

New chorological data on some rare and threatened ferns in Serbia

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with 5 figures

Key words: *Athyriaceae*, *Thelypteridaceae*, chorology, relict species, flora of Serbia, Balkan Peninsula, protected plants.

Summary

VUKOJIČIĆ S., DJORDJEVIĆ V., KABAŠ E., STANKOVIĆ V., ĐUROVIĆ S. & STEVANOVIĆ V. 2023. New chorological data on some rare and threatened ferns in Serbia. – *Phyton* (Horn, Austria) 62–63: 115–126, with 5 figures.

Ferns are a plant group that has been neglected in terms of research on their distribution, ecology and conservation in Serbia. This study reports the first findings of *Athyrium distentifolium* (*Athyriaceae*) in Serbia and presents the distribution of three other ferns of the Serbian flora (*Thelypteris limbosperma*, *Thelypteris palustris* and *Phegopteris connectilis*) from the family *Thelypteridaceae*. The distribution data were obtained on the basis of field investigations, checking and revision of herbarium material and published sources. The distribution maps of these taxa in Serbia were created on a 10×10 km UTM grid system. Data on their habitat and ecological preferences, conservation status and threat factors within the study area are provided.

1. Introduction

Ferns are a group of vascular plants that are insufficiently chorologically studied in the Balkan Peninsula, including Serbia. Most data on the distribution of ferns in Serbia are sparse and imprecise. According to the Checklist of the Vascular Flora of Serbia 1, there are 13 families with 65 taxa of the class *Polypodiopsida* in Serbia (NIKETIĆ & TOMOVIĆ 2018), of which 16 taxa are strictly protected and five are protected according to the national law (SL. GLASNIK RS 2010–2016). However, two strictly protected species (*Dryopteris cristata* (L.) A. GRAY and *Pilularia globulifera* L.) are considered extinct in Serbia (NIKETIĆ & TOMOVIĆ 2018).

Based on field research and revision of material from the Herbarium of the Institute of Botany and Botanical Garden ‘Jevremovac’ of the University of Belgrade (BEOU), two species of the genus *Athyrium* (*Athyriaceae* ALSTON) were found to occur in Serbia: *A. filix-femina* (L.) ROTH and *A. distentifolium* OPIZ. Both the previous and the new records of *A. filix-femina* are numerous. The findings of *A. distentifolium* represent the first records of this species

in Serbia. The new findings of *A. distentifolium* were confirmed from the herbarium material, which was determined ad hoc in the field as *A. filix-femina*.

A large family of ferns, the *Thelypteridaceae* PIC. SERM., which includes almost 1000 species (SMITH 1990), is represented in the flora of Serbia by only three taxa: *Thelypteris limbosperma* (ALL.) H. P. FUCHS, *Thelypteris palustris* SCHOTT and *Phegopteris connectilis* (MICHX.) WATT (NIKETIĆ & TOMOVIĆ 2018). These species are protected by national legislation (SL. GLASNIK RS 2010–2016) and are also on the European Red List (BILZ & al. 2011).

Although not enough attention has been paid to ferns, several important findings on fern species in Serbia have been reported recently, contributing to a better knowledge and understanding of the distribution and ecology of ferns in this country (PERIĆ & PANJKOVIĆ 2015, RANĐELOVIĆ & al. 2021, SABOVLJEVIĆ & al. 2021, NOVOVIĆ & al. 2022).

The aims of this study were: (a) to report the first findings of *Athyrium distentifolium* in Serbia, (b) to present new and unpublished distribution data of the three species of the family *Thelypteri-*

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daceae – *Thelypteris limbosperma*, *T. palustris* and *Phegopteris connectilis*, (c) to determine the habitat and ecological preferences of the studied species, and (d) to determine the conservation status and threat factors of these species in Serbia.

