Rare species of natural steppe flora – on prospects for their conservation in Samara region \textit{in situ} and \textit{ex situ}

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Abstract. The virgin steppes survived only in inappropriate for plowing places or in natural reserves are valuable natural heritage due to significant number of world's flora protected species. This article is devoted to comparison of passive and active measures of biological diversity preservation for regional flora rarities. A spatial analysis in the Arc View GIS3.2 system was used for distribution study of protected areas and rare plant species according to the municipal districts of Samara region. The results of the Botanical Garden activities native flora preservation are given using data of its flora department and 2011–2020 delectuses. The number of higher plants species included in regional Red Data Book found in municipal districts varies from 23 to 115, whereas protected areas percentage there does not reach 5%, only in two slightly exceeds it. The natural monuments have low efficiency as natural reserves for highly fragmented steppe ecosystems. The passive measures for the biodiversity conservation need to be supplemented by active ones. Over 10 years, the Botanical Garden of Samara University provides \textit{ex situ} conservation for 39 flowering plants species included in regional Red Book as permanent populations. The fund of \textit{ex situ} plants is successfully used for reintroduction.

1. Introduction

The biological diversity conservation is a set of measures aimed at survival in natural habitats (or, if the latter is impossible, at least in culture) of species or their samples, protected by various acts included in the Red Data Books, stipulated in various international Agreements and Conventions, then there are one way or another declared protected [1]. Measures used to preserve biodiversity are conventionally subdivided into passive and active. Passive measures for the preservation of rare and threatened plant and animal species in their natural habitats (\textit{in situ}) include the Red Data Book system with relevant legal acts, the development and improvement of specialized reserves network complex including wildlife reserves, national parks and natural monuments [2].

One of the active forms of conservation of rare and endangered plant species is their cultivation in botanical, forestry, agricultural and other institutions (\textit{ex situ}). Botanical gardens and arboreta should play a leading role in this matter. According to the Action Strategy of Botanical Gardens, one of the main tasks of each garden should be the preservation of the flora of its own region [3]. At the same time, the forms of activity can be different, from scientific research to the involvement of the local population in work on the protection and restoration of habitats of endangered species [4].

Occupying once vast areas on the plains of the temperate and subtropical belts of the Northern and Southern hemispheres, the steppe plant communities over the past centuries have undergone plowing and other forms of anthropogenic transformation of ecosystems (including overgrazing, technogenic...
pollution, the development of secondary salinization, erosion of the soil cover) [5, 6]. As a result, in European Russian Federation, in countries of Western and Central Europe, virgin steppes fragments were able to survive exclusively in unsuitable for plowing areas or in natural reserves [5]. On the other hand, steppe ecosystems are valuable objects of natural heritage and components of the planet's biological diversity due to the growth of a significant number of protected and rare species here [6].

In the countries of Western Europe, in recent years, an international practice has been developed for the conservation of steppe and meadow ecosystems (valuable herbaceous communities), including measures for the protection and monitoring of communities with a reduced agricultural load or its absence [7-9]. In particular, the environmental legislation of the European Union countries provides for the conservation and monitoring of the so-called “high nature value (HNV) farmlands” (for example, [10, 11]). The tasks are set to identify, including using remote sensing technologies [11], as well as to preserve unique communities and rare species of flora.

As for the Samara region, specially protected natural areas network include reserves of federal level (Zhigulevsky State Natural Biosphere Reserve named after I.I. Sprygina, Samarskaya Luka National Park, Buzuluk Bor National Park - 51288 hectares in the Samara Region) and numerous natural monuments of regional significance - 211 plots of land, water surface and air space above them, where natural complexes and objects with special environmental, recreational, health-improving, scientific, cultural and economic significance [12]. The total percentage of all specially protected natural areas in the Samara region is 5.40%, taking into account only natural monuments - 1.78%.

