Rare plants of the Voronezh region in ecosystems of Khrenovsky pine forest

N O Kin\textsuperscript{1} ORCID 0000-0002-2823-5739, N Yu Demchenko\textsuperscript{2}, S N Ryabtsov\textsuperscript{3}

\textsuperscript{1}Institute of Steppe of the Ural Branch of the Russian Academy of Sciences, Russia, Orenburg
\textsuperscript{2}Bobrovskaya Secondary General Education School #1, Russia, Voronezh
\textsuperscript{3}Orenburg State Pedagogical University, Russia, Orenburg

E-mail: kin_no@mail.ru

Abstract. To evaluate the environmental significance of Khrenovsky Bor isolated pine forest, we identified rare plant species in this area. We have been conducting floristic surveys for 10 years using route method. Herbarium specimens, literary and archival data were also analyzed. This allowed us to identify 850 species pertaining to 718 genera and 130 families in the forest area. The flora of Khrenovsky pine forest encompasses 5 plant species listed in the Red Data Book of the Russian Federation and 46 species in the Red Data Book of the Voronezh region. It accounts for 19.4\% of all rare vascular plant species in the region. Most of the rare species are representatives of boreal, boreal-nemoral, nemoral, boreal-nemoral-forest-steppe latitude groups. This indicates high importance of the pine forest in conservation of rare species, and forest species make up the greater portion of them. One of the important results was the discovery of \textit{Elatine alsinastrum} L. in the forest area. A proposal has been put forward to include this species in the rare taxa cadastre of the Voronezh Region and regional Red Data Book. We consider the possibility of giving the nature protection status to Khrenovsky Bor pine forest as a unique forest area, where rare plant species are preserved, and for some of them this forest area is the only habitat in the region.

1. Introduction
Khrenovsky pine forest is an isolated forest massif with an area of 402.1 km\textsuperscript{2}. It is situated within typical forest-steppe, in the Oka-Don Lowland [1]. It is geographically confined to the left bank of the Bityug river in Bobrovsky district of the Voronezh Region.

The continental climate in the pine forest region is not favorable enough for the development of forest vegetation. But nevertheless, rare boreal and nemoral species survive in forest communities of Khrenovsky pine forest. The total area covered by forests in the Voronezh Region is only 7\%. For this reason Khrenovsky pine forest is a valuable forest resource for the region. Despite this, the forest has no conservation status, with the exception of 14 natural monuments located in the area.

It is known that absence of conservation status and protection by environmental authorities leads to serious consequences due to human impact. Annual timber harvesting, fires, and uncontrolled recreational load not only directly, but also indirectly significantly affect the biota of the forest area. In order to identify the role of Khrenovsky pine forest in conservation of rare plant species some research work was done to find such species in the area.
2. Materials and Methods
We have been doing floristic surveys for 10 years using route method. Herbarium collections made during the work (more than 1500 samples) are stored at Institute for Steppe Research, Russian Academy of Sciences – Ural Branch (with the ORIS label). Our study included the work with herbarium materials of Voronezh State University (VOR) and Voronezh State Nature Reserve (VGZ).
We also analyzed distribution and habitat ecological features of rare plant species in the study area through personal observations, browsing herbarium, literature [2, 3, 4, 5 and others sources] and archive data. The Red Data Books of the Russian Federation [6], Voronezh region [7] and the International Union for Conservation of Nature (IUCN) database [8] were analyzed. Latitudinal geographical analysis is based on the “principle of biogeographic coordinates” [9]. The attribution of a species to a particular latitudinal group is based on the fact of the predominant distribution of the species within geographical zones. Latin names of vascular plants taxa are given according to S. Cherepanov’ review [10].

3. Results and Discussion
Floristic surveys allowed us to identify 850 species pertaining to 718 genera and 130 families in the forest area. Red-listed species makes up 5.4% of the total number of species recorded in the forest flora.

Khrenovsky pine forest flora was found to include 5 species of plants listed in the Red Data Book of the Russian Federation [6]. They are Orchis militaris L., Fritillaria ruthenica Wikstr., Stipa pennata L., Pulsatilla pratensis (L.) Mill. (rarity category 3); Iris aphylla L. (rarity category 2 with decreasing taxa).

The study area has 46 out of 237 (19.4%) rare species of higher vascular plants of the Voronezh region [7]. And 3 out of 4 species of Lycopodiophyta that are believed to be rare for the Voronezh region occur in the forest. They include Lycopodium clavatum L., L. annotinum L. and Dipsasium complanatum (L.) Holub. We also found 2 out of 6 Polypodioiphyta species, listed in the Red Data Book of the Voronezh region, in Khrenovsky pine forest: Botrychium virginianum (L.) Sw. and Matteuccia struthiopteris (L.) Tod.

