

Inventory and characteristics of rare medicinal plants in the Republic of Tatarstan, Russia

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Abstract. This work presents the structural analysis of rare medicinal plants of the flora in Tatarstan, Russia. The wild medicinal flora of Tatarstan includes 357 species, 9.5% of which have the status of protected plants. In Tatarstan, the protected species belonging to the subkingdom Higher spore plants are represented by two classes, two families and three genera. Protected Seed plants include Gymnosperms, represented by one class and one family, but the basis of the flora is formed by Angiosperms, including two classes, 15 families and 30 species. The most numerous families of rare plants in Tatarstan are Orchidaceae and Ericaceae. All representatives of this family are tuberiferous plants. Limited vegetative propagation leads to the reduction in species abundance. Plants of the family Ericaceae are confined to the ecological-cenotic group of oligotrophic plants, the distribution of which is associated with rare communities of sphagnum bogs. In general, on the territory Tatarstan, the composition of protected medicinal plants is dominated by wetland species. Among rare plants, more than 40% are located on the border of their range. However, the most common limiting factor for rare and endangered species is the direct or indirect influence of human activities on the natural habitats of medicinal plants.

1 Introduction

The biodiversity conservation as a necessary condition for the sustainable existence of the biosphere is a fundamental research area [1-4]. Within this field of research, special attention is paid to the study and preservation of rare medicinal plants. Studying the state and conservation of medicinal plant populations is one of the global challenges, which requires coordinated approaches [5]. Rare species constitute the most vulnerable part of the flora. Less abundant plants with a limited range are especially at risk. The presence of rare species in a plant community is one of the indicators of its uniqueness and vulnerability. For the Republic of Tatarstan, Russia, where most natural plant habitats have been disturbed or destroyed, identifying unique communities is an important step in the study and conservation of biodiversity.

The vulnerability of rare medicinal species is determined by both internal and external factors, including the characteristics of the ecological-cenotic environment and the intensity

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of anthropogenic impacts [6-8]. In addition to the direct removal of species from communities, the negative anthropogenic impact is associated with a significant reduction in the area of natural habitats as well as with the fragmentation of communities and transformation of landscape complexes. To identify rarity criteria and vulnerability factors, it is necessary to analyze the systematic, ecological-cenotic and morphological characteristics of rare medicinal plants. This allows to assess the influence of factors and biological characteristics of plants that limit their competitiveness and abundance in phytocenoses. Updating the information on the ecological and phytocenotic locations of rare medicinal plants, their systematization and analysis contributes to the development of integrated approaches for their conservation [5]. This includes the creation of species inventory systems and condition monitoring, as well as the need for coordinated conservation methods, based on both *in situ* and *ex situ* strategies [9].

The aims of this study were to analyze the species composition of rare medicinal plants and to characterize the ecological-cenotic and morphological structure of rare medicinal plants of the flora in Tatarstan, Russia.

2 Materials and methods

A consolidated list of species of rare medicinal plants constituting the flora in Tatarstan was compiled [10-11]. The systematic position of vascular plant taxa was given in accordance with the international database The World Checklist of Vascular Plants [The World Checklist of Vascular Plants: URL: <https://wcvp.science.kew.org>]. Floristic spectra were compiled. Indicators of taxonomic richness were considered, which included the total numbers of species, genera and families. To carry out the ecological-cenotic analysis, we used the Database of Ecological-Cenotic Groups, which was developed at the Institute of Mathematical Problems of Biology of the Russian Academy of Sciences using methods of the mathematical analysis [12]. This system of ecological-cenotic groups is consistent with the functional response groups of S. Lavorel and E. Garnier [13]. Ecological-cenotic groups contain plants with the same response to abiotic and other environmental factors. The database contains information about 1166 vascular plants belonging to 15 ecological-cenotic groups in the taiga, subtaiga and broad-leaved zones of European Russia. Life forms were characterized according to the classification of N.P. Savinykh et al. [14].

3 Results and Discussion

The wild medicinal flora of the Tatarstan Republic included 357 species, of which 34 species have the protected status. In percentage terms, this is 9.5% of the total number of flora species (Figure 1).

