

Original research

Distribution and state of *Botrychium virginianum* (Botrychiaceae) populations in Ukraine

Viktor Melnyk ^{1*}, Vitalij Volodymerets ², Borys Bertash ³, Svitlana Didenko ¹

¹ M.M. Gryshko National Botanical Garden, Ukrainian Academy of Sciences, Tymirjazevska Str. 1, Kyiv, Ukraine

² National University of Water and Environmental Engineering, Soborna Str. 11, Rivne, Ukraine

³ Rivne State Humanitarian University, Plastova Str. 31, Rivne, Ukraine

*Corresponding author. E-mail: melnykviktor6@gmail.com

Received: 10 November 2023. Accepted: 25 March 2024. Published online: 20 May 2024.

Abstract

Melnyk V., Volodymerets V., Bertash B., Didenko S., 2023: Distribution and state of *Botrychium virginianum* (Botrychiaceae) populations in Ukraine. – Botanica, 30(2): 59–69. <https://doi.org/10.35513/Botlit.2024.2.1>

We performed a detailed study on the distribution and current state of *Botrychium virginianum* (L.) Sw. (Botrychiaceae) populations in Ukraine. From the beginning of floristic studies to the present day, only 28 localities of *Botrychium virginianum* have been recorded in Ukraine, and only two of these populations have survived to the present day. The population of the aspen and birch forest in Chernihiv Region consists of nine individuals. We discovered a new small population in *Corylus avellana* stands in Rivne Region, consisting of 50 individuals. The status of this population was described, and the habitat characteristics were analysed. A comparison of the known populations of *Botrychium virginianum* in Ukraine with populations of this species in other parts of its range shows that they are declining throughout Eurasia and South America. Recommendations for conserving *Botrychium virginianum* populations in Ukraine were developed and discussed.

Keywords: community, conservation, flora, habitat, range, rare species.

INTRODUCTION

The species of the genus *Botrychium* Sw. (Botrychiaceae) are the oldest representatives of the order Ophioglossales, surviving to the present day as a remnant of the ancestral group of seed plants. It is characterised by primitive features for ferns, linking its gametophytes with the embryo of fossil plants of the division Rhynophyta, as well as the feature linking it with highly developed plants of the class Cycadopsida and the order Glossopteridales (Kato, 1988).

Unfortunately, the species of this relict genus are threatened with extinction, especially in Europe. *Botrychium virginianum* Sw. (Botrychiaceae) is one of the rarest species in the European flora. All European species of the genus *Botrychium* (*Botrychium boreale* Milde, *Botrychium lanceolatum* (S.G. Gmelin) Anyström, *Botrychium lunaria* (L.) Swartz in Schrad-er, *Botrychium marticariifolium* (Retz.) A. Braun ex Koch, *Botrychium multifidum* (S.G. Gmelin) Rupr., *Botrychium simplex* E. Hitche and *Botrychium virginianum* (L.) Swartz.) are declining (Rothmaler, 1993; Melnyk, 2009; Horn et al., 2017).

Botrychium virginianum (L.) Sw. (*Botrychium anthemoides* (C. Prest.) Val., *Botrypus virginianus* (L.) Michx., *Osmunda virginiana* L.) (*Botrychiaceae*) is an American-Euroasiatic species, represented by two subspecies: *Botrychium virginianum* subsp. *virginianum* in the Americas and *Botrychium virginianum* subsp. *europaeum* (Angstr.) Glausen in Eurasia. The American part of the range of *Botrychium virginianum* covers the area from the western islands of the Canadian archipelago and Alaska to the Andes and the Atlantic coast of Brazil. This species is widespread in North America, except for the eastern islands of the Canadian Archipelago and the adjacent Arctic coast of Canada, central and southern California. In South America, *Botrychium virginianum* is distributed mainly in the Andes (Colombia, Venezuela, Ecuador, Peru, Bolivia) and as a separate exclave in the Atlantic coast of Brazil up to 30° South latitude. The Eurasian part of *Botrychium virginianum* range occupies the area from Scandinavia (Sweden) and the Alps (Germany, Switzerland, Austria, Italy, Slovenia) to Siberia, more southern from 60° Northern latitude with separate exclaves in the Caucasus, the Himalayas, the Tibetan mountains and the Far East (China, Japan, Korea, Russia) (Meusel et al., 1965; Jalas & Suominen, 1972; Hultin & Fries, 1986; Young & Leon, 1993).

Botrychium virginianum is included in the Red Data Books and lists of protected plant species of Austria, Belarus, Estonia, Finland, Germany, Hungary, Italy, Latvia, Lithuania, Poland, Romania, Slovenia, Sweden, Switzerland and Ukraine (Landoldt, 1991; Conti et al., 1992; Aronsson, 1995; Skoberne, 1996; Ludwig & Schnittler, 1996; Rytteri et al., 1998; Niklfeld, 1999; Király, 2007; Dihoru & Ne-grean, 2009; Dubovik, 2015; Eglite, 2003; Kagalo & Chornej, 2009; Kull et al., 2002; Rasimavičius, 2021; Naujalis, 2007; Zarszycki, 2001). This species is also included in the European Red List of Lycopods and Ferns (Criado et al., 2017) and the Convention on Conservation of European Wildlife and Natural Habitats (Council of Europe, 1995).