The work on new flora species identifying for the Samara Region, discovering preserved natural communities with a high proportion of rare components during field surveys, preparing materials for identifying boundaries and designing new natural monuments were carried out by specialists from Samara University during traditional expeditionary field surveys with further office processing. New opportunities for interdisciplinary interaction made it possible to identify the habitats of rare species of flora using modern information technologies - with the involvement of Earth remote sensing (ERS) materials [11]. In 2018, based on the analysis of various types of herbaceous communities typical for the south of the Samara region, we identified target classes with their semantic description. For the classification, the support vector machine and composites of multispectral ERS images of medium resolution for the growing season were used. Experimental testing of the classifier was carried out for the protected area "Fescue-feather grass virgin steppe" with adjacent area, and portion of the protected area "Urochizsche Mulin Dol", which is rich for many rare species from various steppe phytocenoses types. The used approach to the reference areas selection allowed in the future to consciously identify them, taking into account the decryption of the used space images, thereby reducing the volume of field studies and increasing their efficiency. The addition of the target block “Especially valuable natural communities, typical for the Samara region and adjacent regions: Steppes fescue-feathergrass, forb-fescue-feathergrass, forb, fescue-wormwood” to the regional base of reference ground support plots for remote sensing became the result of concrete stage of our work. For the reference plots, a GPS coordinate referencing, a comprehensive survey of the vegetation cover and an assessment of their environmental significance based on the presence of rare species were carried out. The developed technology will be used in the future for the preliminary identification of the localities of valuable plant communities on satellite images, which with a high degree of probability are typical for the growth of rare steppe species, including those recently identified and received the protected status.

The purpose of this article was to compare the possible contribution of passive and active measures (in situ and ex situ forms) to preservation of rare species of the natural flora of the region. The tasks set were to analyze the existing situation of the spatial distribution of rare flora components in the municipal districts of the Samara region and assess the contribution of the Botanical Garden of Samara University to the preservation of rare natural flora.

2. Methodology
The database related to the municipal districts indicators of the Samara region replenished with new target indicators was used to conduct in the ArcView GIS3.2 system a spatial analysis of the distribution of specially protected areas and floristic rarities in relation to the municipal districts of the
Samara region. Statistical data on natural monuments presented in the State Report [12] and characteristics of species included in the Red Data Book of the Samara Region [13] were used as primary data. To present the results of the activities of the Botanical Garden on the preservation of natural flora rare species, quantitative data from the working journals of the flora department of the Botanical Garden and indicators of lists of proposed seeds (delectuses) for 2011-2020 were used.

3. Results and Discussion

Our biotopic confinement analysis showed that out of 224 species of flowering plants included in the 2nd edition of the Red Data Book of the Samara Region [13], 93 species (almost 42%) are components of various types of steppe communities. In particular, 65 species are associated with biotopes of stony steppes, chalk outcrops, rubble slopes, and it is this group that is characterized by the presence of 23 endemics of different geographic confinement, as well as 2 relics.

The results of the visualization of specially protected areas and floristic rarities performed in the ArcView GIS3.2 system relative to the municipal districts of the Samara region (figure 1) showed that with the share of agrocenoses between 51 and 93% of the municipal districts area, the number of higher plants species included to The Red Data Book of the Samara Region (2nd edition) [13] noted in these districts reaches a number from 23 to 115 species (figure 1A). However, specially protected areas in most municipal districts does not reach 5%, and in two districts it slightly exceeds it (figure 1B). An exception to the general picture is the Samara region, which includes the Zhigulevsky state nature reserve and the Samarskaya Luka national park.

![Figure 1](image_url)

**Figure 1.** Some features of plant biodiversity and its conservation in Samara region: the distribution of flowering plants species from Red Data Book of the Samara Region, 2017 [13], across municipal districts (A); the share of protected areas in the corresponding municipal districts (B).

During preparing the second edition of the regional Red Book, the list of plants included in it was changed. This was due both to a critical analysis of the conservation significance of species that had previously received the protected status, and to the identification of rare species new to the region in the preserved natural biotopes. As a result, for some of the municipal districts of the region, there was a formal decrease in the number of species of flowering plants recorded here in the Red Data Book of the Samara Region (by a maximum of 34 species). For others, on the contrary, this indicator increased (by a maximum of 57 species). We presented a picture of these changes in the form of a map diagram (figure 2).