2. Materials and methods

During floristic surveys of some fern species on the territory of Serbia in the period from 2020 to 2022, data were collected on their distribution, habitat preferences and threat factors. In addition to the field surveys, numerous specimens from the Herbarium of the Institute of Botany and Botanical Garden ‘Jevremovac’ of the University of Belgrade (BEOU) (acronym according to THIERS 2023) as well as literature data on selected taxa were evaluated. The identification of species was done according to TUTIN & al. (1993), JERMY (1993) and MCHAFFIE (2005), while the nomenclature follows the Euro+Med database (EURO+MED 2006). All plant material collected for this article is deposited in BEOU. The morphological description of *Athyrium distentifolium* is based on herbarium specimens, with some qualitative and quantitative characters added according to JERMY (1993) and MCHAFFIE (2005).

During field surveys, geographic coordinates (latitude and longitude) and altitude were determined using a Garmin eTrex 30 hand-held GPS device in the World Geodetic System 84 (WGS 84) format. In addition, published chorological data and data from herbarium collections were georeferenced using OziExplorer 3.95.4s software in the WGS 84 format. The overall distribution of each studied plant species in Serbia, based on a compilation of new records, revised and unpublished herbarium data, and on available corresponding floristic literature, is presented on grid maps with 10×10 km squares based on the Military Grid Reference System and the Universal Transverse Mercator (UTM) projection (LAMPINEN 2001), grid zone 34T. The bedrock types were determined using the geological maps of the study area on a scale of 1:100,000. The chorological types (floristic elements) were determined according to the principles defined by MEUSEL & al. (1965, 1978), MEUSEL & JÄGER (1992) and STEVANOVIĆ (1992).

3. Results and discussion

3.1. *Athyrium distentifolium* OPIZ – Alpine Lady-fern (Fig. 1)

Synonyms: *Aspidium alpestre* HOPPE, *Athyrium alpestre* (HOPPE) T. MOORE [NON CLAIRV. 1811], *Athyrium flexile* (NEWMAN) DRUCE, *Pseudathyrium flexile* NEWMAN, *Polypodium rhaeticum* auct.

Morphology: Perennial, suberect herb with a short rhizome. The fronds are bi-pinnate, ovate-lanceolate, suberect or spreading, yellow-green, 20–150 cm long. The petiole is pale yellow-green to purple-red, one fifth to one quarter of the length of the blade, usually broad, with pale brown scales. The lamina is lanceolate, thin, flaccid and light green. The pinnae are widely spaced near the base of the frond and sometimes deflexed, crowded near the tip, and meet the rachis at a 90° angle in the middle of the blade or are slightly ascending. The longest pinnae are up to 25 cm long, decreasing towards the leaf base, linear-lanceolate, tapering at the tip. The pinnules are oblong or oblong-lanceolate, broadest at the base, tapering to a point; the segments of pinnules are usually blunt and often tridentate at the tip. The sori are orbicular, less than 1 mm in diameter, near the leaf margin, with irregular filaments concentrated in the upper part of the frond and becoming sparse toward the base. The indusium is rudimentary or caducous at a very early stage, while the spores are reticulate with narrow wings. The plants are often infertile.

The main differences of *A. distentifolium* compared to *A. filix-femina* are the orbicular sorus, the reduced and caducous indusium and the winged spores (JERMY 1993). In *A. filix-femina* the sorus is oblong, the indusium is persistent and the spores are not winged.

General distribution: In a broad sense, *Athyrium distentifolium* (incl. *A. americanum* (BUTTERS) MAXON) is characterized by a wide disjunct range in the Holarctic. *Athyrium distentifolium* s.l. has been found from North America across South Greenland, Iceland, Europe, Siberia, Japan and as far as Kamchatka. In Europe, it occurs in Iceland, the Faroe Islands, the Highlands of Scotland, the Scandinavian mountains, Lapland, and the mountains of Central and Southern Europe, with extension to northeastern Anatolia and Caucasus (BANAŠ & al. 2010, CHRISTENHUSZ & al. 2017a). It also occurs in the Urals, central Siberia and Dahuria, and along the Pacific part of Asia from Kamchatka to southern Sakhalin and Japan (ODLAND 1991, PAGE 1997, MCHAFFIE 2005). In the Balkans, this plant has been found in Bulgaria, North Macedonia, Montenegro, Bosnia and Herzegovina and Croatia (CHRISTENHUSZ & RAAB-STRAUBE 2013+) and represents a glacial relict species in these areas. *Athyrium distentifolium* s.str. belongs to the Boreoatlantic-Eurosiberian Boreal (W-C) – Central European mountainous – Southwest Asian mountainous floristic element.