The lack of data on the status of *Botrychium virginianum* populations in Ukraine has been an obstacle to the proper organisation of the conservation of the species. This study aimed to determine the current distribution and status of *Botrychium virginianum* populations in Ukraine and compare it with those in other parts of its range.

MATERIALS AND METHODS

The study is based on field surveys performed between 2006 and 2022. Two populations of *Botrychium virginianum* were studied in Chernihiv and Rivne Regions. The study of habitats and populations of *Botrychium virginianum* was conducted by applying the methods of population biology (Harper, 2010).

To investigate the dynamics of the distribution of *Botrychium virginianum* in Ukraine, we studied the geographical distribution of this species in a historical aspect from the beginning of floristic research till now, analysing the chorological data of each half-century and the whole period from 2000 to date. The herbarium specimens of *Botrychium virginianum* deposited at the Herbaria of Ukraine, Poland and Russia were used for the study: M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine (KW), M.M. Gryshko National Botanical Garden (KWA), Taras Shevchenko National University of Kyiv (KWU), Ivan Franko National University of Lviv (LW), Yuriy Fedkovych National University of Chernivtsi (CHER), W. Szafer Institute of Botany in Kraków (KRAM), Jagiellonian University in Kraków (KRA), V.L. Komarov Botanical Institute in St.-Petersburg (LE) and M.V. Lomonosov Moscow University (MW).

RESULTS

Distribution of *Botrychium virginianum* in Ukraine

In Ukraine, *Botrychium virginianum* grows near the southern limit of its range in Europe and the lowland part of the country in the zone of mixed forests in the Polesian Lowland and forest-steppe zone. The statement of G. Bobrov (1974) about its growth in the Carpathians near the town of Rahiv is incorrect. Herbarium specimens and literature data do not support this statement.

In the forest-steppe zone of Ukraine, *Botrychium virginianum* was first found by V. Chernjaev in 1827 in the Central Russian Uplands near the city of Kharkiv (LE Herbarium). In addition to this locality, five other localities were recorded in the

Central Russian Uplands within Kharkiv Region in the vicinity of Andriyivka in the Velikij Burl district, in the village of Pechenigy near the town of Chuguev, between the villages of Pokotylivka and Zeleny Gaj in Kharkiv district, in the Ozerjanskij ravine near the city of Kharkiv (Fomin, 1935). The last record of *Botrychium virginianum* from the Central Russian Uplands dates to 1926 (Melnyk, 2009).

Several *Botrychium virginianum* localities have been recorded in the right bank forest-steppe zone, mainly in the Podolian Upland. There, this species has been found in the vicinity of the villages Koltiv, Popirnja, Khmeleva, Trostjanez, Obertasiv, Krugiv, Sasiv village in Zolochiv district of Lviv Region and the town Vynnyky near Lviv (Mađalski, 1938; Motyka, 1947) in beech forests on rendzina soils (Mađalski, 1938; Motyka, 1947). The largest of the six populations found by Mađalski (1938) occupied an area of 625 m² and consisted of 60 plants of different ages. Five other populations had two to ten individuals. The last herbarium specimen of *Botrychium virginianum* from the Podolian Upland was collected by Mađalski in 1938 (LW).

Two localities of *Botrychium virginianum* were found in the Roztochya Upland in the 19th century and the first half of the 20th century: in the Jaryna forest near the town of Janiv in the Yavorivskij district of Lviv Region and near the village of Derevach near the city of Lviv (Mađalski, 1938).

Five localities of *Botrychium virginianum* have been recorded in the Khotyn Upland, Khotyn district, Chernivci Region. Four of them have been found in stow Goljak in the vicinity of Kolinbuc between Zaporozany and Klychkivci villages, in the Klychkivskij Forest, near Pomasiv village (Topa, 1935). Recent searches for this species by botanists from the University of Chernivci have been unsuccessful.

In the second half of the 20th century (in 1961), a new locality of *Botrychium virginianum* in a wet hornbeam oak stand was found by Gorochova in the Khotyn Upland in the Ruchotynske Forest near the village of Blychczade (Khotyn district, Chernivci Region, CHER).

In the first half of the 19th century and the 20th century, five localities of *Botrychium virginianum* were found in the Polissian Lowland. Two of them were recorded on the left bank of Polissia in the vi-

cinity of Ripky town (Chernihiv Region) (Rogovich, 1855) and in the area of Kyiv city behind Darnica (Smalhauzen, 1895). Three other localities were found in Male (Little) Polissia: in the durmast oak forest near Zhovkwa town (Lviv Region) (Rehman, 1870), near Slavuta town (Khmielnickiy Region) (Fomin, 1935) and in the rendzina soil between Mizoch and Shumsk towns in Teremno forestry (Rivne Region) (Motyka, 1947).

In 2006, the local historian V.M. Popruga found a new locality of *Botrychium virginianum* near the village of Uglova Rudna (Ripky district, Chernigiv Region). Grafin (2006) has erroneously localised this record in the Jasenske tract near the village of Zubachy. We specified this locality and found that it coincides with the Puchkarivske tract near Uglova Rudna village. This population consisted of nine plants.

