Asian Journal of Conservation Biology, July 2021. Vol. 10 No. 1, pp. 22-27 AJCB: FP0151/64971
ISSN 2278-7666 ©TCRP Foundation 2021 https://doi.org/10.53562/ajcb.XEMO5031

Research Article

Steppe and forest-steppe pine forests as refugiums in the conservation of rare and unique plant species

Kin N.O., Velmovskiy P.V.*

Institute of Steppe of the Ural Branch of the Russian Academy of Sciences
460000, 11 Pionerskaya str., Orenburg, Russia

(Received: October 13, 2020; Revised: March 10, 2021; Accepted: May 15, 2021)

ABSTRACT

This report includes data on rare plant species of steppe and forest-steppe pine forests. We have identified the proportion of rare species that live in the studied forests for the regions where they are located, and for Russia as a whole. We have identified regional species found only in pine forests. The article shows that pine forests play an important role in the conservation of forest (boreal, boreonemoral, nemoral and boreonemoral forest-steppe) species and in the conservation of regional phytodiversity.

Keywords: Pine forests, Red Data Book, steppe and forest-steppe regions, rare species, refugium, conservation.

INTRODUCTION

Pine forests, at the southern extremity of the range of the Common Pine, are widely distributed in the steppe and forest-steppe zones. By pine forests, following E.A. Starodubtseva (1999), we mean island woodlands (isolated areas) on the sandy left banks, where the main area of forests is occupied by plant communities with a predominance of the Common Pine. It is important that the forests are located in regions where the percentage of forest cover is low, which is due to arid climate conditions that are extreme for forest ecosystems (Stefańska-Krzaczek, 2019). This increases the importance of pine forests in the conservation of forest species. The flora of pine forests differs significantly from the flora of the surrounding landscape and contributes significantly to the phytodiversity of the regions. The role of these woodlands is also important in terms of preserving the natural heritage, both at the regional level and in the country as a whole. One of the important indicators of natural heritage is rare species listed in the Red Data Books of different levels (Glazunov, 2019).

MATERIALS AND METHODS

We have studied the flora of 4 pine forests (Figure 1): Usmansky and Khrenovskoy forests located in the forest-steppe biome of the Oka and Don Rivers lowland (Milkov, 1977), Buzuluksky and Krasnosamarsky forests that are located in the steppe zone of the Trans-Volga region (Buzuluksky Bor, 1949; Korchikov *et al*., 2009). The studied forests currently have the status of specially protected natural areas or are promising for creation of these areas.

Usmansky pine forest is located at the junction of Lipetsk and Voronezh regions. The total area covered by forests is 7.6% in the Lipetsk region and 7% in the Voronezh region. Usmansky pine forest occupies 70.7 thousand hectares, but only 31.053 thousand hectares are included in the state nature reserve, founded in 1927.

Khrenovskoy pine forest, with an area of 40.21 thousand hectares, is located within the Voronezh region. This forest is included in the list of perspective (planned for organization) specially protected natural areas of regional significance in the Voronezh region (Executive Order…, 2015).

Buzuluksky pine forest is the largest forest area (106.788 thousand hectares), which received the status of a national park in 2007. It is located in two subjects of the Russian Federation, namely in the Orenburg and Samara regions (Velmovskiy, Chibilyov, 2019). The share of forested areas in the Orenburg region is 4.5%, and 13% in the Samara region.

Krasnosamarsky pine forest (13.554 thousand hectares) is connected with Buzuluksky pine forest by a narrow strip of forest (about 36 km long) running along the right bank of the Samara river, completely located within the Samara region and is part of the Samara Municipal Park.

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When conducting floristic surveys for 20 years, studying the literature and herbarium samples, we were

