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Unique plant community with *Osmorhiza aristata* Rafin. in ecosystems of ribbon pine forests in the south of Western Siberia

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Abstract

The article presents the results of a geobotanical study of the plant communities with the participation of a relic species *Osmorhiza aristata* Rafin. on the territory of the Barnaul Ribbon Forest (Altai Krai). The study of *Osmorhiza aristata* population was carried out during three growing seasons of 2019–2021. The phytocoenotic relationship in the conditions of habitats in Siberia, morphological characters, and origin were determined, which make it possible to suggest the natural origin of the species in the territory of the hemiboreal lowland forests in the south of Western Siberia. We determined the species composition of the forest communities in the areas of *Osmorhiza aristata* growth. In these communities, the number of higher vascular plants totals 30 species. The habitat characteristics of *Osmorhiza aristata* in the ribbon pine forests were identified. The species under consideration is included in the Red Data Book of Altai Krai (2016), the Red Data Book of the Altai Republic (2007), the Red Data Book of Kuzbass (2021), as well as in the Red Data Book of the Russian Federation (2008). Before 2019, there were four growing areas of *Osmorhiza aristata* known in the spruce-fir forests of Western Altai. The species was not found in the lowland part of the region. We established a new locality of the stenotopic species *Osmorhiza aristata*, which is not characteristic of the local flora, in the territory of Western Siberia.

Keywords

Relic, ribbon forests, *Osmorhiza aristata*, disjunctive distribution, Western Siberia

Introduction

In any territory, as a rule, there are a considerable number of species that are a part of modern plant communities, but are the remains of the past eras' floras. The ranges of these species are often isolated and disjunctive. This disjunction is associated with the history of the flora, namely with global changes in the climate and the ecological situation in general, which occurred from the past period to the present day. The study of relics and their ranges makes it possible to understand the diversity of the elements that make up the flora, to explain the patterns and features of their modern distribution.

The problem of relic plants has been discussed in the domestic scientific literature for more than a hundred years. The ideas of D.I. Litvinov, I.I. Sprygin, E.V. Vulf, S.I. Korzhinsky, E.M. Lavrenko greatly influenced the formation of modern concepts of the relic origin and characteristics in the flora (Ivanova, Kazanovsky, Kiseleva 2016; Silantyeva et al. 2021; Davydov et al. 2018; Elenevsky and Radygina 2002; Yelesova et al. 2020; Yelesova et al. 2021; Kamelin et al. 1999; Klyuykov et al. 2016; Krapivkina 2007, 2009).

The problem of studying relic plant species is relevant in botany at the present time. Modern relic finds are of interest for elucidating the paths of florogenesis, whereas the locations of relic species give us an idea of the boundaries of certain vegetation complexes in different geological epochs (Krivenko and Chernysheva 2019; Lavrenko 1930; Nekratova and Nekratova 2013; Kharitontsev 2008; Kholina et al. 2021; Chubarov 2016; Sheremetova and Khrustaleva 2019). A lot of studies have been devoted to the results of *Osmorhiza aristata* introduction (Vesnina 2001, 2002, 2005).

The authors established a new location of the stenotopic species *Osmorhiza aristata* in the territory of Western Siberia, which is not characteristic of the local flora. The studied community with the coenopopulation *Osmorhiza aristata* is a "buffer" in the structure of the ribbon pine forests of Altai Krai.

The Barnaul ribbon forest, where the research was carried out, crosses two natural zones from the northeast to the southwest – the steppe zone within the Kulunda (lowland) plain and the forest-steppe zone within the Priobskoye plateau. Theforest-steppe zone within the region is divided into three subzones: north-forest- steppe, middle-forest-steppe, southern-forest-steppe. The steppe zone comprises dry-steppe, arid-steppe and moderate-arid-steppe subzones. The forest is locatedin the Barnaul hollow of the ancient runoff. Being an intrazonal phenomenon, the Barnaul Ribbon Forest accounts for significant changes in the bioclimatic and phytocoenotic conditions of the territory.