In 2021, a new locality of *Botrychium virginianum* consisting of five individuals was found on the floodplain terrace of the Horyn River in Volhynian Polissia in the vicinity of Sush village Derazne municipality of Rivne district, in Rivne Region (Danylyk et al., 2023). During the field survey, it was found that this population consisted of 50 individuals, including 15 fertile and 35 sterile plants, and occupied an area of 300 m × 15 m.

The study of herbarium specimens of *Botrychium virginianum* showed that only 28 localities of this species had been recorded in Ukraine since the beginning of floristic studies (Fig. 1, Table 1). Most of the localities (25) were discovered in the 19th century and the first half of the 20th century. In the second half of the 20th century, only one new locality of *Botrychium virginianum* was discovered. After 2000, *Botrychium virginianum* was only recorded from two localities in Ukraine (Fig. 1, Table 1).

The results of our research show that *Botrychium virginianum* is an endangered species in the flora of Ukraine. The two surviving populations of *Botrychium virginianum* in Ukraine are exceedingly small and characterised by a low number of individuals. In the past, populations of this species occupied a much larger area. The felling of trees in these forests and the replacement of natural forests by silviculture, deforestation and the replacement of forests by agricultural land, and the drainage of land have led to a reduction in the population (Melnyk, 2009).



Fig. 1. Distribution of *Botrychium virginianum* in Ukraine. Recording periods: ▲ – before 1900; ● – 1900–1950; ■ – 1951–2000; ◆ – after 2000; Solid lines indicate the boundaries between natural zones: 1 – mixed forest zone; 2 – forest-steppe zone; 3 – steppe zone.

Table 1. Number of *Botrychium virginianum* records in different periods in two geographical zones of Ukraine

Geographical zone	Periods (years)				Total
	before 1900	1901–1950	1951–2000	2001–2022	
Mixed forests	3	3	0	2	8
Forest step	2	17	1	0	20
Total	5	20	1	2	28

Habitats of *Botrychium virginianum* in Ukraine

In the Puchkarivske tract near the village of Uglova Rudka, Ripky district, Chernihiv Region, *Botrychium virginianum* (Fig. 2) occurred in an aspen-birch forest near a large mire. The mean age of the stand was 60 years, the mean diameter of the stems was 28 cm, and the crown density was 0.8. *Betula pubescens* Ehr. and *Populus tremula* L. were co-dominants in the tree layer accompanied by *Ulmus laevis* Pall. The shrub layer was formed by *Cornus sanguinea* L. and *Viburnum opulus* L. The herb layer was sparse;

its coverage was 50%. Co-dominant species in the herb layer were *Aegopodium podagraria* L. (10%) and *Asarum europaeum* L. (10%). The herb layer also included *Agrostis tenuis* Sibth., *Equisetum hyemale* L., *Geranium palustre* L., *Cirsium heterophyllum* (L.) Hill., *Paris quadrifolia* L. Two rare species in Ukraine, *Ophioglossum vulgatum* L. and *Epipactis helleborine* (L.) Cranz, were found in this community. *Botrychium virginianum* grew in patches without other herbs. Only three fertile individuals and six sterile plants of *Botrychium virginianum* were found at this site in 2009 and again in 2018.



Fig. 2. *Botrychium virginianum* in an aspen-birch forest in Chernihiv Region. Photograph by V. Melnyk.



Fig. 3. *Botrychium virginianum* in Rivne Region. Photograph by V. Melnyk.

A new locality of *Botrychium virginianum* was discovered by V.O. Volodymyrets in Volhynian Polissia, north of the village of Susk, Rivne district (formerly Kostopil district), Rivne Region. This population of *Botrychium virginianum* (Fig. 3) occurred along the edge of the right floodplain terrace of the Horyn River and comprised a belt of about 300 m long and 15 m wide. The geological structure of the area is characterised by large chalk deposits covered by a thin layer of glacial sediments. The soil is rendzina.

The vegetation was presented by shrub thickets formed by *Corylus avellana* L. (Fig. 4) with single individuals of *Euonymus verrucosus* Scop. and *Prunus padus* L. Shrubs of *Corylus avellana* L. were well developed and reached 5 m in height. Solitary trees of *Pinus sylvestris* L., *Tilia cordata* Mill., *Quercus robur* L., *Ulmus laevis*, *Sorbus aucuparia* L. occurred in the shrub layer. The herb layer was sparse and covered about 40% of the surface. The herb layer was formed mainly by mesophytes. *Asarum europaeum* L. was the dominant species in the herb layer. Other plant species, *Aconitum lasiostomum* Rchb.