Distribution in Serbia (Fig. 2A): Although *A. distentifolium* occurs on the Balkan Peninsula, there has been no information about its occurrence in the flora of Serbia until now.



Fig. 1. *Athyrium distentifolium* OPIZ: (A) Herbarium sheet. – (B) Detail of the plant with sori (all from Mts Šar planina).

New and unpublished records (Fig. 2A): E Serbia: Mt Stara planina, Tri Kladenca, UTM FP30, by the stream in the ravine (leg./det. RAJEVSKI, L., sub *Athyrium filix-femina*, 12 Aug 1946, rev. VUKOJIĆ, S., BEOU s.n.); Metohija: Mts Šar planina, Orman peak, Gornji Orman, UTM EM07 (leg. RUDSKI, I., sub *Nephrodium filix-mas*, 16 July 1930, rev. VUKOJIĆ, S., BEOU s.n.); Mts Šar planina, Piri-breg – above Durlov stream, UTM EM06, rocks and heaths, N-NW-NE exp., siliceous bedrock, 1700 m (leg. STEVANOVIĆ, V., sub *Athyrium filix-femina*, 27 Aug 1992, rev. VUKOJIĆ, S., BEOU 1235/92); Mts Šar planina, Prevalac-Lovačka house, Jažinačko lake, UTM DM96 (leg. STEVANOVIĆ, V., LAKUŠIĆ, D., NIKETIĆ, M., sub *Athyrium filix-femina*, 29 Sep 1991, rev. VUKOJIĆ, S., BEOU 2375) (Fig. 2A).

The findings of *A. distentifolium* at Mt Stara planina and Mts Šar planina are the first records of this species on the territory of Serbia. In total, this species was found in four 10×10 km UTM squares in Serbia (Fig. 2A). The locality on Mt Stara planina (Tri kladenca) represents the northeasternmost, whereas the localities on Mts Šar planina (Piri-breg

and Prevalac-Lovačka house) are the southernmost limits of the species' distribution in Serbia.

Habitat and ecology: From the information on the herbarium labels and the personal communications of the collectors, it can be concluded that this species grows in the mountainous and high-mountainous regions of Eastern Serbia and Metohija at altitudes between 1700 m and 2000 m a.s.l. On Mts Šar planina this plant inhabits the vegetation of siliceous rocks (V. STEVANOVIĆ, pers. obs.), while on Mt Stara planina it occurs in wet habitats near streams. These habitats represent refugia for the survival of this arctic-alpine relict species in Serbia.

Athyrium distentifolium is a chionophilous fern that occurs in montane, subalpine, and alpine areas of the Northern Hemisphere from 455 m to 2800 m a.s.l., inhabiting mainly moist gullies, damp pockets on scree slopes and hollows on acidic rocks where a long-lasting winter snow cover is present (ODLAND 1991, ROTHERO 1994, MCHAFFIE 1999, 2005). Within its range, this species has been found on siliceous bedrock types such as granite, but also on carbonate rocks, including limestone, on soils with

a pH between 3.2 and 5.4 (MCHAFFIE 2005). From previous studies, this species is known to be most abundant in different types of tall-herb vegetation, such as the *Luzula sylvatica* – *Vaccinium myrtillus* tall-herb community, then in the community of the alliance *Lactucion alpinae* (ODLAND 1995, MCHAFFIE 2005). In addition, *A. distentifolium* has been found to grow in communities associated with poor soils and low soil fertility, such as the *Cryptogramma crispa* – *Athyrium distentifolium* snowbed vegetation, whereas some populations of this species have been found in the *Polytrichum sexangulare* – *Kiaeria starkei* snowbed community (RODWELL 1992, MCHAFFIE 2005). In glacial cirques it can form the association *Adenostylo alliariae*–*Athyrietum alpestris* (FUDALI 2010). Similar tall-herb communities are formed by this species throughout its range (e.g., DIERSSEN 1996, ERMAKOV & al. 2000, KARNER & MUCINA 1993, KOČI 2001, KRAJČIOVÁ-ŠIBÍKOVÁ & al. 2005). Recently, species extinctions have been observed in these communities (DUNAJSKI & al. 2016), probably due to climate change (MCHAFFIE 2005, GARCÍA CRIADO & al. 2017).