**Corresponding Author's E-mail: velmovskiy@gmail.com*

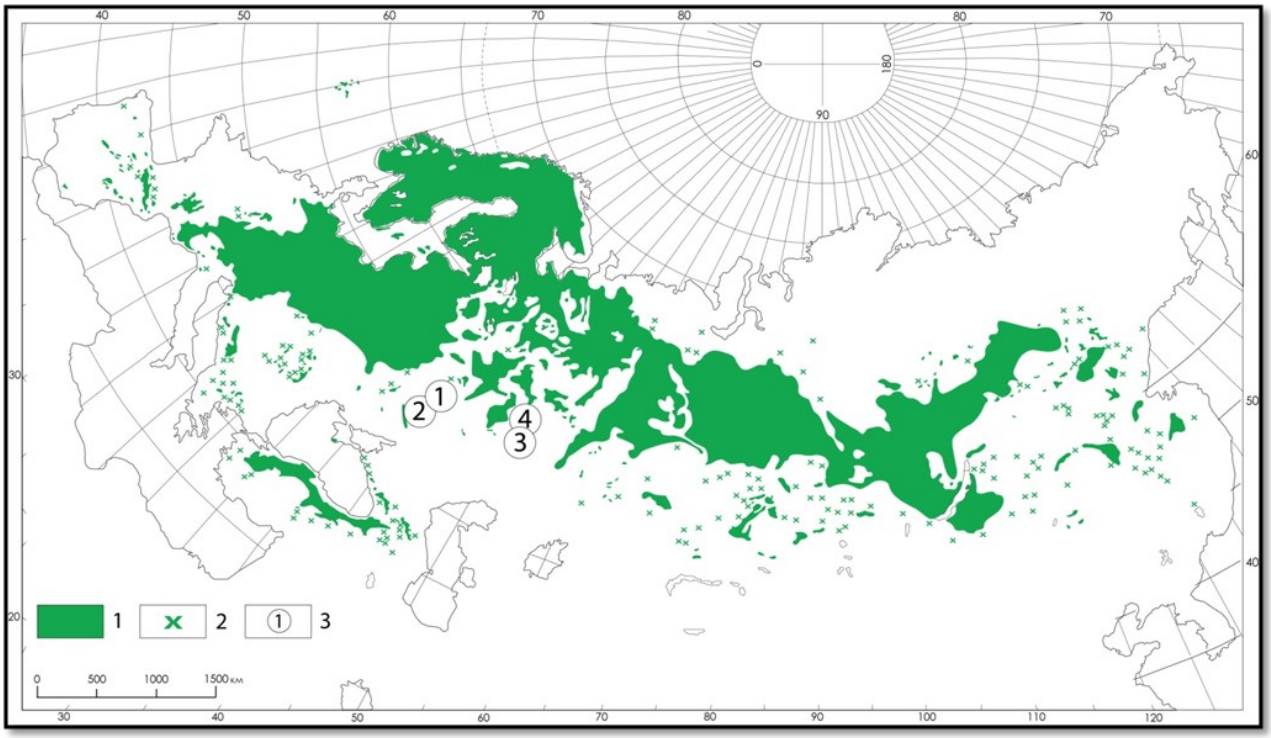

Figure 1. Schematic map of the studied pine forests location (Crichfield, Little, Jr., 1966, in the authors' version). Legend: 1 – Main range of Pinus sylvestris; 2 – Areas separated from the main range of Pinus sylvestris; 3 – Studied pine forests: 1 – Usmansky, 2 – Khrenovskoy, 3 – Buzuluksky, 4 – Krasnosamarsky.

able to establish that the largest number of species of higher vascular plants is 1076 species in Usmansky forest (Starodubtseva, 1999). In Khrenovskoy (850 species) (Kin, Starodubtseva, 2012; Seregin, 2015) and Buzuluksky (794 species) (Kin, 2009) pine forests, the number of taxa is approximately the same. Krasnosamarsky forest includes 674 species of plants (Korchikov *et al*., 2009).

To establish the role of pine forests in the conservation of rare plant species in the country and regions, the Red Data books of Russia (2008) and the corresponding administrative regions were analyzed: Voronezh (2011), Lipetsk (2014), Orenburg (2019), Samara (2017). Regional Red Data Books, of course, are not the only indicators of rare taxa, their habitats and location, but they serve as guidelines for informing about the current situation with populations of rare and unique species of flora and fauna in regions.

RESULTS AND DISCUSSION

In the studied forests, we registered 11 species of plants listed in the Red Data Book of the Russian Federation (2008), which is 2.1%. They included 7 species in the Buzuluksky pine forest flora, and 6 species in Khrenovskoy, Krasnosamarsky and Usmansky pine forests each. All the studied pine forest were inhabited by *Orchis militaris* L. and *Fritillaria ruthenica* Wikstr listed under 3 category in the Red Data Book of the Russian Federation (2008). Populations of *Iris aphylla* L., a declining species in Russia (2008), were found in the Usmansky, Khrenovskoy and Buzuluksky pine forests. In the floras of the Khrenovskoy, Buzuluksky and Krasnosamarsky pine forests, on sandy steppe areas, *Stipa pennata* L can be found. *Pulsatilla pratensis* (L.) Mill occurs in Usmansky and Khrenovskoy pine forests. Rare species of Russia (Red Data Book..., 2008) from the family *Orchidaceae* – *Cephalanthera rubra* (L.) Rich. and *Cypripedium calceolus* L. were found in the Buzuluksky and Krasnosamarsky forests, and *Neottianthe cucullata* (L.) Schlehter was recorded in Buzuluksky and Usmansky pine forests. Threatened orchids (Red Data Book..., 2008) included *Liparis loeselii* (L.) Rich. in Usmansky pine forest and *Orchis coriophora* L in Khrenovskoy pine forest. Krasnosamarsky pine forest became a haven for *Iris pumila* L.