Fig. 4. Habitat of *Botrychium virginianum* in Rivne Region. Photograph by V. Melnyk.

ex Besser, *Aconitum variegatum* L., *Aegopodium padagraria* L., *Campanula trachelium* L., *Circaea lutetiana* L., *Cimicifuga foetida* L., *Clinopodium vulgare* L., *Epipactis helleborine* L., *Euphorbia cyparissias* (L.) Scop., *Listera ovata* (L.) R. Br., *Lilium martagon* L., *Melampyrum nemorosum* L., *Melica nutans* L., *Neottia nidus-avis* (L.) Rich., *Primula veris* L., *Pteridium aquilinum* (L.) Kuhn., *Pulmonaria officinalis* L., *Rubus saxatilis* L., *Sanicula europaea* L., *Tanacetum corymbosum* (L.) Sch.Bip., *Thalictrum aquilegifolium* L., *Viola mirabilis* L., *Viola odorata* L., were less abundant in the plant community. Xerophilous species such as *Anthericum ramosum* L., *Anthyllis vulneraria* L., *Asperula cynanchica* L., *Prunus fruticosa* Pall., *Gypsophila paniculata* L., *Inula hirta* L., *Cytisus nigricans* L., *Origanum vulgare* L., *Salvia verticillata* L., were recorded on outcrops of chalk rocks. *Botrychium virginianum* occupied patches free of other herbaceous plants. In 2023, we counted 50 individuals of this species, of which 15 were fertile and 35 were sterile.

DISCUSSION

State of *Botrychium virginianum* in Europe

Throughout the European range of *Botrychium virginianum*, both in the countries neighbouring Ukraine and in most of the more distant regions, populations of this species are rare, relatively small and in most cases endangered.

All five localities of *Botrychium virginianum* recorded in Poland in the provinces of Masuria and Warmia (Piska and Napivodsko-Ramucka forests) are considered extinct. The newly discovered populations of *Botrychium virginianum* in the moist spruce forest *Tilio-Carpinetum* Traczyk 1962 in the Starozyn Nature Reserve in the Puszcza Augustowska Forest with a little more than a dozen individuals of *Botrychium virginianum* is only one persisting population in Poland (Pawlikowski, 2011).

In Slovakia, *Botrychium virginianum* is considered an extinct species (Čeřovský et al., 1999). The only locality of *Botrychium virginianum* in Hungary has been found near the Kunfehértó village in an oak-ash-elm gallery forest (1040 individuals, 40% of these were fertile) (Csiky, 1997). Ten localities of

Botrychium virginianum have been recorded in Romania, where the species is endangered (Dihoru & Negrean, 2009).

Botrychium virginianum is a rare and endangered species of the flora of the Alps. Only eight localities in Carinthia have been recorded in the Austrian Alps. The last occurrence of this species was recorded in 1991 in the *Alnetum incunae* Lüdi 1921 forest in the Gailtal valley in south-western Carinthia, where the population of this species consisted of about 50 individuals in an area of 200 m² (Wilfried, 1991).

In Italy, *Botrychium virginianum* is exceedingly rare. It is known from three localities in South Tyrol. One of them was discovered at the end of the 19th century. In the other locality, only two individuals were found at the end of the 20th century (Horn et al., 2005). Recently, a population has been found in Italy in the San Lucano Valley Agordo Dolomites-Veneto-Belluno province. It is in the riparian *Alnion incanae* Pawłowski et al. 1928 forest and consists of about a thousand individuals (Giovagnoli & Tassinazzo, 2015).

Botrychium virginianum is a rare species in Slovenia. Most of the known localities (17 out of 18) in this country are in the Julian and Kamnik-Savinja Alps, and only one locality is in the sub-Pannonian Region. *Botrychium virginianum* grows in beech and spruce forests and riparian willow forests. Most of the alpine populations of *Botrychium virginianum* in Slovenia have been reported as relatively abundant, but the population near the village of Koritnica consists of about 20 individuals. In the southernmost population in Slovenia, on the Gorjancii hill, only one individual has been found (Dakskobler, 1993; Kosec & Dakskobler, 2014).

In Germany, only three populations have been recorded in the Bavarian Alps. Two of them in Berchtesgaden Land are considered extinct. The only remaining population is on the shore of Lake Eibsee. The results of monitoring the number of individuals in these populations in different years indicate their gradual decline. In 1999, 274 individuals were found; in 2008, their number decreased to 97; in 2016, only 16 of *Botrychium virginianum* remained (Wagner & Wagner, 2008; Horn et al., 2017).

Populations of *Botrychium virginianum* are more numerous in Fennoscandia than in other parts of Europe. However, the species is also rare in the northern

part of its European range. A total of 59 localities of *Botrychium virginianum* have been recorded in Central Sweden, mainly in the early successional stages of spruce forests on calcareous soils. In such conditions, the populations of this species contain the most significant number of individuals (the mean number is 146). Populations in 30-year-old coniferous forests contain fewer individuals (the mean number is 26 individuals). In contrast, *Botrychium virginianum* is rare and scarce in old coniferous forests, as the mean number of individuals is only seven (Stahl, 1990, 1998).

In Finland, *Botrychium virginianum* has been found in only a few localities in the south-western part of the mainland. Fewer than 100 individuals have been recorded there, most in the population near Suomusjärvi. More than 20 localities have been recorded in limestone-rich areas around Oulu, Kemi and Rovaniemi, and 16 of these populations are surviving. There are about 1600 individuals in total, but almost half of these are in one population in the municipality of Rovaniemi (Ryttäri et al., 1988).

