3), residential family burrows of the steppe marmot (2022); (4), abandoned family burrows; (5), numbers of colonies.

ble, after which, starting in 2012, began to decrease and in the period from 2017 to 2019 reached its minimum for the entire time of observation, 55 families. In 2022, during remapping of nesting family burrows on the site, 74 families were noted. Below is a more detailed description of the spatial distribution of marmots within each colony.

Colony No. 1 is located along the southern boundary of the site on the lower and middle most gentle parts of the slopes of the right bank of the ravine of the Dusansay stream. On the south side, the colony is bounded by a ravine; on the northern, western, and eastern sides the territory is surrounded by steeper slopes (the steepness is about 40°–50°) with outcrops of remnants. The biotope is undulating steppes on the southern thin gravelly medium loamy chernozems. The vegetation cover is dominated by *Helictotricheta desertorum* steppes, along with which communities of

Stipeta lessingianae formation are characteristic; halophytic and petrophytic variants of *Festuceta valesiaca* and *Galatelleta villosae* steppes occur in spots (Kalmykova, 2008). The territory of the colony was previously used for grazing.

For the entire period of observations within the colony, a maximum of ten residential families were noted. The same number of families was noted in 2022. However, within the colonies there was a redistribution of residential plots: four family plots were abandoned, the entrances to nesting burrows were filled in, and one of the family burrows was taken over by a badger, but four previously empty plots were cleared and populated. The area of the colony is approximately 0.45 km^2.

Colony No. 2 is located 500 m southeast of colony No. 1 upstream of the Dusansay gully and delimited from the latter by the Kulinsay ravine. There is no visual-sound connection with the designated colony. The soils are southern thin crushed stone medium loamy chernozem in combination with meadow chernozem and medium thick medium loamy soil (*Krasnaya kniga pochv* ..., 2001). The vegetation cover, as in the location of colony No. 1, is characterized by petrophytic variants of the steppes with a predominance of communities of *Helictotricheta desertorum* formation. A significant part is taken by *Stipeta zalesskii* steppes (Kalmykova, 2008).

In different years, one to two families were noted in this colony. In 2022, it was represented by a single family, with an area of 0.02 km^2.

Colony No. 3 is located in the upper reaches of the gully of the Beloglinka stream on gently sloping slopes with southern carbonate incompletely developed gravel heavy and medium loamy chernozems. Feather-grass forests predominate here (*Stipeta zalesskii*) steppes, on gravelly slopes, petrophytic variants of the steppes are common, represented by phytocenoses of *Galatelleta villosae* and ovsets *Helictotricheta desertorum* formations (Kalmykova, 2008). Before the creation of the reserve, cattle were grazing on the territory of the colony and a pond was made for a watering place.

Of the 14 most noted nesting family burrows, marmots disappeared in 8; 2 of them were near a restored fire-fighting reservoir, i.e., apparently, they were abandoned due to flooding, badgers settled in 3, which possibly drove the marmots out of their holes, the rest were abandoned for unknown reasons. Within this colony, four new families were formed on previously abandoned burrows, the total number of families reached ten. The area of the colony is about 0.72 km^2.

Colony No. 4 is located on the left bank of the flattened bottom of the valley of the Beloglinka stream in its middle course and occupies biotopes with a predominance of *Stipeta zalesskii* steppes, with patches of communities from *Festuceta valesiacae* and *Galatelleta villosae* formations and a noticeable participation of *Poeta transbaicalicae* steppes in places with slightly increased moisture (Kalmykova, 2008) on southern chernozems.

The colony is rather unstable: out of six families, three vary, animals either appear in them, winter, or disappear; currently four family plots remain occupied. Including all six family plots, the colony covers an area of about 0.30 km^2.

Colony No. 5 is the largest in the area. It is located in the middle course of the Beloglinka creek, the channel of which in some places takes the form of a ravine with steep slopes. The colony occupies the gently undulating lower slopes of the South Carmen Rise. The soils are southern residually carbonate low-humus thin crushed stone soils on eluvial-deluvial heavy loams and clays. At present, turf grasses predominate here, often in communities the same phytocenotic role is played by *Stipa lessingiana*[1], *S. zalesskii* and *Festuca valesiaca*; rhizomatous grasses are also noted, actively developing on the fallows (Kalmykova, 2008). From the south, the colony is bounded by a stream bed, from the east by the Shchurova gully, which cuts the South Carmen Rise in the meridional direction and flows into the Beloglinka gully from the north, and by the slopes of the South Carmena Rise; in the west, the colony continues beyond the boundaries of the plot. Previously, the territory was used for arable land, but the outcrops of a significant amount of rubble on the soil surface led it to be left fallow.