Conservation status and threats: *Athyrium distentifolium* should be classified as a strictly protected species in Serbia, as there are only a few localities and the population size is small. In the IUCN Red List, *A. distentifolium* is listed as Least Concern (LC) (CHRISTENHUSZ & al. 2017a). The same category (LC) is found in the European Red List of Lycopods and Ferns, where it is listed under the synonym *A. alpestris* (GARCÍA CRIADO & al. 2017).

No significant threat factors to this species were identified at the sites in Serbia. Although the effects of climate change on *A. distentifolium* have not yet been studied, it is suspected that the species may change its range in the future, as it requires a cold climate and snow cover. However, MCHAFFIE (2005) emphasized that grazing has a significant impact on the production of new fronds of this spe-

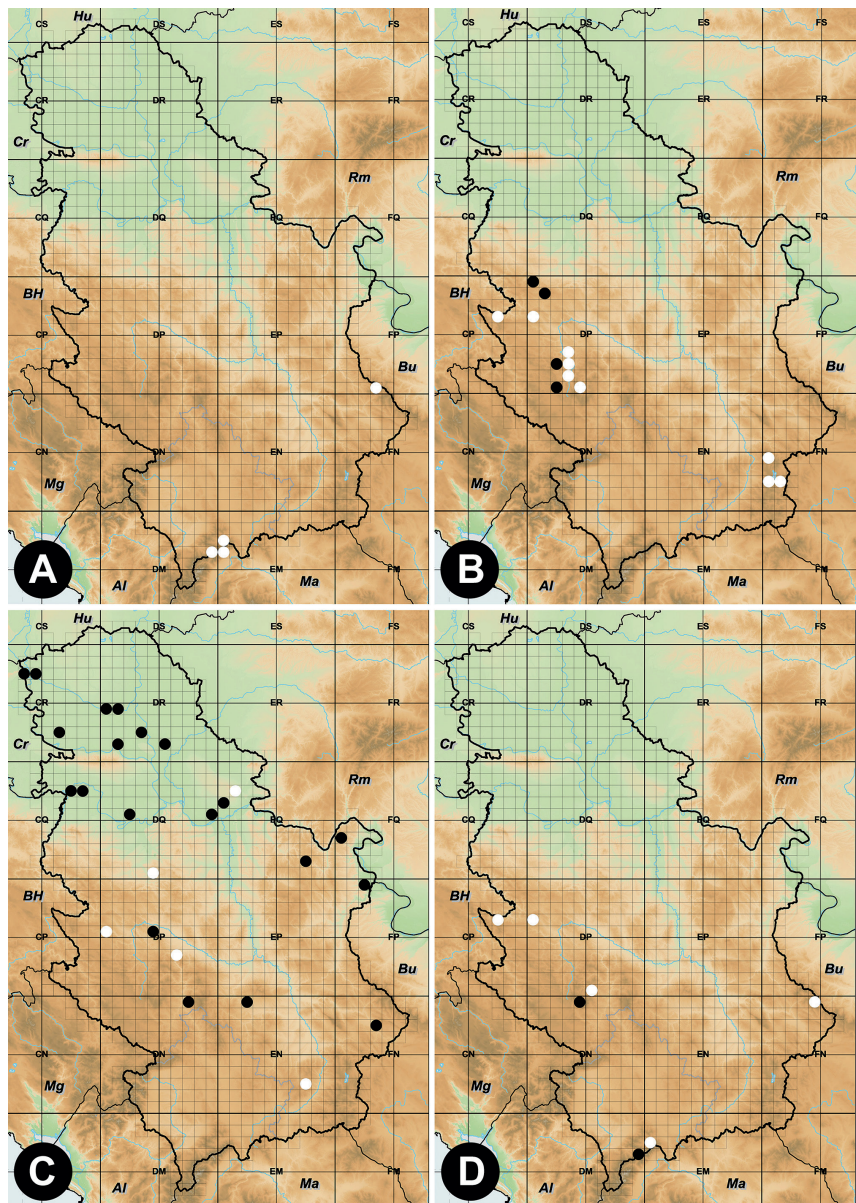


Fig. 2. Distribution of the four studied fern species in Serbia (white dot: new and unpublished data; black dot: published data): (A) *Athyrium distentifolium* OPIZ. – (B) *Thelypteris limbosperma* (ALL.) H. P. FUCHS. – (C) *Thelypteris palustris* SCHOTT. – (D) *Phegopteris connectilis* (MICHX.) WATT.

cies in its range, and that acidification may lead to its slower growth.

3.2. *Thelypteris limbosperma* (ALL.) H. P. FUCHS – Lemon-scented Fern (Fig. 3)

Synonyms: *Lastrea limbosperma* (ALL.) HOLUB & POUZAR, *Oreopteris limbosperma* (ALL.) HOLUB, *Polypodium limbospermum* ALL.

General distribution: *Thelypteris limbosperma* is a boreal-montane relict distributed in Eurasia and the northern and western parts of North America (VUKIĆEVIĆ 1992, CHRISTENHUSZ & al.