According to the distribution map of *Botrychium virginianum* in Estonia, this species has been recorded in 52 grid squares, and 21 grid squares, this species has been recorded recently (Kull et al., 2002). In Latvia, *Botrychium virginianum* is an endangered species recorded in 19 localities (Eglite, 2003). In Lithuania, *Botrychium virginianum* has been recorded in 14 localities. From 2007 to 2018, this species was recorded in six localities. Populations are exceedingly small, with a few individuals, usually less than ten plants, and rarely up to 50 individuals (Naujalis, 2007; Rasimavičius, 2021).

In Belarus, only six populations of *Botrychium virginianum*, with a low number of individuals in all populations, have been recorded (Dubovik, 2015). Recently, a new and the largest surviving population of this species has been found in the Lepelskij district of Vitebsk Region of Belarus. The population is restricted to open forests and occupies an area of 70 m × 100 m. This population consists of 70 plants of different maturity stages (Lebedko & Savchuk, 2020).

Botrychium virginianum is most frequent and abundant in the north-western and north-eastern Regions of the European part of Russia. In Leningrad Region, 15 localities have been recorded. In one population of *Botrychium virginianum* from this region, 20 individuals were recorded at the end of the

20th century, but only one individual was found at the beginning of the 21st century. In 2014, 11 individuals were recorded in another population, but no surviving individuals have recently been found. All surviving populations of *Botrychium virginianum* in Leningrad Region now consist of less than 250 individuals. In Novgorod Region, six localities of *Botrychium virginianum* have been recorded, but only one of them is relatively new, discovered in 1997. In Pskov Region, only nine localities of this species have been recorded, but only one was discovered in 1989, which is new. In Novgorod and Pskov Regions, the populations of *Botrychium virginianum* probably consist of less than 50 individuals in each region (Efimov et al., 2022).

In the Kologrivskiy Forest Reserve, located in the Manturov district of the Kostroma Region, *Botrychium virginianum* grows in a birch stand occupying the plot in the form of a strip 1110 m long and 20–30 m wide. The total number of individuals more than 1000, and the mean density 136 plants per 100 m² (Sirotnina et al., 2014).

Two small populations of *Botrychium virginianum* have been recorded in the Sinekovojskoje Forest (Bolchebero-Znikovky district, Mordovian Republic). The first population occupies 100 m² of an aspen stand and consists of 45 individuals, while the second occupies 15 m² at the edge of the forest and consists of 25 individuals (Kozhevnikova & Filin, 2002).

Recently, a small population of *Botrychium virginianum* has been recorded in Khrenovskij Bor, Voronezh Region, hundreds of kilometres away from all the above-mentioned Russian populations (Kin & Kalmykova, 2019).

State of *Botrychium virginianum* in Asia

Botrychium virginianum is rare in Asia, recorded only in widely scattered populations. In the Caucasian Mountains, it is known from only two localities (Kudrjachova, 2003). Four localities have been recorded in the Altai Mountains (Shmakov, 2005). Except for Altai, this rare species is sporadically distributed in Siberia, mainly in Tomsk, Tiumen and Krasnoyarsk Regions, Buryatia and Yakutia (Malychev & Sobolevskaja, 1980; Mochalov et al., 2010).

Botrychium virginianum is an exceedingly rare species in the Russian Far East and has been record-

ed so far in Khabarovsk Region (five localities) and Sakhalin Island (one locality) (Tzvelev, 1991).

In China, only four localities of *Botrychium virginianum* have been recorded in the Tibetan Autonomous Region and Hubey Province (Zou & Wagner, 1986).

State of *Botrychium virginianum* in North and South America

In contrast to the Eurasian part of the range, *Botrychium virginianum* is the most common *Botrychium* species in North America (Wagner & Wagner, 1993). This species is almost evenly distributed in the American part of the range without any significant disjunctions. In the Lehigh Mountain Upland Reserve in the suburbs of Bethlehem in Pennsylvania, *Botrychium virginianum* grows in a deciduous forest dominated by *Quercus alba* L. and *Liriodendron tulipifera* L. The population of *Botrychium virginianum* covers an area of 40 m², in which 22 individuals have been found (Sirotnina et al., 2014). A small population of *Botrychium virginianum* has been studied in northern California in the Salmon Mountains, about 15 km south of Etna, in a forested swamp area. Only five plants of *Botrychium virginianum* have been recorded there (Game, 1997). Although *Botrychium virginianum* is relatively common in North America, populations are generally small.

Observations of *Botrychium virginianum* in the Peruvian Andes indicate that this species is rare in South America. *Botrychium virginianum* is currently known from the eastern Andes of Peru at altitudes of 1800–3500 m above sea level in forest and shrub habitats. Only 29 *Botrychium virginianum* plants have been found in a one-hectare plot in Rio Abisco National Park, including just four fertile individuals in this population (Young & Leon, 1993).

Conservation of *Botrychium virginianum* in Ukraine

The analysis of the status of *Botrychium virginianum* populations in different parts of its range showed that this species is rare and endangered everywhere except North America. Intense anthropogenic pressure has led to a regression of the range of *Botrychium virginianum* on all continents. Long-term intensive degradation and fragmentation of popula-

tions under the influence of deforestation, drainage and other factors have occurred in different parts of the range, including Ukraine. Therefore, an urgent task is to organise protected areas to conserve *Botrychium virginianum*. This task is actual for Ukraine, where there are only two surviving populations of this species. We developed scientific justifications for the organisation of botanical reserves to protect *Botrychium virginianum* in Chernihiv and Rivne Regions of Ukraine.