Within the boundaries of the reserve, the colony has an area of 1.60 km^2. The number of families increased from 12 in 1996 to 32 in 2006, and since 2012 it has started to decrease. According to the results of mapping in 2022, only 12 residential family plots were noted in this colony.

Colony No. 6 is located in the undulating lower part of the southwestern slope of the Muyuldy plateau on the left bank of the valley of the Tavolgasai brook. The vegetation cover is dominated by *Stipeta zalesskii* steppes (Kalmykova, 2008) on southern thin gravelly chernozems; cattle camps are characterized by large monodominant groups of *Agropyron pectinatum*. The territory was used for grazing, near the pond there was a parking lot for cattle.

For a long time, the colony consisted of one family, then the number of families increased to six and the marmots occupied both banks of the stream. At present, the colony consists of four families, and within its current boundaries has an area of 0.20 km^2.

Colony No. 7 is the second in terms of area. It is located along the western border of the site in the interfluve of the brook. Kainar and Tavolgasai. Against the background of the prevailing *Stipeta lessingianae* steppes on the chernozems of the southern carbonate low-humus crushed stone on cartilagi-

[1] Latin names of plants are given according to the work of S.K. Cherepanov (1995).

nous loams, solonetz-steppe complexes are distinguished on meadow-marsh solonchak heavy loamy soils on which marmots avoid settling.

On an area of 1.40 km^2 in 1999 there were 20 families. Along with residential burrows during mapping, several abandoned nesting burrows were noted, which were later settled by marmots. A maximum of 25 families were recorded in this colony. According to the results of mapping in 2022, eight family plots turned out to be abandoned, most of them showed traces of badgers and the animals themselves, which were hiding in the protective holes of marmots. In previously uninhabited burrows, 3 new families were formed, bringing the total number of families to 20.

Colony No. 8 is located in the lower part of the western slope of the Muyuldy plateau. The biotope is a wavy-ridged steppes on the chernozems of southern gravel heavy and medium loamy sandstones on eluvio-deluvium. In the vegetation cover against the background of the prevailing *Stipeta zalesskii* steppes, petrophytic steppes are distinguished, mainly from *Galatelleta villosae* formation on strongly gravelly soils and, less frequently, small patches of halophyte-steppe communities near marmots.

In 1999, two families of marmots were registered in this colony, by 2001 this number doubled. Currently, four families live on the territory of the colony, however, one of the previously residential family plots turned out to be abandoned, but a new one appeared 150 m from it. The area occupied by this colony is 0.24 km^2.

Colony No. 9 is represented by a single family and is located in the valley of the creek. Kainar, 100 m northwest of the cordon house. The plot of this family with an area of 0.06 km^2 occupies the southern slope of one of the ridges (relative height, about 10–15 m). The surrounding area is represented by meadow-steppe tracts with tussock mire and hollows on meadow-marsh solonchak soils. The slopes are characterized by *Stipeta zalesskii* steppes. On leveled areas, comb-shaped wheatgrass is abundant *Agropyron pectinatum*. Marmots often graze at the foot of the ridge, protective burrows are also found on its top.

Colony No. 10 is located along the southwestern border of the site in the middle reaches of the Tavolgasai River. The settlement occupies undulating-ridged slopes with steppes of *Stipeta zalesskii* and *Stipeta lessingianae* formations on southern thin gravelly medium loamy chernozems. All family burrows are occupied; another family appeared, as a result, the number of families increased to seven. The colony has an area of 0.27 km^2.

On the Burtinskaya Steppe Site settlements of the steppe marmots occupy a territory with a total area of 5.26 km^2, which is 11.7% of the total area of the site. For quite a long period of time (more than 30 years) not a single new colony has appeared on the territory of the site and there are also no nonresidential burrows outside the selected settlements; during periods of population growth the size of existing colonies did not change. All this may indicate that all suitable biotopes that meet the vital needs of these animals are already occupied.