2017b). However, according to POWO (2023a), the species has a disjunct temperate Eurasian range, occurring mainly in humid Atlantic regions and on mountain slopes in western and southern Europe, extending eastwards across northeastern Anatolia, the Caucasus and the northern Iranian mountains through central and southern Siberia to Altay. A disjunct part of its range is in Korea and Japan. It belongs to the Western to Central Eurasian floristic element and to the disjunct part of East Asia (Korea and Japan). In the Balkans, it grows in Slovenia, Croatia, Bosnia and Herzegovina and Serbia (NIKETIĆ 1999, CHRISTENHUSZ & al. 2017b).

Distribution in Serbia (Fig. 2B): The species was found in the following localities: Katići near Ivanjica (UTM DP22) in Western Serbia (PANČIĆ 1874, VUKIĆEVIĆ 1992); Lelić and Leskovice – UTM DP09 and Bukovi – DP18 in Northwestern Serbia (MAJSTOROVIĆ 1929, NIKETIĆ 1999). In the Red Book of the Flora of Serbia, it is listed as a taxon that was assumed to have disappeared in Serbia (NIKETIĆ 1999). However, PERIĆ & PANJKOVIĆ (2015) recently recorded this species on Javor Mountain, near the village of Kladnica – UTM DP20. According to the earlier publications cited here, *T. limbosperma* has been found in Serbia in four 10×10 km UTM squares so far.

New and unpublished records (Fig. 2B): W Serbia: Mt Golija, Rivotine, N 43.423809°, E 20.269862°, UTM DP40, 1540 m, phyllite-micaschist, spruce forest (leg./det. VUKOJIĆIĆ, S., LAZAREVIĆ, P., 20 Oct 2022, BEOU 68563); Mt Golija, Lupoglav (Kosovica), N 43.487438°, E 20.188359°, UTM DP31, 1065 m, sericitic schists, edge of the beech forest by the road (leg./det. VUKOJIĆIĆ, S., LAZAREVIĆ, P., 19 Oct 2022, BEOU 68596); Mt Golija, Bratljevo, N 43.467628°, E 20.187435°, UTM DP31, 1085 m, sericitic schists, edge of the beech forest by the road (leg./det. VUKOJIĆIĆ, S., LAZAREVIĆ, P., 19 Oct 2022, BEOU 68597); Mt Tara, Manita ravan, N 43.9117034°, E 19.4098891°, UTM CP76, 1140 m, limestone, ass. Piceo-Abieto-Fagetum s.l. (leg./det. VUKOJIĆIĆ, S., ĐUROVIĆ, S., TOMOVIĆ, G., 16 June 2022, BEOU BBD_124); Mt Tara, Mitrovac (Dečje oporavilište), N 43.9185829°, E 19.4202454°, UTM CP76, 1078 m,