The regional Red Data Book lists 2 species of Pinophyta and one of them, Juniperus communis L., occurs only in pine forests of the region – in Khrenovsky and Usmansky pine forests.

The largest number of species listed in the Red Data Book of the Voronezh region pertain to Magnoliophyta (224) and 40 of them were found in Khrenovsky pine forest. It totals 17.9% of all protected species pertaining to Magnoliophyta. Khrenovsky pine forest is the only location of Botrychium virginianum (L.) Sw. and Centaurea piniticola Iljin. in the Voronezh region.

All identified rare species refer to 10 latitudinal groups (figure 1).

The diagram shows that a significant portion (59.0%) is accounted for forest species that pertain to boreal, boreal-nemoral, nemoral, boreal-nemoral-forest-steppe latitudinal groups. Thus, rare species with distribution range in the taiga and broad-leaved biomes predominate. This indicates the high importance of the studied forest area in the preservation of the region's phyto-diversity, given its low forest cover.

In addition to the rare taxa already included in the regional Red Data Book, we recommend that Elatine alsinastrum L. be included in the cadastre of rare species of the region.

In June 2020, in the Bobrovsky district on the tract “Green Meadow” of the Khrenovsky forest, we discovered a cenopopulation of Elatine alsinastrum in the soil of a low-lying grass drying swamp that is part of the Bityug River Basin (51°04’43, 40°08’06). Plants were in the phase of flowering. The swamp had completely dried up to the middle of summer and plants were found only in the dried state. This was attributed to rapid change of environmental conditions resulting from drying up of the temporary reservoir. Plants of the Elatine alsinastrum species are well adapted and sensitive to the conditions of soil moisture, have a very short growing season and become fructescent only in favorable conditions, demonstrating a long-term ability to germinate [11, 12].
Figure 1. Spectrum of rare plant species in the latitudinal geographical structure of the flora of the Khrenovsky pine forest (according to the Red Book of the Voronezh Region).

*Elatine alsinastrum* is European-West Asian species that tends to nemoral and steppe biomes with general distribution in Europe, the Caucasus and Central Asia. In Russia, this plant occurs across the European part, the Ciscaucasia and in Western Siberia. Despite its wide distribution in the chernozem zone of the Voronezh Region its locations are limited [8; 13; 14] for several reasons. Firstly, the search for it is time-consuming and not always effective. Secondly, the habitat of the species is confined to unstable ecotones [15; 16].

*Elatine alsinastrum* is listed in the Red Data Book of the Ivanovo region [17], Kurgan region [18], Moscow region [19], the Red Data Book of the Udmurt Republic [20] and regional Red Data Books of Ukraine [21]. Also the species categorized Near Threatened in the Red List of Threatened Species [8].

In the Voronezh Region, this species was previously found only in two protected areas: Voronezh State Nature Biosphere Reserve named after V. M. Peskov and Khopoyrsky State Reserve [8; 14]. The Moscow State University herbarium (MSU) holds collections (09.06.1993) by Shcherbakov, Sokolov, Chernikh [22] from the Bobrov district of the Voronezh region. The specimens were found in vicinity of the Khrenovoe village (1.5 km to the north), at an overgrown lake, in a pine forest depression. There is also information provided by E. V. Pechenyuk [13] about distribution of *Elatine alsinastrum* in the region, on floodplain areas of the Khoper River and Savala River, outside Khopoyrsky Reserve. Here, the species occur in small meadow and forest sedge swamps, and in low-level meadows.

4. Conclusion

Khrenovsky pine forest is a valuable forest area for conservation of rare species in the Voronezh region, and most of them primarily typical for the forest biome. In the pine forest, we found *Elatine alsinastrum* that needs in monitoring and protection throughout the region. Due to the lack of conservation status for Khrenovsky Bor pine forest and timber harvesting in the area, *Elatine alsinastrum* is under serious threat resulting from deforestation and drainage reclamation as predominant anthropogenic factors.

Given low forest cover of the region, the flora of Khrenovsky Bor pine forest includes a large number of rare forest species, and for some of them this forest is the only habitat location in the region. Based on our study, it is necessary to make a proposal to declare the environmental status for Khrenovsky Bor pine forest.
Acknowledgement
This work was done as part of the Steppe Institute Theme (#GP AAAA-A21-121011190016-1).