The Red Data Book of the Voronezh region (Vascular plants, 2011) lists 272 rare species of higher vascular plants, and 78 of them were found in Usmansky pine forest, which is 28.7% of all rare species pertaining to this division in the region. Fewer rare species have been registered in Khrenovskoy pine forest: 46 (16.9% of all specified plants in this division). In Khrenovskoy and Usmansky pine forests grow 3 out of 4 rare representatives of lycopsids: *Lycopodium clavatum* L., *L. annotinum* L. and *Diphasiastrum complanatum* (L.) Holub. Among 7 red-listed fern species 6 were found in Usmansky pine forest. The only habitat in the Voronezh region for *Phegopteris connectilis* (Michx.) Watt is the edges of sphagnum swamps of this forest (Vascular plants, 2011). Khrenovskoy pine forest included 2 rare ferns. When conducting floral research in Khrenovskoy pine forest, we found *Botrychium virginianum* (L.) *Sw. var. europaeum* (Angstr.) Clausen in a wet thin-stemmed thicket forest (Kin, Kalmykova, 2019). This species is not listed in the current Red Data Book of the Voronezh region, as previously there was no information about it in the area.

In the regional Red Data Book, 3 species of gymnosperms are listed, including *Juniperus communis* L. that occurs only within Khrenovskoy and Usmansky pine forests.

Angiosperms make up the largest number among those listed in the Red Data Book of the Voronezh region: 257. Of these number, 68 species occur in Usmansky pine forest, which is 26.5% of all protected plants pertaining to this division; and 40 species (15.6%) were found in Khrenovskoy pine forest. Among the rare angiosperms there are species that occur in the Voronezh region only in pine forests: 5 out of 23 rare representatives of the *Orchidaceae* family have their habitats in Usmansky pine forest: *Gymnadenia conopsea* (L.) R. Br., *Neottianthe cucullata* (L.) Schlehter, *Dactylorhiza maculata* (L.) Soó, *Dactylorhiza fuchsii* (Druce) Soó, *Coeloglossum viride* (L.) C. Hartm. Usmansky pine forest is also the only location of *Omphalodes scorpioides* (Haenke) Schrank and *Eriophorum latifolium* Hoppe in the region. This forest area remained the only refugium for 5 of the 7 species of the family *Ericaceae* listed in the Red Data Book of the Voronezh region: *Vaccinium vitis-idaea* L., *V. myrtillus* L., *Calluna vulgaris* (L.) Hull, *Ledum palustre* L., *Oxycoccus palustris* Pers. The Red Data Book of the region indicates that populations of species pertaining to the genera *Oxycoccus Vaccinium* and *Calluna* are also present in Khrenovskoy pine forest, but the data are not confirmed by modern findings (Kin, Starodubtseva, 2012).

Khrenovskoy pine forest is the only place in the Voronezh region where populations *Orchis coriophora* and *Centaurea pineticola* Iljin can be found.

In total, 89 rare species of higher vascular plants for the Voronezh region grow in Usmansky and Khrenovskoy pine forests, which is 34.6% of the protected plants of this group in the region.

The share of red listed species from the total number of species recorded in the pine forest flora is 7.2% in Usmansky pine forest and 5.4% in the Khrenovskoy pine forest.

The location of Usmansky pine forest in two regions makes it necessary to analyze the situation for rare plants and in the Lipetsk region. In total, the Red Data Book of the Lipetsk region (Vascular plants..., 2014) lists 175 species of higher vascular plants that need monitoring and protection in the region. This number includes 76 species that were found in Usmansky pine forest, which is 43.4% of all rare higher vascular plants. Here, 3 of 4 rare species of lycopsids, 2 of 5 fern species and 1 of 2 gymnosperm species were recorded. Among the 163 angiosperm species listed in the Red Data Book of the Lipetsk region, 70 were found in Usmansky pine forest. This forest area is the only habitat of *Carex remota* L. and *Hottonia palustris* L. for the Lipetsk region. For many rare species listed in the Red Data Book of the region, Usmansky pine forest has become one of the few habitats in the Lipetsk region. They include: *Calluna vulgaris*, *Dentaria quinquefolia* Bieb., *Pedicularis sceptrum-carolinum* L., *Iris sibirica* L., *Hammarbia paludosa* (L.) O. Kuntze, *Orchis militaris*, *Teucrium scordium* L.