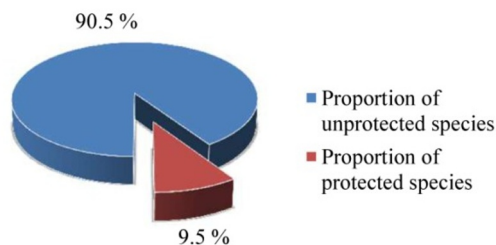


Fig. 1. The percentage of protected species in the wild medicinal flora of Tatarstan.

List of rare medicinal species of Tatarstan. Species names are given in accordance with [WFO (2024): World Flora Online. Published on the Internet; URL: <https://www.worldfloraonline.org>].

- Marsh mallow (*Althaea officinalis* L.).
- Marsh Labrador tea (*Ledum palustre* L.) *Rhododendron tomentosum* Harmaja.
- Northern firmoss (*Huperzia selago* (L.) Bernh. ex Schrank & Mart.).
- Marsh grass of Parnassus (*Parnassia palustris* L.).
- Crowberry (*Empetrum nigrum* L.).
- Red baneberry (*Actaea rubra* (Aiton) Willd.).
- Marsh gentian (*Gentiana pneumonanthe* L.).
- Hog's fennel (*Peucedanum ruthenicum* M.Bieb.).
- Moonwort (*Botrychium lunaria* (L.) Sw.).
- Alpine delphinium (*Delphinium elatum* L.).
- Bog stitchwort (*Stellaria uliginosa* Murray).
- Lesser centaury (*Centaurium pulchellum* (Sw.) Druce).
- Common centaury (*Centaurium erythraea* Rafn).
- Sea lavender (*Limonium sareptanum* (A.K.Becker) Gams).
- Cranberry (*Vaccinium oxycoccos* L.).
- Fragrant orchid (*Gymnadenia conopsea* (L.) R.Br.).
- Nymphaea candida (*Nymphaea candida* C.Presl) *Nymphaea candida* J.Presl & C.Presl.
- Tormentil (*Potentilla erecta* (L.) Raeusch.).
- Lesser butterfly-orchid (*Platanthera bifolia* (L.) Rich.).
- Dwarf Russian almond (*Prunus tenella* Batsch).
- Marsh lousewort (*Pedicularis palustris* L.).
- Yellow foxglove (*Digitalis grandiflora* Mill.).
- Burnt orchid (*Neotinea ustulata* (L.) R.M.Bateman, Pridgeon & M.W.Chase).
- Early marsh-orchid (*Dactylorhiza incarnata* (L.) Soó).
- Marsh-orchid (*Dactylorhiza russowii* (Klinge) Holub).
- Heath spotted-orchid (*Dactylorhiza maculata* (L.) Soó).
- Common spotted orchid (*Dactylorhiza fuchsii* (Druce) Soó) *Dactylorhiza maculata* subsp. *fuchsii* (Druce) Hyl.
- Common club moss (*Lycopodium clavatum* L.).
- Bog-rosemary (*Andromeda polifolia* L.).
- Round-leaved sundew (*Drosera rotundifolia* L.).
- Kinnikinnick (*Arctostaphylos uva-ursi* (L.) Spreng.).
- Sea grape (*Ephedra distachya* L.).
- Everlasting flower (*Helichrysum arenarium* (L.) Moench).
- Military orchid (*Orchis militaris* L.).

The 34 protected flora species belong to 18 families and 28 genera (Table 1). The most numerous family was Orchidaceae, represented by eight species and five genera. Many species of this family grow on the territory of Tatarstan under non-optimal conditions. They are very decorative and thus, are often collected for bouquets. The second largest family was Ericaceae, represented by five species and three genera. These species grow mainly in peat and sphagnum bogs; some species are used for food or collected as medicinal raw materials (e.g., *Vaccinium oxycoccos*, *Empetrum nigrum*, and *Arctostaphylos uva-ursi*). Noticeably, the species *Empetrum nigrum* has the protected category of 0 (probably extinct species). The Gentianaceae family was represented by three species and two genera. One of the species (*Gentiana pneumonanthe*) grows in flooded meadows, the number of which is small, while the other two species (*Centaurium pulchellum* and *C. erythraea*) are annual

plants, the life of which is very dependent on the specific climatic conditions of a year. The Lycopodiaceae family was represented by two species and two genera. Both species (*Huperzia selago* and *Lycopodium clavatum*) are associated with small coniferous forests with specific conditions. The remaining families consist of one genus and one species per family.