Soddy-podzolic soils are formed under the Barnaul ribbon forest on the ancient alluvial sands of the ancient runoff hollows of the Kasmalinskaya assise of the Neo-Pleistocene. The parent rocks for soils are fine and medium-grained loose sands. Groundwater is close (excluding the southeastern ancient deltaic part) – at the depth of 2-3 and 4 m. The soils of the pine forest sands themselves are divided into

two groups according to a set of characteristics: soddy-podzolic sandy-sabulous soils, formed on elevated hilly areas of the forest, and soddy-podzolic gleic soils, developed along the mesorelief depressions in the conditions of constant contact with groundwater.

By the nature of the vegetation, as compared to other ribbon pine forests, such as Burlinsky (Aleussky), Kulundinsky, Kasmalinsky, the Barnaul ribbon pine forest, located further to the south, bears a lot of steppe coenoelements that are also found in sand dunes.

A geobotanist G.G. Pavlova (1963) notes that the nature of coenoses changes from the northeast to the southwest along the ribbon forest. Thus, the associations of mesophilic herbaceous and herbaceous-cowberry pine forests are widespread in the northern part of the forest, while in the southern parts, they are replaced by the steppe-grass, herbaceous lichen and dead cover communities. However, the process of xerophytization of pine forests when moving from northeast to southwest is somewhat weaker than the xerophytization of grass vegetation formations. Similar patterns have persisted to the present day. Moreover, it is very important to pay attention to the following observation of the researcher. The pine forest as a vegetation community creates its own unique phytoclimate, which more or less limits the penetration of other plants that are not characteristic of it into the forest. Therefore, the influence of the steppe vegetation on the grass stand of the undisturbed forest is relatively weak and is observed only in a wide strip along the border with the steppe, whereas a much stronger factor influencing the character of the forest is the human activity.

In any territory, as a rule, there are a considerable number of species that are a part of modern vegetation communities, but at the same time, are the remains of the floras of the past geological epochs. Their ranges are disjunctive, often isolated. This disjunction is connected with the history of the flora, namely, with global changes in the climate and the ecological situation in general, which took place from the Tertiary period to the present day.

The study of the relics and their ranges makes it possible to understand the diversity of the elements that make up the flora, to explain the patterns and features of their modern distribution, to solve many florogenetic issues, namely, to outline the proposed ways and times of the species movement, i.e. to trace the stages of the flora formation.

The purpose of the work is to establish the geographical distribution of *Osmorhiza aristata*, to study the phytocoenotic confinement to the new locations and the ecological features in Siberia.

The authors proposed two hypotheses for a new location of *Osmorhiza aristata* in Western Siberia, which is not characteristic of the local flora:

1. The relic species might be characterized by a disjunction of the range, which has exclusively natural-historical (not anthropogenic) reasons associated with the ecological features of the relic.

2. Relic species may have the ability to spread to the new territories as advents, which could be associated with their adaptation to the characteristics of the habitats.

Material and methods

In the work, we applied route methods, during which geobotanical descriptions, mapping of work points, herbarization and photography were carried out. After the field work was completed, office data processing was carried out. Geobotanical descriptions were carried out on the sites 400 m^2 in size.

The coenopopulation of *Osmorhiza aristata* is represented in the Barnaul forestry in the vicinity of the Barnaul city, Altai Krai (Fig. 1).