proluvial deposits, tall herb vegetation with *Chaerophyllum hirsutum* (leg./det. VUKOJIĆIĆ, S., ĐUROVIĆ, S., TOMOVIĆ, G., 16 June 2022, BEOU BBD_146); Mt Tara, Karajića bara, UTM CP76, 1270 m, diabase-chert formation, tall herb vegetation with *Chaerophyllum hirsutum* (leg./det. VUKOJIĆIĆ, S., ĐUROVIĆ, S., TOMOVIĆ, G., 17 June 2022, BEOU BBD_613); Mt Jelova Gora, Bukovac (above Jovanova voda), N 43.924734°, E 19.797015°, UTM DP06, 935 m, phyllites, beech forest (leg./det. VUKOJIĆIĆ, S., Oct 2020, BEOU 80054); Mt Jelova Gora, Bujadnjača (along forest road from the ramp to Jovanova voda), N 43.945527°, E 19.786925°, UTM DP06, 948 m, metamorphosed quartz conglomerates and breccias, beech forest (leg./det. VUKOJIĆIĆ, S., 11 Nov 2021,



Fig. 3. *Thelypteris limbosperma* (ALL.) H. P. FUCHS: (A) Habitus, Mt Crvena Gora. – (B) Detail of the plant, Mt Jelova Gora (photos S. VUKOJIĆIĆ).

BEOU 80165); Mt Jelova Gora, Okolišta (road to Kondera), N 43.936443°, E 19.773858°, UTM DP06, 930 m, sericitic quartzites, ass. Piceo-Abieto-Fagetum s.l. (leg./det. VUKOJIĆ, S., 10 Oct 2020, BEOU 80030); Mt Jelova Gora, Laništa (Zaglavak), N 43.921747°, E 19.761178°, UTM DP06, 790 m, sericitic quartzites, beech forest (leg./det. VUKOJIĆ, S., 31 Oct 2020, BEOU 80075); Mt Jelova Gora, Bujadnjača (above Tatalija river), N 43.946212°, E 19.777655°, UTM DP06, 993 m, phyllites, ass. Piceo-Abieto-Fagetum s.l. (leg./det. VUKOJIĆ, S., 10 Aug 2021, BEOU 80113); Mt Jelova Gora, Okolišta – Lijeska, between the first and second bog, N 43.935109°, E 19.778722°, UTM DP06, 945 m, metamorphosed quartz conglomerates and breccias, edge of the fen community (leg./det. VUKOJIĆ, S., 07 Aug 2021, BEOU 80121); Mt Jelova Gora, Okolišta – Lijeska, bog under the road, N 43.934956°, E 19.779209°, UTM DP06, 950 m, sericitic quartzites, edge of the fen community (leg./det. VUKOJIĆ, S., 11 July 2021, BEOU 80128); Mt Jelova Gora, Okolišta, N 43.936709°, E 19.772164°, UTM DP06, 943 m, sericitic quartzites, edge of the fen community (leg./det. VUKOJIĆ, S., 10 July 2021, BEOU 80141); Mt Jelova Gora, Rasadnik, N 43.924619°, E 19.795215°, UTM DP06, 952 m, metamorphosed quartz conglomerates and breccias, ass. Piceo-Abieto-Fagetum s.l. (leg./det. VUKOJIĆ, M. & S., 11 July 2021, BEOU 80155); Mt Mučanj, next to the forest road that leads to the top, N 43.550922°, E 20.0301°, UTM DP22, 1280 m, limestone, ass. Piceo-Fagetum s.l. (leg./det. VUKOJIĆ, M. & S., 13 Aug 2021, BEOU 80116); Mt Crvena Gora, Kaluševići – Jasikovica (Javorak spring), N 43.544359°, E 20.172304°, UTM DP32, 840 m, phyllites, edge of the beech forest (leg./det. VUKOJIĆ, S., 21 July 2021, BEOU 80145); Mt Crvena Gora, Tolska kosa (Ridovi), N 43.542166°, E 20.155706° UTM DP32, 1020 m, metamorphosed quartz conglomerates, degraded beech forest (leg./det. VUKOJIĆ, S., 21 July 2021, BEOU 80146); Ivanjica, Gliječa (Zelenika), N 43.581688°, E 20.171451°, UTM DP32, 913 m, sericitic schists, beech forest on the roadside (leg./det. VUKOJIĆ, S., 09 July 2022, BEOU 68598); Kotražica – Ivanjica, Jasikovac, UTM DP33, beech forest (leg./det. ?, 08 Aug 1979, sub *Thelypteris phegopteris*, rev. VUKOJIĆ, S., BEOU 11977); SE Serbia: Mt Oštrozub, Bistrica, UTM FN04, bogs (leg. ?, 11–27 July 1959, sub *Dryopteris*, det. VUKOJIĆ, S., BEOU s.n.); Vlasina, UTM FN02, FN12, bogs (leg. ?, 11 July 1950, sub *Phegopteris*, det. VUKOJIĆ, S., BEOU s.n.) (Fig. 2B).