Table 1. Genera and species in the families of protected medicinal plants in Tatarstan.

Family	Number of genera		Number of species		Ratio
	Number	%	Number	%	Number of genera: number of species
Caryophyllaceae	1	3.57	1	2.94	1:1
Celastraceae	1	3.57	1	2.94	1:1
Compositae	1	3.57	1	2.94	1:1
Droseraceae	1	3.57	1	2.94	1:1
Ephedraceae	1	3.57	1	2.94	1:1
Ericaceae	3	10.71	5	14.71	1:1.67
Gentianaceae	2	7.14	3	8.82	1:1.5
Lycopodiaceae	2	7.14	2	5.88	1:1
Malvaceae	1	3.57	1	2.94	1:1
Nymphaeaceae	1	3.57	1	2.94	1:1
Ophioglossaceae	1	3.57	1	2.94	1:1
Orchidaceae	5	17.86	8	23.5	1:1.6
Orobanchaceae	1	3.57	1	2.94	1:1
Plantaginaceae	1	3.57	1	2.94	1:1
Plumbaginaceae	1	3.57	1	2.94	1:1
Ranunculaceae	2	7.14	2	5.88	1:1
Rosaceae	2	7.14	2	5.88	1:1
Umbelliferae	1	3.57	1	2.94	1:1
Total	28	100	34	100	

Representatives of the kingdom Plants belong to 2 subkingdoms: Higher spore plants and Seed plants. Protected species of the subkingdom Higher spore plants belong to 2 classes, 2 families and 3 genera. Protected Seed plants include Gymnosperms, represented by 1 class and 1 family, but the basis of the flora is formed by Angiosperms, including 2 classes, 15 families and 30 species (Figure 2).

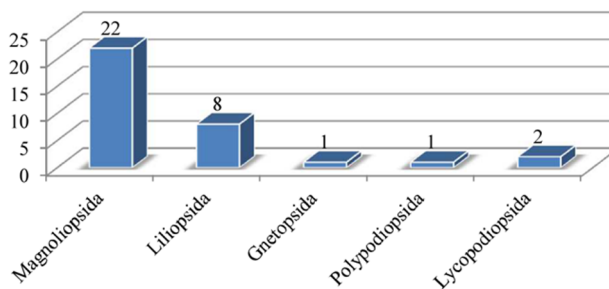


Fig. 2. Taxonomic structure of rare medicinal plants in Tatarstan, Russia.

From the rare and protected plants in Tatarstan, 2 species (*Neotinea ustulata* and *Dactylorhiza russowii*) are included in the Red Data Book of the Russian Federation [URL: <https://redbookrf.ru>]. Among the medicinal plant species protected by law in Tatarstan, 41% are species of the second category (decreasing species) and also 41% are of

the third category (rare species) (Table 2). Four species are endangered: *Huperzia selago*, *Stellaria uliginosa*, *Limonium sareptanum* and *Neotinea ustulata*. Two species, *Empetrum nigrum* and *Dactylorhiza russowii*, are considered probably extinct.

Table 2. Distribution of protected medicinal plant species by rarity categories.

Parameter	Number of species			
	0: Probably extinct	1: Endangered	2: Decreasing	3: Rare species
Number	2	4	14	14
Percentage, %	6	12	41	41

The decline in abundance and rare occurrence of Red Data Book species can be explained by natural causes. For many rare medicinal plants (14 species out of 34, i.e. 41%), the territory of the Tatarstan Republic is located near the boundaries of their natural ranges. Eight species are near the southern border of their range: *Huperzia selago*, *Lycopodium clavatum*, *Delphinium elatum*, *Rhododendron tomentosum*, *Empetrum nigrum*, *Vaccinium oxycoccos*, *Andromeda polifolia*, and *Arctostaphylos uva-ursi*. Five species are near the northern border of their range: *Ephedra distachya*, *Prunus tenella*, *Althaea officinalis*, *Centaurium pulchellum*, and *Limonium sareptanum*. One species, *Peucedanum ruthenicum*, occurs near the northeastern border of its range. The rarity of *Digitalis grandiflora* can be explained by the fact that on the territory of Tatarstan, there is only a section of this species' range, which is isolated from the main section. The relict status of the species (*Delphinium elatum* and *Empetrum nigrum*), the low competitiveness of the species in phytocenoses (*Botrychium lunaria*, *Dactylorhiza russowii*, *Orchis militaris*, *Andromeda polifolia*, *Arctostaphylos uva-ursi*) and other reasons, such as low reproductive capacity, slow development and reproduction of species, are also considered as natural reasons for the decline in the abundance of rare medicinal plants species.