The share of rare species from the division of higher vascular plants in the Lipetsk region is 7.1% out of all species recorded in the flora of Usmansky pine forest.

Buzuluksky and Krasnosamarsky pine forests are important in the conservation of rare plants in the Samara region. The Red Data Book of the Samara region (2017) provides information about 243 rare species of higher vascular plants, and 54 species of them were recorded in Buzuluksky pine forest, which is 22.2% of all protected species in the region. Krasnosamarsky pine forest accounts for 42 species (17.3%).

Only *Diphasiastrum complanatum*, out of 3 lycophytes listed in the Red Data Book of the region, was found in Buzuluksky pine forest. This is 1 of 3 locations on the territory of the Samara region. Buzuluksky pine forest also plays the most important role in the conservation of ferns. Here, we found 5 of 14 rare species of ferns. In Krasnosamarsky pine forest only 1 rare species was recorded: *Matteuccia struthiopteris* (L.) Tod.

The only rare horsetail for the Samara region, *Equisetum ramosissimum* Desf., was also found in the ecosystems of Krasnosamarsky pine forest.

Ephedra distachya L., 1 of 2 rare gymnosperm species for the Samara region, is a very rare inhabitant of Buzuluksky pine forest.

Angiosperms form the basis of rare plant species in the region. In Buzuluksky pine forest, 48 species of rare flowering plants were found (21.5% of all rare species in this division).

Among the rare species of the Samara region, there are none that have been recorded only in the Buzuluksky pine forest, but this forest area is one of the few shelters for some of them, for example, *Drosera rotundifolia* L. *Herminium monorchis* (L.) R. Br., *Listera ovata* (L.) R. Br., *Carex arnellii* Christ., *Hylotelephium zhiguliense* Tzvel.

Krasnosamarsky pine forest accounts for 41 out of 223 rare angiosperm species in the Samara region, which is 18.4% of the protected plant species of this group. This forest area is one of the few in the region where they have their habitats: *Lactuca quercina* L., *Listera ovata* (L.) R. Br., *Orchis militaris*.

Indeed, Buzuluksky and Krasnosamarsky pine forests include, in total, 78 rare species of higher vascular plants listed in the Red Data Book of the Samara region (2017). This is 32.1% of all protected plants from this group for the region.

Buzuluksky pine forest includes 6.8% and Krasnosamarsky pine forest does 6.2% species from all the rare vascular plant species in the Samara region.

A significant part of Buzuluksky pine forest is located in the Orenburg region. The Red Data Book of this region includes 173 species of higher vascular plants (Plants..., 2019), of which 44 species grow in the pine forest (25.4% of all rare plants in this division). For lycopsids Buzuluksky pine forest is the only place of habitation in the Orenburg region. The population of *Diphasiastrum complanatum* survives here. Out of 17 species of rare ferns for the region, 10 species grow in the Buzuluksky pine forest, including *Botrychium lunaria* (L.) Sw. that was recorded only in this forest area across Linden-birch-aspen communities with *Acer platanoides* L. (Kin, Kalmykova, 2019).

Table 1. Regional Red Data Book rarity categories for plant species found in the studied pine forests

Rarity category	Number of plant species					
	1	2	3	4	5	6
0	3	1	1	–	–	–
1	19	15	5	7	6	2
2	24	24	11	7	16	–
3	32	22	28	32	20	30
4	–	9	1	2	2	2
5	–	5	–	6	–	8
Species in total:	78	76	46	54	44	42

Legend: Number of plant species: 1 – in Usmansky pine forest from the Red Data Book of the Voronezh region; 2 – in Usmansky pine forest from the Red Data Book of the Lipetsk region; 3 – in Khrenovskoy pine forest forest from the Red Data Book of the Voronezh region; 4 – in Buzuluksky pine forest from the Red Data Book of the Samara region; 5 – in Buzuluksky pine forest from the Red Data Book of the Orenburg region; 6 – in Krasnosamarsky pine forest from the Red Data Book of the Samara region.