We proposed, and Chernihiv Regional Council, based on the scientific justification, on 10 February 2023, decided to create a protected tract “Rudnjanske”, occupying 150 ha area for conservation of floristic diversity of Ripkinskij district, including rare and endangered species listed in the Red Data Book of Ukraine (Diduch, 2009): *Botrychium virginianum*, *Cypripedium calceolus* L., *Dactylorhiza incarnata* (L.) Soó, *Epipactis atrorubens* (Hoffm.) Besser, *Epipactis palustris* (L.) Crantz, *Iris sibirica* L., *Salix starkeana* Willd. and regionally rare species *Ophioglossum vulgatum* L.

We also submitted to the Rivne Region Council a scientific justification for creating the protected area “Lysa Gora” near the village of Susk in Rivne Region. The organisation of this protected area should improve the conservation status of *Botrychium virginianum* and other species included in the Red Data Book of Ukraine (Diduch, 2009): *Epipactis helleborine* (L.) Crantz, *Lilium martagon* L., *Listera ovata* (L.) R.Br. and regionally rare species *Aconitum lasiostromum* Rchb. ex Besser, *Aconitum variegatum* L. and *Prunus fruticosa* Pall.

CONCLUSIONS

Botrychium virginianum (L.) Sw. (Botrychiaceae) is widely distributed in Europe, Asia, and North and South America. It is a rare and endangered species in a large part of Europe and is included in the Red Data Books or Red Lists of 15 European countries, including Ukraine.

From the beginning of floristic research until today, only 28 localities of *Botrychium virginianum* have been recorded in Ukraine, 25 of them in the 19th century and the first half of the 20th century, one in the second half of the 20th century and two in the 21st century.

The surviving populations of *Botrychium virginianum* in Ukraine are exceedingly small and characterised by low numbers of individuals. The population in the aspen-birch forest in the Chernigiv Region consists of nine individuals. In comparison, the population in the thickets of *Corylus avellana* in Rivne Region consists of 50 individuals. Anthropogenic pressure (substituting natural forests by silviculture, conversion of forests into agricultural land and drainage of marshes and other wetlands) has resulted in a regressive change of species range, fragmentation of habitats and decline of populations.

A comparison of the status of *Botrychium virginianum* populations in Ukraine with populations in other parts of its range shows that this species is threatened throughout its range, except for North America. We proposed creating two protected areas for conserving *Botrychium virginianum* in Ukraine.

Author contributions. Conceptualisation by V.M. and V.V., data analysis by V.M. and S.D., investigations by V.M., V.V., B.B. and S.D., writing and original draft preparation by V.M. and S.D., reviewing and editing by V.M., V.V., B.B. and S.D. All authors have read and approved the final version of the article.

REFERENCES

- Aronsson M., Hallingbäck T., Mattsson J.-E. (eds), 1995: Rödlistade växter i Sverige 1995 (Swedish Red Data Book of Plants). Uppsala.
- Bobrov A.E., 1974: [Polypodiophyta – Pteridophytes]. – In: Flora of the European part of USSR, 1: 68–99. Leningrad.
- Čeřovský J., 1999: Červená kniha ohrožených a vzácných druhů rostlin a živočichů ČR u SR. Vyšší rostliny. Bratislava.
- Conti F., Manzi A., Pedrotti F. (eds), 1992: Libro Rosso delle Piante d'Italia, WWF Italia. Roma.
- Council of Europe, 1995: Convention on the Conservation of European Wildlife and Natural Habitats. Standing Committee. Recommendation № 44 adopted on 24 March 1995 on the Conservation of Some Threatened Plants in Central Europe. Strasbourg.
- Criado M.G., Vare H., Nietol A., Elias R.B., Dyer R., Ivanenko J., Ivanova D., Lansdown R.V., Molina J.A., Rouhan G., Rumsey F., Troia A., Vrba J., Christenhusz M., 2017: European Red List of Lycopods and Ferns. Brussels.
- Csiky J., 1997: A *Botrychium virginianum* (L.) Sw. fitocönológiai és ökológiai vizsgálata a kunfehértói holdrutás erdőben. – Kitaibelia, 1: 56–68.
- Dakskobler J., 1993: Novo nahajališče vrste *Botrychium virginianum* (L.) Sw. v Julijskih Alpah. – Hladnikia, 1: 29–34.
- Danylyk I.M., Volodymyrets V.O., Kuzyarin O.T., 2023: [*Botrychium virginianum*, a new species of the flora of Volyn Polissa (Ukraine)]. – Ukrainian Botanical Journal, 80(6): 476–481. <https://doi.org/10.15407/ukrbotj80.06.476>
- Dihoru G., Negrean G., 2009: *Botrychium virginianum* (L.) Sw. – In: Cartea rosie a plantelor vasculare din Romania: 107–108. Bucuresti.
- Dubovik D.V., 2015: [*Botrychium anthemnoides* C. Presl. (*B. virginianum* auct. non (L.) Sw.)]. – In: Red Data Book of Belarus (4 ed.): 92–93. Minsk.
- Efimov P.G., Konechnaya G.Yu., Kurbe R., Maksimov N.V., Smirnov I.A., Sorokina I.A., Tceytin N.G., 2022: [*Botrychium virginianum* (L.) Sw. in the North-West of European Russia: distribution, dynamics in the number of localities, conservation status]. – Transactions of the Karelian Research Centre of RAS, 1: 49–82. <https://doi.org/10.17076/bg1510>
- Eglite Z., 2003: *Botrychium virginianum* (L.) Sw. – In: Red Data Book of Latvia. Rare and Threatened Plants and Animals: 296–297. Riga.
- Fomin O., 1935: [Pteridophyta]. – In: Flora USSR, 1: 51–79. Kyiv.
- Game J.C., 1997: *Botrychium virginianum* in California. – American Fern Journal, 77(4): 150–152.
- Giovagnoli L., Tasinazzo S., 2015: *Botrychium virginianum* (*Ophioglossaceae*) nella Valle di S. Lucano (Dolomiti Agordine-Veneto). – Informatore Botanico Italiano, 47(1): 47–52.
- Grafm M., 2006: [The finds of *Botrychium* species in Chernigiv Region]. – In: Modern Problems of Natural Sciences: 53. Nizhyn.
- Harper J.L., 2010: Population Biology of Plants. Caldwell.
- Horn K., Sackwitz P., Wilhelm T., 2005: Die Verbreitung seltener Mondrauten (*Botrychium* spp., *Ophioglossaceae*, *Pteridophyta*) in Südtirol und