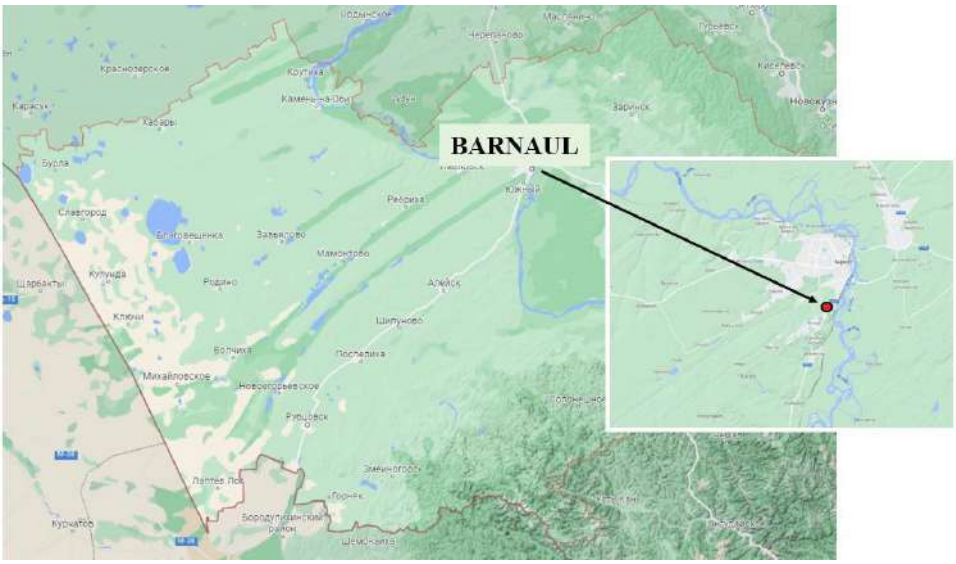

Figure 1. Map-scheme of *Osmorhiza aristata* locations in the territory of Altai Krai.

Results

The relic species under study, *Osmorhiza aristata* Rafin., is a representative of the genus *Osmorhiza*, the family Apiaceae (Umbellifers), a polycarpic herb with a simple or branched in the upper part stem, 30-80 cm tall, with short rhizomes and secondary roots. The leaves are broad triangular, thin, bright green, twice trifoliate, pubescent on both sides with sparse hairs, 10-30 cm long, 7-20 cm wide. Umbels are simple or compound with several umbellets on a flowering shoot, 12-25 cm in diameter, corymbose, on long legs, with 2-9 glabrous, noticeably unequal rays (most often 5). There are no involucres or they are from 1-5 early falling leaves. The

leaflets of the involucre are ciliated, entire, lanceolate. The teeth of the calyx are not pronounced. Petals are white, glabrous, dedalous at the apex, with a flower part bent inwards. Fruits (cremocarps) are 10-25 mm long, 2-2.5 mm wide. (Pimenov et al. 1996).

It is characterized by weak seed reproduction, due to the peculiarities of the corcule development. Seed germination coefficient is low (Kamelinet al. 1999). In relation to the habitat moistening, the species is a mesophyte; in relation to light, it is a scioheliophyte; and to heat, it is a microthermophyte (Silantyeva an Elesova, 2014). In Altai Krai, it occurs in coniferous spruce-fir and mixed forests in the territory of Western Altai (Zmeinogorsky, Soloneshsky, Charyshsky administrative districts). The general distribution comprises Russia (Altai, the Far East, Sakhalin, the Caucasus), Kazakhstan, China. In the lowland hemiboreal forests, the species was first found by the staff of the Botany Department, the Institute of Biology and Biotechnology, Altai State University, in the territory of the Barnaul ribbon forest near Barnaul in 2019 and was observed in 2020-2021. (Terekhina et al. 2020).

On account of the point of view that relic species have different biological activity, an important addition to the definition of the species relictness concept and the consideration of their biological activity degree was made by A.V. Polozhiy (1964). She paid special attention to the extreme variability of some species. These changes ensure the survivability of species in certain habitats that have largely retained the previous conditions of existence. Normal and good development without the signs of distress and with a large number of individuals is observed in the conditions that most completely correspond to the ecological nature of the species. A Pacific group of relics stands out. In terms of age, it more or less corresponds to the Atlantic group, but its origin is associated with East Asia, sometimes with North America. *Osmorhiza aristata* (Polozhiy and Krapivkina 1985) in the territory of Gornaya Shoriya and Kuzedeevsky linden island refers to it.

According to E.D. Krapivkina (2007), the main range of this species covers broad-leaved and mixed forests of Japan, Manchuria, and the Far East. Further to the west, away from the main range of distribution, this species is found in the dark coniferous forests of the Altai and Sayan Mountains. Then, again after a huge disjunction, Osmorhiza aristata grows in the broad-leaved and coniferous-broad-leaved forests of the Caucasus.

The studied species is included in the Red Data Book of Altai Krai (2016), the Red Data Book of the Altai Republic (2007), the Red Data Book of Kuzbass (2021), as well as in the Red Data Book of the Russian Federation (2008). Until 2019, 4 growing areas of *Osmorhiza aristata* were known in the spruce-fir forests of Western Altai; the species was not found in the lowland part of the region. Our study area is located in the territory of the Barnaul ribbon pine forest (Altai Krai).