In total, *T. limbosperma* has been recorded in nine new 10×10 km UTM squares in Serbia (Fig. 2B). The findings of *T. limbosperma* at the localities on Mt Oštrozub and in Vlasina are the first records of this species in the region of Southeastern Serbia. The locality on Mt Tara (Mitrovac) is the western-

most, while the locality at Vlasina represents the southeasternmost limit of the species' distribution in Serbia.

Habitat and ecology: According to our field observations, the newly recorded localities of *T. limbosperma* in Serbia are situated at altitudes above 750 m a.s.l. The most frequent habitats of this species on Mts Golija, Jelova Gora, Mučanj, Crvena Gora, Tara and in the locality of Gliječa near Ivanjica are along forest paths and forest edges, near streams, mainly in the zone of beech forests and mixed beech-spruce, beech-fir and beech-fir-spruce forests, and rarely in pure spruce forests. The following accompanying taxa were frequently found at the new sites with *T. limbosperma* in Serbia: *Rubus caesius* L., *Fagus sylvatica* L., *Abies alba* MILL., *Picea abies* (L.) H. KARST., *Frangula alnus* MILL., *Mycelis muralis* (L.) DUMORT., *Dryopteris filix-mas* (L.) SCHOTT, *Gentiana asclepiadea* L., *Fragaria vesca* L., *Huperzia selago* (L.) SCHRANK & MART., *Vaccinium myrtilloides* L., *Blechnum spicant* (L.) ROTH, *Sorbus aucuparia* L., *Pteridium aquilinum* (L.) KUHN, *Galeopsis speciosa* MILL. and *Prenanthes purpurea* L. A special feature is that a very similar fern species – *Athyrium filix-femina* – is present at almost all newly discovered sites. On Mt Mučanj, the lemon-scented fern was found in the ecotone zone between the beech-spruce forest and the community of *Epilobium angustifoliae* s.l., with the following accompanying taxa: *Epilobium angustifolium* L., *Rubus caesius*, *Tussilago farfara* L., *Salix caprea* L., *Fragaria vesca* L., *Dactylorhiza saccifera* (BRONGN.) SOÓ and *Fagus sylvatica*. Among the habitats, the fen habitat dominated by sphagnum mosses (*Sphagnum* spp.) on Mt Jelova Gora stands out. Besides the sphagnum mosses, *Lysimachia nemorum* L., *Vaccinium myrtilloides*, *Blechnum spicant* and *Potentilla erecta* (L.) RAUSCH. are also strongly represented in this habitat. On Mt Tara, this fern species was found in the tall herb community (*Chaerophylletum hirsutae* s.l.) and in the ecotone zone between this tall herb habitat and the forest habitat, where the following associated taxa were also present: *Fagus sylvatica*, *Abies alba*, *Picea abies*.