However, the most common limiting factor for rare and endangered species is the direct or indirect influence of human activity on the habitats of medicinal plants. This might contribute to the decrease in the abundance of the majority of rare medicinal plants on the territory of Tatarstan: e.g., *Althaea officinalis*, *Rhododendron tomentosum*, *Huperzia selago*, *Parnassia palustris*, *Empetrum nigrum*, *Actaea rubra*, *Gentiana pneumonanthe*, *Botrychium lunaria*, *Delphinium elatum*, *Stellaria uliginosa*, *Centaurium erythraea*, *Vaccinium oxycoccos*, *Gymnadenia conopsea*, *Nymphaea candida*, *Potentilla erecta*, *Pedicularis palustris*, *Neotinea ustulata*, *Dactylorhiza incarnata*, *Dactylorhiza maculata*, *Dactylorhiza fuchsii*, *Andromeda polifolia*, *Arctostaphylos uva-ursi*, *Ephedra distachya*, *Helichrysum arenarium*, *Orchis militaris*. Among different forms of anthropogenic pressure, even recreation can have serious consequences for the natural phytocenoses in which medicinal plants grow. For example, *Lycopodium clavatum*, *Botrychium lunaria*, *Gymnadenia conopsea*, *Platanthera bifolia*, *Neotinea ustulata*, *Dactylorhiza maculata* subsp. *fuchsii*, *Orchis militaris*, *Nymphaea candida*, *Actaea rubra*, *Prunus tenella*, *Gentiana pneumonanthe*, *Centaurium erythraea*, and *Arctostaphylos uva-ursi* suffer from trampling and collecting into bouquets.

Often, the impact of anthropogenic factors on plant habitats is superimposed on the natural causes of a decline in medicinal plant species abundances. In addition, populations of some protected species of medicinal plants are exploited as sources of medicinal raw materials (e.g., *Lycopodium clavatum*, *Potentilla erecta*, *Althaea officinalis*, *Digitalis grandiflora*), which is completely unacceptable. The mentioned probable causes for the decline in the abundance of rare species of medicinal plants are in line with other reports, e.g., the flora analyses conducted on the territory of the Chuvash Republic, Russia [15].

Analysis of the totality of plant species according to the ecological-cenotic groups is carried out to identify the diversity of biotopes and regimes of the main environmental factors, as well as to classify communities in a given region [16]. According to the

ecological-cenotic analyses, the composition of protected medicinal plants in Tatarstan is dominated by wetland species (Wt), the growth of which is associated with coastal and aquatic habitats, wet meadows and lowland swamps (Fig. 3). These included *Althaea officinalis*, *Centaurium pulchellum*, *Parnassia palustris*, *Pedicularis palustris*, *Stellaria palustris*, *Nymphaea candida*, as well as such representatives of the Orchidaceae family as *Dactylorhiza incarnata*, *D. maculata*, and *Orchis militaris*. Despite the high seed productivity of tuberoid orchids, maintaining the spatial-ontogenetic structure of their coenopopulations is possible in the presence of areas with reduced interspecific competition [17]. Among the species of this group, only *Nymphaea candida* belongs to true aquatic plants, while the distribution of other plants is determined by the excessive soil moisture.

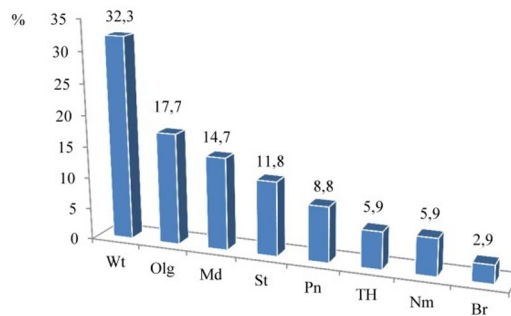


Fig. 3. Ecological-cenotic characteristics of medical plants included in the Red Data Book of the Tatarstan Republic. Ecological-cenotic groups: Br – boreal, Nm – nemoral, Nt – nitrophilic, Pn – pine forest, Olg – oligotrophic, TH – boreal tall-grass, Md – meadow-edge, St – steppe, Wt – wetland.