- dem angrenzenden Trentino (Italien). – *Gredleriana*, 5: 59–84.
- Horn K., Bennert H.W., Zehm A., 2017: Die Bestandssituation seltener und bedrohter Farne im Bayerischen Alpenraum und Maßnahmen zu ihrem Schutz. – *Berichte der Bayerischen Botanischen Gesellschaft*, 87: 71–82.
- Hulten E., Fries M., 1986: *Atlas of North European Vascular Plants North of the Tropic of Cancer*, 1. Königstein.
- Jalas J., Suominen J. (eds), 1972: *Atlas Florae Europaeae*, 1: 1–122. Helsinki.
- Kagalo O.O., Chornej I.I., 2009: [*Botrychium virginianum* (L.) Sw]. – In: *Red Data Book of Ukraine*: 37. Kyiv.
- Kato M., 1988: The phylogenetic relationships of Ophioglossaceae. – *Taxon*, 19(2): 381–386. <https://doi.org/10.2307/1222147>
- Kin N.O., Kalmykova O.T., 2019: New findings of the species of *Botrychium* genus in the European part of Russia. – *Turczaninovia*, 22(1): 61–62. <https://doi.org/10.14258/turczaninovia.22.1.7>
- Király G., 2007: *Red List of the Vascular Flora of Hungary*. Sopron.
- Kosec J., Dakskobler J., 2014: A new locality of *Botrychium virginianum* in the Gorjanci hills, the southernmost locality in Slovenia and Central Europe. – *Folia Biologia et Geologia*, 52(2): 61–74.
- Kudrjachova G.L., 2003: [Classis Ophioglossopsida]. – In: *Conspectus Florae Caucasi*: 172–173. St.-Petersburg.
- Kozhevnikova A.D., Filin V.R., 2002: [Distribution and local abundance of *Botrychium virginianum* (L.) Sw. (Ophioglossaceae) in European Russia]. – *Bulletin of Moscow Society of Nature Explorers*, 107(6): 48–51.
- Kull K., Kukk T., Lehti M., Krall H., Kukk U., Kull K., Kuusk V., 2002: Distribution trends of rare vascular plant species in Estonia. – *Biodiversity and Conservation*, 11: 171–196. <https://doi.org/10.1023/A:1014564521151>
- Landoldt E., 1991: *Liste rouge des plantes vasculaires menacées en Suisse. List rouges national et regional*. Bern.
- Lebedko V.N., Savchuk S.L., 2020: [Finding of the largest population *Botrychium anthemnoides* in Belarus]. – *Ecological Culture and Environment Protection*: 139–140. Vitebsk.
- Ludwig G., Schnittler M., 1996: *Rote Liste gefährdeter Pflanzen Deutschlands*. Bundesamt für Naturschutz. Bonn–Bad Godesberg.
- Mađalski J., 1938: *Botrychium virginianum* Sw. na północnej krawedzi Podola. – *Kosmos*. Ser. A., 63(3): 363–375.
- Malychev L.I., Sobolevskaya K.A., 1980: [Rare and endangered plants of Siberia]. Novosibirsk.
- Melnyk V., 2009: [The species of the genus *Botrychium* Sw. (*Botrychiaceae*), recommended for inclusion in the Red Data Book of Ukraine: Geographical Distribution and Modern State of Populations]. – *Scientific Transactions of NaUKMA. – Biology and Ecology*, 93: 45–53.
- Meusel H.E., Jäger E., Weinert E., 1965: *Vergleichende Chorologie der Zentraleuropäischen Flora*, 1. Jena.
- Mochalov A.S., Gureeva I.I., Naumenko N.I., 2010: Pteridoflora of the Urals. I. An annotated list of the ferns of the Urals and contiguous territories. – *Vestnik of Tomsk State University*, 3(11): 18–30.
- Motyka J., 1947: *Rozmieszczenie i ekologia roślin naczyniowych na polnocnej krawedzi Zachodniego Podola*. Lublin.
- Naujalis L.R., 2007: *Botrychium virginianum* (L.) Sw. – In: *Lietuvos raudonoji knyga*: 393. Kaunas.
- Niklfeld H., 1999: *Rote Listen gefährdeter Pflanzen Österreichs*. 2. Auflage. Grüne Reihe des Bundesministeriums für Umwelt, Jugend und Familie. Band 10. Graz.
- Pawlikowski P., 2011: *Botrychium virginianum* (Ophioglossaceae) rediscovered in Poland. – *Polish Botanical Journal*, 56(1): 81–84.
- Rasimavičius M., 2021: *Botrychium virginianum*. – In: *Rašomavičius V. (ed.), Red Data Book of Lithuania. Animals, Plants and Fungi*: 380. Vilnius.
- Rehman A., 1870: *O formacjach roślinnych Galicyi. Obwód Żółkiewski*. – *Sprawozdanie Komisji Fizjograficznej PAN*, 5(4): 186–235.
- Rogovich A., 1855: [Overview of vascular and semi-vascular plants in the flora of the Kiev, Chernigov and Poltava governorates]. Kiev.
- Rothmaler W., 1993: *Botrychium* Swartz. – In: *Tutin T.G. et al. (ed.), Flora Europaea. Psilotaceae to Platanaceae* (2nd ed.), 1: 10. Cambridge.
- Ryttäri T., Kravchenko A., Kuznetsov O., 1988: *Botrychium virginianum*. – In: *Red Data Book of East Fennoscandia*: 63–64. Helsinki.