In the territory of the Barnaul pine forest, mixed maple-pine and pine-maple forests with *Osmorhiza aristata* were found in the Barnaul forestry in the vicinity of Barnaul. There are the following associations: horsetail-sedge maple-pine forest (*Acer negundo – Pinus sylvestris – Equisetum pratense + Carex macroura*), horsetail-

sweetroot pine-maple forest (*Pinus sylvestris – Acer negundo – Equisetum pratense + Osmorhiza aristata*), maple-birch sedge-horsetail pine forest (*Pinus sylvestris – Acer negundo + Betula pendula – Carex macroura + Equisetum pratense*).

The forest stand composition formula is as follows: 8M2P, 4M6P, 5M3P2B. The proportion of the ash-leaved maple (*Acer negundo* L.) in the forest communities varies from 80 to 30%. The tree stand is usually two-layered, the first 20-25-meter-tall layer is composed of *Pinus sylvestris* L., *Betula pendula* Roth, *Betula alba* L. in humid places, *Populus tremula* L. The second layer is 5-to-14-meter-tall and is composed of the ash-leaved maple (*Acer negundo*). The crown closure varies from 60 to 90%. The undergrowth features *Salix caprea* L., *Sorbus sibirica* Hedl., *Padus avium* Mill., *Acer negundo*.

The shrub layer of 1-2 sublayers is composed of *Rubus idaeus* L., *Viburnum opulus* L., *Rosa majalis* Herrm., *Sambucus sibirica* Nakai., *Caragana arborescens* Lam., sometimes Ribes spicatum Robson. The shrub layer closure varies from 3 to 10%. In case of a high density of the tree canopy, the shrub layer may be absent, or there are single specimens of *Rosa majalis*, *Sambucus sibirica*, *Caragana arborescens*, and *Viburnum opulus*.

The total projective cover (TPC) of the herbaceous layer, depending on the regimes of illumination and moisture, is 15-60%, 35% on average. A 400 m^2 site features from 9 to 16 species of higher vascular plants in the grass layer. Ferns include *Equisetum hiemale* L., *E. pratense*, *Dryopteris filix-mas* (L.) Schott, *D. carthusiana* (Vill.) H. P. Fuchs. In most associations, grasses and legumes are absent, occasionally there is *Brachypodium pinnatum* (L.) Beauv., *Lathyrus vernus* (L.) Bernh. (legumes), and *Carex macroura* Meinsh. (sedges). As for the forbs, there are *Osmorhiza aristata, Filipendula ulmaria* (L.) Maxim., *Cirsium incanum* (S.G. Gmel.) Fisch, *Urtica dioica* L., *Rubus saxatilis* L., *Fragaria vesca* L., *Geum aleppicum* Jacq., *Agrimonia pilosa* L., *Impatiens parviflora* DC, *Geranium bifolium* Patrin., *Pulmonaria mollis* Wulf. ex Hornem., *Angelica sylvestris* L., *Pleurospermum uralense* Hoffm., *Phlomis tuberosa* L., *Crepis sibirica* L., *Lilium martagon* (Freyn) Miscz., *Humulus lupulus* L., *Viola uniflora* L., *V. mirabilis* L., etc.

In total, from 14 to 24 species of higher vascular plants were recorder in the associations of maple and pine-maple forests on the studied sites. The description of typical associations is provided further.

Discussion

The distribution areas of *Osmorhiza aristata* in Altai Krai are currently the Zmeinogorsky district (the valleys of the Belaya and Malaya Belaya rivers), habitats in the upper reaches of the Inya river (Charyshsky district), Soloneshensky district (Bashchelaksky range, mount Khrebet), Charyshsky district (mount Sem Bratyev).

A new location of the stenotopic species *Osmorhiza aristata* has been found in the territory of Western Siberia, which is not characteristic of the local flora. The size of this coenopopulation reaches 100x100 m^2.

The authors described a pine-maple forest with the horsetail-sweetroot grass cover and a maple-pine horsetail-sedge forest with *Osmorhiza aristata*.

Pine-maple forest with horsetail-sweetroot grass cover (*Pinus sylvestris – Acer negundo – Equisetum pratense* + *Osmorhiza aristata*) (N'53°16', E83°43', Altai Krai, outskirts of Barnaul, 0.6 km south of the dermatovenerologic dispensary) (Fig. 2).