The second largest ecological-cenotic group included oligotrophic plants (Olg), the distribution of which is associated with sphagnum bogs. It includes shrubs of the Ericaceae family, such as *Rhododendron tomentosum*, *Oxycoccus palustris*, *Andromeda polifolia*, *Empetrum nigrum*, as well as representatives of other families, e.g., *Drosera rotundifolia* and *Dactylorhiza russowii*. The Republic of Tatarstan is characterized by a highly dissected topography, a wide distribution of carbonate source rocks, a relatively low climatic coefficient, which determines the weak swampiness of the territory [18] and, accordingly, the lack of suitable habitats for plants of raised and transitional bogs.

The number of meadow-edge, steppe, and pine forest species among rare and protected medicinal plants was small (9-15%). These included *Digitalis grandiflora*, *Centaurium erythraea*, *Amygdalus nana*, *Limonium sareptanum*, as well as *Arctostaphylos uva-ursi* and *Helichrysum arenarium*. Nemoral *Dactylorhiza maculata* subsp. *fuchsii* and boreal tall grasses (e.g., *Delphinium elatum*) formed the smallest groups.

Based on the analyses, about 50% of all vulnerable and rare species of medicinal plants in Tatarstan prefer the habitat conditions of lowland and flooded meadows, raised bogs, while the growth of more than 30% of species is associated with more drained and dry habitats of meadows, steppes and pine forests. The remaining species are adapted to the conditions of taiga and nemoral forests.

The analysis of life forms (Table 3) showed that many rare medicinal species are plants that are characterized by a low ability for vegetative propagation (rachis-rootet, tuberiferous, short-rhizomed, and cluster-rooted life forms), and these plants are represented in various types of vegetation in Tatarstan. Rare medicinal plants included many species of the family Orchidaceae with a tuber-forming, tuberiferous life form. In the spectrum of life forms of rare medicinal plants of the Tatarstan flora, the share of such plants was about 27%. In natural phytocenoses, vegetative propagation is not typical for these plants, which probably leads to a reduction in population abundances. Noteworthy,

there is a high proportion of shrubs and evergreen shrubs (family Ericaceae), the total share of which was 20%. The plants are confined to rare azonal communities, and the reduction in their abundances is determined by the reduction in natural habitats. These are also probable reasons for the rarity of the semi-parasitic *Pedicularis palustris* and the carnivorous brush-root perennial *Drosera rotundifolia*. For annual plants, the reduction is associated with the narrow ecological valency of the species. Ruderal species are confined to the conditions of wet, disturbed habitats.

Table 3. Life forms of rare medicinal plants in Tatarstan.

Life form	Number	Percentage, %
Evergreen undershrubs	5	16.7
Undershrubs	1	3.3
Tuberiferous plants	8	26.7
Rachis-rooted	5	16.7
Short-rhizomed	4	13.3
Long-rhizomed	1	3.3
Aquatic long-rhizomed	1	3.3
Cluster-rooted	1	3.3
Carnivorous, cluster-rooted	1	3.3
Subperennials, semi-parasitic	1	3.3
Annuals	2	6.7

4 Conclusions

One of the factors in the transition of plants to the category of rare species is the reduction of atypical plant communities, especially for species with limited vegetative propagation and narrow environmental tolerance. The relict status of species, the location of species on the border of the natural range, the collection of decorative and medicinal plants by people, as well as other anthropogenic impacts are also important factors. The majority of rare species in Tatarstan belong to the Orchidaceae family, and according to their ecological-cenotic location, to lowland and flooded meadows, raised bogs, with rarity categories 2 (decreasing species) and 3 (rare species). The species *Huperzia selago*, *Stellaria uliginosa*, *Limonium sareptanum* and *Neotinea ustulate* are endangered, while two species, *Empetrum nigrum* and *Dactylorhiza russowii*, are considered probably extinct.

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