The maximum increase in the number of rare species occurred in Samarskaya Luka and Trans-Volga region, where, among other things, herbaceous communities of stony steppes and other types of herbaceous communities were found. For three municipal districts - Kinelsky and Borsky (the center
and east of the region), as well as Bolshechernigovsky (the extreme south of the region, where the share of agrocenoses is maximum), the increase in the number of rare species ranged from 13 to 17 species, among which the newly identified components of various steppe communities are widely represented.

The growing role of these areas for the floristic diversity preservation of the region is also determined by the prospects for finding here species new for the Samara region, confined to various types of steppe communities. However, it should be noted that the status of natural monuments is not a sufficient guarantee of vegetation cover protection also as its especially vulnerable components from negative anthropogenic impact, including grazing in excess of the permissible grazing load, or grass fires (steppe fires). We have repeatedly recorded such facts during field surveys. This, like the preservation of steppe ecosystems in their highly “fragmented” version, gives no reason to hope for the rare flora components preservation under the existing protection regime, which is essentially not supported by real measures. Currently, the region officials are working on the buffer zones allocation for regional natural reserves, which will help to increase their environmental efficiency. Nevertheless, the implementation of the above-mentioned passive measures for floristic diversity preservation in modern conditions requires a mandatory addition of active measures. Their diverse and successful implementation has been carried out for a long time by the efforts of the employees of the Botanical Garden of Samara University.

The natural flora rare plants of Samara Region and other regions have been included in the collections of the Botanical Garden since 1932. They were planted in specially prepared areas of the local flora and taxonomy of higher plants, along the banks of ponds, in the ornamental center of the garden. The collection site of rare plants of natural flora has existed in the botanical garden since 1977 and is the main base for studying the factors limiting the development of these plants in culture. The collection of the flora department is formed in two directions: rare plants of the Samara region and plants of other regions included in the Red Book of the RSFSR and the Red Book of the USSR. For the formation and replenishment of the collection of rare plants of the regional flora, the local material of seeds and living plants is widely used, which, in accordance with the existing rules and restrictions, is collected during expedition trips. Many plant species are obtained by seed exchange. Undoubted value are those few species that have survived since 1977 - the stage of the beginning of the formation of the collection fund of the flora department (Gypsophila zhegulensis Krasnova, Paeonia tenuifolia L., et c.).

The flora department collection includes more than 800 flowering plants taxa that are grown on collection and display areas: local flora, steppe, exposition "Flora of the Zhiguli Mountains", rock gardens, arboretum. Of these species, 183 are rare and endangered, including 50 from the Red Data Book of the Samara Region (2nd edition) [13]. Population groups of most taxa are currently represented by 10 or more specimens, for many species the number in groups has reached 50

**Figure 2.** The number of flowering plants species in the Red Data Book of the Samara Region in municipal districts: changes caused by their list alteration (from first to second edition, 2007-2017).
Glycyrhiza glabra L. and others, 100 or more specimens (Clematis integrifolia L., Iris aphylla L., Iris halophila Pall., Iris pumila L., Iris sibirica L., Paeonia tenuifolia L., Primula macrocalyx Bunge, etc.). The main collections of the department are the generic complexes Iris, Paeonia, Allium, Dianthus, Penstemon, Lilium, Tulipa, Sedum, Primula, Echinacea, Monarda, Thymus, etc. The flora department has a sufficient collection of specific irises from different sections. It should be noted that representatives of the genus Iris L. characterized by high vitality, they go through all stages of ontogenetic development, are highly decorative, bear fruit and form viable seeds. Many of them were included in the Red Data Books and various lists of rare plants (Iris laevigata Fisch. et Mey. included in the Red Data Book of the USSR; Iris ensata Thunb., Iris notha Bieb. and Iris pumila L. - in the Red Data Book of the RSFSR; Iris aphylla L., Iris pseudacorus L., Iris pumila L., Iris sibirica L. are included in the list of protected plants). Among the plants included in the Red Book of the Samara region, there are species that have long been present in the collections of the Botanical Garden of Samara University. For them, the department of flora developed a regionally optimized agrotechnology for growing in culture, taking into account the specific agro-climatic conditions of the forest-steppe of the Middle Volga region (Laser trilobum (L.) Borkh., Lilium martagon L., Paeonia tenuifolia L., Primula macrocalyx Bunge, Iris pseudacorus L., Iris pumila L., Iris sibirica L., etc.).