Along with the presence of a sufficient layer of fine earth for the construction of nesting burrows, the depth of the groundwater, and a good overview of the area, the presence of vegetative vegetation in accordance with the specialization of marmots is one of the leading factors that determine the territorial structure of the settlements of the steppe marmot. Family plots are laid down at the initial stages of development of the territory in such a way as to fully satisfy the needs of all family members for food. As a rule, such a configuration and size persist for many years due to the fact that for the marmot, like all territorial animals, a system of interfamily relations rigidly fixes the outer boundaries of the plots (Seredneva, 1991; Mashkin, 1997). With an abundance and diversity of food, the areas of family plots are small, while with a shortage, they increase (Bibikov, 1967). Thus, in the European part of the range, the smallest family plots (0.2–4.0 ha) are much smaller in biotopes with intensive grazing, where vegetation is constantly growing, than in biotopes with a low level of anthropogenic load (Nikolsky and Savchenko, 2002; Tokarsky et al., 2011; Ronkin et al., 2017). When moving to the east, in the Kazakhstani part of the range, the areas of plots increase to 4.75–7.0 ha (Shubin et al., 1978).

The study area is characterized by rather large sizes of family plots, 5.22 ± 0.6 ha on average (3.0–8.7 ha, $n = 75$, $p \le 0.05$). The size distribution showed that the largest number of families (52%) have a size of 3–5 hectares. The middle of this class (4 ha) is smaller than the mean (5.22 ± 0.6 ha) and median (4.96 ha). The maximum sizes (8–9 ha) belong to 7% of the families. The winter burrows of neighboring colonies are located at a distance of 35–355 m (on average 193.3 ± 16 m, $n = 75$, $p \le 0.05$) from each other, with no overlap of closely spaced neighboring sites (Soroka, 2001). The shape of family plots is from almost round to elongated. Winter burrows make up 4.5% of the total number of burrows. An increase in the size of habitats leads to an increase in the number of protective holes ($n = 75$, $r = 0.60$, $p < 0.001$), which increases the possibility for marmots to hide in the nearest one when danger suddenly appears. The number of protective burrows per colony varies from 9 to 52 (20.4 ± 3.2, $n = 87$, $p \le 0.05$). The ratio of nesting winter, summer, and protective holes is 1 : 1 : 20.4 respectively ($n = 87$). The most remote visited protective burrows were found at a distance of 200–220 m from the winter ones. Observations of tagged animals showed that on the periphery of the family area marmots usually do not move farther from the nearest protective burrows than 30–50 m ($n = 12$). As a result, the greatest distance of animals leaving the nesting hole is 230–270 m.

It should be noted that such a spatial structure on the territory of most colonies developed even before the organization of the reserve with a significant pasture load and remains to this day. Therefore, for this territory, grazing cannot be considered among the main factors that determine the well-being of the steppe marmot. The ability of plants to grow again and vegetate for a longer period after alienation, which is necessary for the provision of marmots with young plant parts rich in proteins, is limited by the reserves of productive moisture in the soil under dry conditions (Abaturov and Lopatin, 1985). The destruction of bedding by hooves leads to even greater drying of the soil and accelerates the burning of vegetation.

The study area is located in a continental climate. This is reflected in the low moisture supply of the steppes and, as a result, the short duration of the growing season, which ends with the establishment of high air temperatures. In order to provide themselves with sufficient food, marmots are forced to increase the feeding area, including the lower parts of the slopes, hollows, and gullies, where, due to the accumulation of a large amount of snow and its long-term melting, the vegetation is later and longer. Another adaptation to the short growing season in the study area is the early hibernation of marmots, which begins as early as the second to third decades of July (Soroka, 2000).

The increase in the number of steppe marmot families observed in the first years of the reserve's existence in the area is probably associated with the gradual restoration of the structure and composition of phytocenoses in the conditions of the cessation of grazing. We should also not rule out the cessation of poaching and the extraction of marmots by shepherd dogs. Despite the decline in the total number of families after 2012, in most colonies the number of families either decreased slightly or remained the same and even increased. The strongest fluctuations affected the largest colony in the area, located on an old-growth fallow; in colony No. 5, the number of families decreased to 60% of the maximum number. The reasons for this situation are yet to be clarified.

CONCLUSIONS

On the territory of the Burtinskaya Steppe Site of the Orenburg State Nature Reserve, the population of the steppe marmot has existed for more than 30 years. Ten stably existing colonies with a total area of 5.26 km^2 were identified, which are rather strongly dispersed geographically. The spatial structure on the territory of most colonies developed even before the organization of the reserve, with a significant pasture load, and has been preserved to this day. The spatial structure is more influenced by the continentality of the climate than the presence or absence of grazing. This is expressed in an increase in the size of family plots due to the inclusion in them of the lower parts of the slopes and hollows with a later and longer vegetation vegetation. After the introduction of the reserve regime and the demutation of the vegetation cover in most colonies located on former pastures, the number of families either decreased slightly or remained the same and even increased.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest. The author declares that she has no conflicts of interest.

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

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