In the region, there are 153 species of rare angiosperms and 33 occur in the forest. For many of them Buzuluksky pine forest is the only reliable habitat in the Orenburg region. They include: *Campanula rotundifolia* L., *Drosera rotundifolia*, *Salvia glutinosa* L., *Iris aphylla* L., *Neottia nidus-avis* (L.) Rich., *Neottianthe cucullata*, *Herminium monorchis* (L.) R. Br., *Listera ovata* (L.) R. Br., *Numphaea alba* L. Also, the only habitat of *Calla palustris* L. in the Orenburg region is swampy depressions in Buzuluksky pine forest, but this species was not included in the current Red Data Book due to lack of information.

Buzuluksky pine forest is one of the few places where such rare species can be found in the region as *Cephalanthera rubra* (L.) Rich., *Naumburgia thyrsiflora* (L.) Reichb., *Maianthemum bifolium* (L.) F. W. Schmidt, *Asarum europaeum* L.

The entire higher vascular plants recorded in the flora of Buzuluksky pine forest accounted for 5.5% of Red Data Book species in the region.

Given that the rarity categories in the Red Data Books under consideration were identical and correspond to the following designations: 0 – probably extinct; 1 – endangered; 2 – declining in number; 3 – rare; 4 – uncertain in status; 5 – recoverable and recovering, the following data were obtained (Table 1).

In the studied pine forests a significant number of red-listed species had 3 and 2 categories of rarity. Only in the Krasnosamarsky forest, according to the compiling prescriptions in the Red Data Book of the Samara region, there were no species with declining numbers (category 2), and there were relatively many recovering taxa (category 5). The most endangered species (category 1) were in the Usmansky pine forest, both for the Voronezh and Lipetsk regions.

A significant portion of the rare plant species, that inhabited the studied pine forests, with the exception of Krasnosamarsky pine forest, was confined to the forest biome. In the geographical spectrum, these were species pertaining to latitudinal groups: boreal, boreonemoral, boreonemoral forest-steppe, nemoral (Table 2, Figure 2). These groups contained more than 50% of the rare species that lived in pine forests. A significant share was made up of boreal and boreal-nemoral groups.

Forest-steppe and steppe groups were the most abundant in Krasnosamarsky pine forest. This was primarily due to the small area occupied by this forest and the active penetration of species from the adjacent steppe and forest-steppe landscapes.

CONCLUSION

Our research found that all pine forests contained rare species, both for the region and for the country as a whole. Usmansky pine forest was the only habitat for 14 rare species of the Voronezh region and 2 species of the Lipetsk region. Though, the ecosystems of Khrenovskoy pine forest included 4 rare species of the region. Among the rare species of vascular plants in the Orenburg region 12 had their habitats only in the ecosystems of Buzuluk pine forest. We found no any rare species of the region that were characteristic only for steppe pine forests of the Samara region. However, for many red-listed vascular plants, Buzuluksky and Krasnosamarsky pine forests are still one of the few current habitats in the region. Among the protected species, their significant portion included rare and endangered species. The largest number of endangered species in the Voronezh and Lipetsk regions was found in Usmansky pine forest.

Undoubtedly, the conservation status of the studied pine forests and their territory play an important role. This is evident from both the abundance and ecological characteristics of the identified rare plants (Zhang et al. 2017; Ye et al., 2017).

Table 2. Latitudinal groups of rare plants found in the studied pine forests

Latitudinal group	1	2	3	4	5	6
Boreal	28	24	14	15	7	4
Boreonemoral	11	8	5	9	9	7
Boreonemoral forest-steppe	4	5	2	5	7	2
Nemoral	6	7	2	4	6	4
Nemoral forest-steppe	3	5	2	2	2	1
Nemoral forest-steppe and steppe	1	3	1	2	1	2
Forest-steppe	7	8	5	1	1	–
Forest-steppe and steppe	4	7	7	6	5	6
Steppe	4	3	3	4	0	10
Plurizonal	10	6	5	6	6	6
Species in total:	**78**	**76**	**46**	**54**	**44**	**42**

Legend: See Table 1.