References
[1] Milkov F N 1977 Natural zones of the USSR (Moscow: Mysl) p 293
[2] Vanin A I 1970 Rare herbaceous and shrub plants - a natural monument in Khrenovsky pine forest (Voronezh: Tsentralno-Chernozemnoye knizhnnoye izdatelstvo) pp 120–124
[3] Agafonov V A, Negrobov V V, Kuznetsov B I, Razumova E V and Avdeeva E 2009 Additional materials to the flora of the Voronez region Vestnik VGU 2 pp 76–82
[4] Agafonov V A, Razumova E V, Kuznetsov B I, Negrobov V V and Prochorova O V 2012 New materials to the flora of the Voronez region Botanicheski zhurnal 2 pp 276–281
[5] Seregin A P 2015 Local flora of the sites of the MSU Zonal Practice: 3. Khrenovskaya Bor (Voronez Region); 4 and 5. Additions to floras Zasek (Tula region) and Polybino (Lipetsk region) Flora of the Khopyorsky State Reserve http://oopt.aari.ru/sites/default/files/documents/pravitelstvo-Voronezhskoy-oblasti/N85_31-01-2018.pdf
[6] 2008 Angiosperms. Gymnosperms. Ferns Red Book of the Russian Federation (plants and mushrooms) (Moscow: Tovarishchestvo nauchnyh izdaniy KMK) pp 36–598.
[7] 2018 Resolution of the Government of the Voronezh Region of January 31, 2018 No. 85 on amendments to the Resolution of the Administration of the Voronezh Region of 01.07.2008 No. 561 http://oopt.aari.ru/sites/default/files/documents/pravitelstvo-Voronezhskoy-oblasti/N85_31-01-2018.pdf
[8] 2018 Specially protected natural territories of Russia, available at: http://oopt.aari.ru/bio/34906
[9] Tolmachev A I 1974 An introduction to the geography of plants (Leningrad: Izdatelstvo Leningradskogo universiteta) p 244
[10] Cherepanov S K 1995 Vascular plants of Russia and neighboring countries (within the former USSR) (Saint Petersburg: Mir i Semya) p 992
[11] Popiela A, Łysko A and Molnar A 2013 Recent distribution of the Euro-Siberiansub-Mediterranean species Elatine alsinastrum L. (Elatinaceae) Acta Botanica Croatica 72(2) pp 375–386
[12] Schweinigruber F H, Kučerová A, Adamec L and Doležal J 2020 Elatinaceae Anatomic Atlas of Aquatic and Wetland Plant Stems (Cham: Springer) pp 126–128, available at: https://doi.org/10.1007/978-3-030-33420-8_24
[13] Pechenyuk E V 2011 On the need to introduce wetland systems and fragments of steppe tracts into the ecological network of the southern forest-steppe Geographic foundations of the formation of ecological networks in Russia and Eastern Europe 1 (Moscow: Tovarishchestvo nauchnyh izdaniy KMK) pp 204–208
[14] Tsvelev N N 1988 Flora of the Khopyorsky State Reserve (Leningrad: Nauka) p 191
[15] Maevskiy P F 2006 Flora of the middle zone of the European part of Russia (Moscow: Tovarishchestvo nauchnyh izdaniy KMK) p 365
[16] Popiela A and Łysko A 2011 The distribution of species of the section Elatinella Seub. (Elatine L., Elatinaceae) in Europe Geobotanist and taxonomist (Cracow) pp 147–159
[17] Shilov M P 2010 Elatine alsinastrum L. Red Book of the Ivanovo region 2 (Ivanovo: IPK «PresStoo») p 128
[18] Naumenko N I 2012 Elatine alsinastrum L. Red Book of the Kurgan region (Kurgan: Izdatelstvo Kurganskogo gosudarstvennogo universiteta) p 299
[19] Shcherbakov A V 2008 Elatine alsinastrum L. Red Book of the Moscow region (Moscow: Tovarishchestvo nauchnyh izdaniy KMK) p 621
[20] Baranova O G 2012 Elatine alsinastrum L. Red Book of the Udmurt Republic (Cheboksary: «Perfectum») p 339
[21] Elatine alsinastrum L. Plantarium: an open online atlas-guide of plants and lichens in Russia and neighboring countries. 2007–2020, available at: https://www.plantarium.ru/page/view/item/14003.html
[22] National depositary bank of living systems Digital Herbarium of Moscow State University https://plant.depo.msu.ru/module/itemsearchpublic