The forest stand composition formula is as follows: 1.30P8.7M. The tree stand is two-layered, the first 24-meter-tall layer is formed by *Pinus sylvestris*, the second 13-meter-tall layer is formed by *Acer negundo*. The age of the pine trees is about 80 years. The average diameter of the pine trunks is 26 cm, the maximum is 32 cm. The average diameter of the maple trunks is 9 cm, the maximum is 16 cm, their age is about 15 years. The crown closure is 0.9. The forest is very wet, there is a lot of fallen pine deadwood. The undergrowth features only *Acer negundo*. The 1.2-meter-tall shrub layer is formed by the common raspberry (*Rubus idaeus*) and the viburnum (*Viburnum opulus*). The projective cover of the shrub layer is about 3%.

Figure 2. Pine-maple forest with horsetail-sweetroot grass cover.

The total projective cover of the herbaceous layer is 40%. The dominants of the herbaceous layer are the following: *Equisetum hiemale*, *Osmorhiza aristata*. The grass stand is two-layered. The first sublayer is 65 cm high and is formed by *Osmorhiza aristata*, *Arabis pendula* L., *Urtica dioica* and others. The second sublayer is 35 cm high and is formed by *Equisetum hiemale*, *Pulmonaria mollis*, vegetative shoots of *Angelica sylvestris*. Grasses and legumes are absent. The forbs are represented by 10

species of plants: *Viola mirabilis*, *Pulmonaria mollis*, *Osmorhiza aristata*, *Arabis pendula*, *Urtica dioica*, *Glechoma hederacea* L., *Impatiens parviflora*, *Angelica sylvestris*, *Equisetum hiemale*, *Dryopteris carthusiana*. In total, 15 species of higher vascular plants were noted per 400 m^2.

Maple-pine horsetail-sedge forest (*Acer negundo – Pinus sylvestris – Equisetum pratense + Carex macroura*) (N'53°16', E83°43', Altai Krai, outskirts of Barnaul, 0.5 km south of the dermatovenerologic dispensary) (Fig. 3).

The forest stand composition formula is as follows: 6P4M. The tree stand is two-layered, the first 25-meter-tall layer is formed by *Pinus sylvestris*, the second 10-15-meter-tall layer is formed by *Acer negundo*. The pine trees are approximately 60 years old. The average diameter of the pine trunks is 20 cm, the maximum is 25 cm. The average diameter of the maple trunks is 10-13 cm, the maximum is 18 cm, their age is about 20. The crown closure is 0.6. The undergrowth features 150-200-centimeter-tall *Acer negundo* (1-2 ind./m^2).

The shrub layer is absent; there are occasional specimens of *Spiraea chamaedryfolia* L. and *Sorbus sibirica*.

The total projective cover of the herbaceous layer is 15%. The dominants of the herbaceous layer are the following: *Equisetum pratense*, *Carex macroura*. The grass stand is two-layered. The first sublayer is 40 cm high and is formed by *Impatiens parviflora*, *Equisetum pratense*, and the forbs. The second sublayer is 10-15 cm high and is formed by *Viola mirabilis*, *Vicia sepium* L. Grasses are absent, legumes are represented by *Lathyrus vernus*, *Vicia sepium*, and as for sedges, there is *Carex macroura*. The forbs include 11 species of plants: *Impatiens parviflora*, *Angelica sylvestris*, *Urtica dioica*, *Rubus saxatilis*, *Equisetum pratense*, *Viola mirabilis*, *Pulmonaria mollis*, *Agrimonia pilosa*, *Osmorhiza aristata*, *Glechoma hederacea*. In total, 18 species of higher vascular plants were noted per 400 m^2.

The proportion of advents (alien species) in the forest communities with *Osmorhiza aristata* is below 3%, which indicates their natural origin.

Conclusion

At present, a comprehensive study of rare and endangered plant species, primarily those that are included in state or regional lists of protected plants, has begun in many countries.

The authors carried out an inventory, relocalization of *Osmorhiza aristata*, determined the characters of their biology, the population composition, and the response to adverse anthropogenic impacts. *Osmorhiza aristata* requires further study as a relic and protected species, as well as it is necessary to identify its biological (study of the seed reproduction in the species) and ecological features, to determine the period of appearance in the regional floristic complexes in order to prevent its extinction.

Figure 3. Pine-maple forest with horsetail-sweetroot grass cover.

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