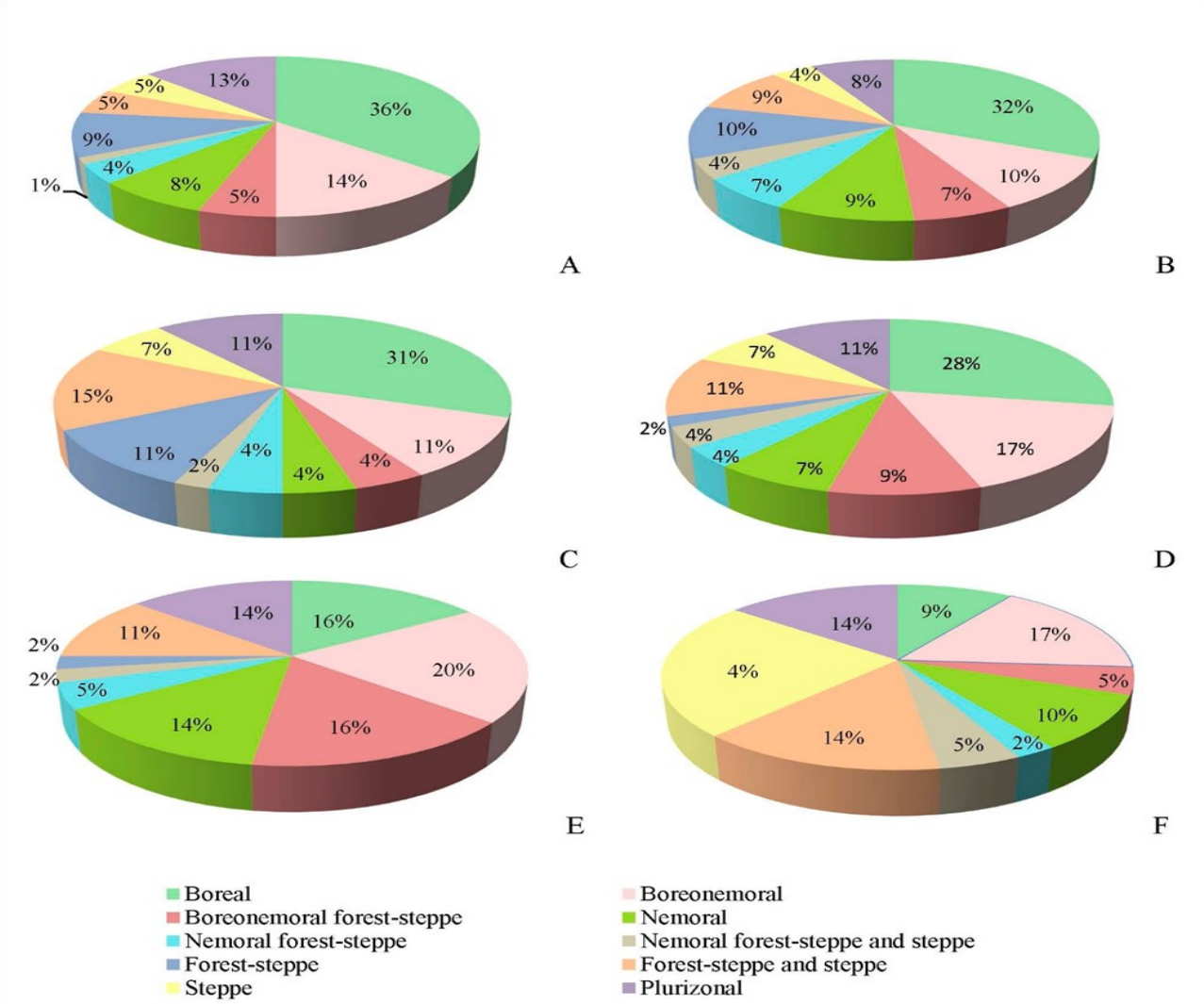

Figure 2. The percentage of rare plant species in the latitudinal and geographical structure of the flora pines forests from the Red Data Book (according to the Red Data Book)

Legend: Number of plant species: A – in Usmansky pine forest from the Red Data Book of the Voronezh region; B – in Usmansky pine forest from the Red Data Book of the Lipetsk region; C – in Khrenovskoy pine forest forest from the Red Data Book of the Voronezh region; D – in Buzuluksky pine forest from the Red Data Book of the Samara region; E – in Buzuluksky pine forest from the Red Data Book of the Orenburg region; F – in Krasnosamarsky pine forest from the Red Data Book of the Samara region.

Steppe and forest-steppe forests are particularly important in preserving the phyto-diversity of low-forest regions, as a significant portion of the rare species found on the woodland territory are representatives of taiga and deciduous forests.

ACKNOWLEDGEMENT

The work was completed under the planned budget-funded topic of the Institute of Steppe of the Ural Branch of the Russian Academy of Sciences "Problems of steppe nature management in the context of modern challenges: optimizing interactions between natural and socio-economic systems" № AAAA-A21-121011190016-1.

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