- Smalhauszen I.F., 1895: [Flora of Central and Southern Russia, Crimea and Northern Caucasus. University of Saint-Vladimir]. Kiev.
- Shmakov A.I., 2005: *Botrychiaceae*. – In: Flora of Altaj, 1: 159–166. Barnaul.
- Sirotnina M.V., Krinitsyn I.G., Zontikov D.N., Parnikoza I.Y., 2014: Analysis and suggestions on monitoring of the populations of *Botrychium virginianum* (L.) Sw. in remote parts of the geographical range (based on the examples of Pennsylvania (USA) and Kostroma region (Russia)). – Advanced Materials Research, 1: 913–939. <https://doi.org/10.4028/www.scientific.net/AMR.955-959.1267>
- Skoberne P., 1996: Rdeci seznam ogrozenih praprotnic in semenk SR Slovenije. Ljubljana.
- Stahl P., 1990: *Botrychium virginianum* – a forest species preferring young successional stages. – Svensk Botanisk Tidskrift, 84(1): 23–36.
- Stahl P., 1998: The establishment of *Botrychium virginianum* in a forest clearing in Gästrikland, Central Sweden. – Svensk Botanisk Tidskrift, 92(2): 81–82.
- Topa E., 1936: Fragmente floristice din Bucovina și Besarabia de Nord. – Buletinul de informații al Grădinii Botanice și al Muzeului Botanic dela Universitatea din Cluj, 15(2): 209–218.
- Tzvelev N.N., 1991: *Botrychiaceae* Nakai. – In: [Vascular Plants of Soviet Far East], 5: 17–22. St. Petersburg.
- Wagner A., Wagner I., 2008: *Botrychium virginianum* (Virginische Mondraute). Bestandskontrolle in Landreis GAP 2008 und Literaturrecherche. Unveröffentlichtes Gutachten in Auftrag des Bayerischen Landesamtes für Umwelt. Augsburg.
- Wagner W.H.Jr. & Wagner F.S., 1993: Ophioglossaceae. – In: Flora of North America, 2: 85–106. New York.
- Wilfried R.F., 1991: Neufunde der Virginischen Mondraute (*Botrychium virginianum* (L.) Sw.) im Gailtal und ihr Gesellschaftsanschluss in Kärnten und Steiermark. – Naturwissenschaftlicher Verein für Kärnten, Austria, 181(101): 573–598.
- Young K.R., Leon B., 1993: Observations on *Botrychium virginianum* (Ophioglossaceae), a fern uncommon in the Eastern Andes of Peru. – American Fern Journal, 83(3): 93–96.
- Zarzycki K., 2001: *Botrychium virginianum* (L.) Swartz. – In: Polska Czerwona Księga Roślin: 45–46. Kraków.
- Zou X., Wagner W.N., 1986: A preliminary review of *Botrychium* in China. – American Fern Journal, 78(4): 122–135.

VM  <https://orcid.org/0000-0001-8315-8468>

VV  <https://orcid.org/0000-0003-2782-300X>

BB  <https://orcid.org/0000-0002-8996-988>

SD  <https://orcid.org/0000-0001-7673-4674>