The preservation, replenishment and comprehensive study of the collection fund of plants are important areas of research in natural flora in ex situ conditions. Data on the number of taxa from the collection of the flora department, whose seeds were offered annually for exchange in delectus, can be considered as one indicator of the effectiveness of ex situ conservation. Figure 3 shows the dynamics of taxa number changes for which the flora department offered seeds for exchange during analysing decade. A slight decrease in the number of taxa from 217 (2011) to 193 (2014) was then replaced by a steady increase to the level of 307 ... 308 taxa.

When working with rare plants collection, as mentioned above, a transition was made from single specimens’ cultivation to the population groups formation. For herbaceous plants, this makes it possible, using a relatively limited plots area, to have a fund of different aged specimens that can be used for vegetative propagation, give seeds, and ultimately serve as the basis for an exchange fund and plant reintroduction.

![Figure 3. Dynamics of seed abundance for natural flora taxa in delectuses of the Botanical Garden of Samara University, 2011-2020.](image-url)
are included in the second edition, 6 were presented in the first, but are absent in the second edition. 24 of these species have been stable components of the collection fund for a long time; their seeds of their own reproduction in the last 10 years have been annually offered to colleagues from domestic and foreign botanical gardens in the list of proposed seeds (delectus). These plants are characterized by different rarity status and are unequally widespread in the territory of the Samara region. Among them are the components of various steppe communities, including those confined to calcareous outcrops and halophytic ones (Aster alpinus L., Globularia punctata Lapeyr., Allium obliquum L., Gypsophila zhegulensis A. Krasnova, Iris aphylla L., Iris halophila Pall., Iris pumila L., Linum perenne L., Plantago maxima Juss. ex Jacq., Potentilla erecta (L.) Raeusch, Thymus zhegulensis Klok.et Shost. et al.).

In recent decades, in the Samara region, there has been a tendency to a slight decrease in the area of agricultural land due to the transfer of land to fallow lands, fodder lands, etc. On them, as a result of secondary successional changes, revitalization became possible - the restoration of natural plant communities with a gradual replacement of ruderal species with the most common steppe and meadow ones. But the most valuable elements of the plant community, especially rare and threatened ones, cannot appear here without reintroduction - the introduction of seeds or living plants by human efforts. Reintroduction is still experimental in many countries around the world. Their mass distribution is hindered by the need for financial costs for the actual reintroduction and subsequent long-term monitoring.

Employees of the Botanical garden of Samara University, having significant experience in growing species of natural flora ex situ, have been carrying out work on the reintroduction of rare plants into nature since 1994. In accordance with a thoroughly worked out methodology, for 2 species that disappeared in the region, growth in natural biotopes was restored. One of them is the fine-leaved peony Paeonia tenuifolia L. New growing areas were also created for the species with a single point of distribution in the region (Cossack juniper Juniperus sabina L.), for which a habitat destroyed by fire on the slope of Zolnenskaya Mountain (Zhigulevsky State Reserve) was also restored. New population groups have also been formed for 7 species of different rarity categories. This work was supported by Botanic Gardens Conservation International (BGCI).

Thus, for conservation of rare steppe flora, it should be considered necessary to use a complex of passive and active measures, in situ and ex situ conservation of plants as part of integrated regional strategy for the biological diversity conservation. The Governor of the Samara region D.I. Azarov recently tasked the specialists with developing this strategy.

4. Conclusions

Thus, the number of higher plants species included in the Red Data Book of Samara region found in municipal districts varies from 23 to 115, whereas the protected areas percentage in these districts does not reach 5%, only in two it slightly exceeds it. Insufficient efficiency of natural monuments as a form of protected areas and the preservation of steppe ecosystems in their “fragmented” version do not give grounds to hope for the rare flora components preservation under the existing regime of protection, which is essentially not supported by real measures. The implementation of passive measures for the preservation of floristic diversity in the Samara region requires a mandatory supplement with active measures, including those implemented by the employees of the Botanical Garden of Samara University. In particular, over the past 10 years, the ex situ conservation of permanent population groups for 39 species of flowering plants included in the Red Data Book of the Samara Region has been carried out. The reserve fund of rare plant species formed in culture is successfully used for reintroduction into natural communities.

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