Thelypteris limbosperma was found on various bedrock types at new localities in Serbia: on phyllites, sericitic quartzites, sericitic schists, as well as on metamorphosed quartz conglomerates and breccias (Mts Jelova Gora, Golija, Crvena Gora and Gliječa); on Quaternary sediments, more precisely on proluvial deposits (Mt Tara: Mitrovac); on ophiolitic mélanges, i.e. diabase-chert formation (Mt Tara: Karajica bara), while it was also found on limestones (Mt Mučanj; Mt Tara: Manita ravan). The results show that the species mainly prefers different siliceous soils, but also grows on carbonate soils, which indicates a great ecological plasticity of the

species. At all newly recorded sites in Serbia, populations are well preserved and numerous.

The habitat preferences of *T. limbosperma* in Serbia generally correspond to its habitat requirements in other parts of its range. It is known that this fern species is distributed from montane to subalpine regions of the Northern Hemisphere (HOLTUM 1981). According to previous studies, the species is widespread on damp mountain slopes, in mesophilous coniferous and deciduous forests near forest paths, clearings, along streams and rivers, on scree slopes, in open places, in marshes and heaths, with an altitudinal range between 0 and 2000 m a.s.l. (VUKIĆEVIĆ 1992, NIKETIĆ 1999, CHRISTENHUSZ & al. 2017b).

Conservation status and threats: Based on a three-year study of the flora in Western Serbia, we concluded that *T. limbosperma* is more widespread in Serbia than previously known. The findings in the BEOU herbarium collection from localities in Southeastern Serbia need to be confirmed by further fieldwork, as they are more than half a century old. Ignorance of the fern and its similarity to *Athyrium filix-femina* and *Dryopteris filix-mas* or some other *Dryopteris* species are certainly the reasons for assuming that this species is rare in Serbia. Considering the large number of findings, the large overall population size and the good preservation of its habitats, *T. limbosperma* should be protected with a lower level of protection in Serbia, taking

into account that it is currently classified as a strictly protected species at national level (SL. GLASNIK RS 2010–2016). The lemon-scented fern is classified as Least Concern (LC) in the IUCN Red List of Threatened Species (CHRISTENHUSZ & al. 2017b) and in the European Red List of Lycopods and Ferns (GARCÍA CRIADO & al. 2017).

In Serbia, the following factors can be cited as threats: deforestation, tourism, changes in the hydrological regime of habitats, especially the capture of springs in the immediate vicinity of forest habitats, as well as the widening of paved roads, the closure of the forest complex due to the overgrowth of woody species, the construction of infrastructure and urbanisation in tourist areas. Although individuals of this species were found on Mt. Jelova Gora on the edges of Douglas fir plantations, their negative effects were not observed. On the same mountain, some specimens of the allochthonous species *Erigeron annuus* (L.) DESF. were observed at the sites of the studied ferns, but without any threatening effect being detected. According to CHRISTENHUSZ & al. (2017b), there are no current threats to this species on a global scale.

3.3. *Thelypteris palustris* SCHOTT – Marsh Fern (Fig. 4)

Synonyms: *Acrostichum thelypteris* L., *Aspidium thelypteris* (L.) Sw., *Dryopteris thelypteris* (L.) A. GRAY, *Lastrea thelypteris* (L.) C. PRESL, *Nephrodium thelypteris* (L.) STREMPER, *Polystichum thelypteris* (L.) ROTH

General distribution: The species has a circum-Holarctic distribution: North America, Europe, North Africa, Central and East Asia (KAVAK 2014). It belongs to the amphiatlantic disjunct East North American–West to East Eurasian / boreal meridional floristic element. On the Balkan Peninsula, it is a boreal relict species (TRYON & al. 1980, VUKIĆEVIĆ 1992).

Distribution in Serbia (Fig. 2C): This species is mainly distributed in the lowlands of Vojvodina province (northern Serbia), but also in some localities in the hilly and mountainous regions of Northeastern,



Fig. 4. *Thelypteris palustris* SCHOTT (Kraljevo, Bogutovačka spa, Lopatnica gorge; photo S. VUKOJIĆIĆ). The group of young fronds is marked in the center. Associated species in this locality are *Filipendula ulmaria*, *Carex paniculata*, *Lythrum salicaria*, *Eriophorum latifolium*, etc.

Eastern and Central Serbia (VUKIĆEVIĆ 1992). According to VUKIĆEVIĆ (1992), the species has been recorded at the following localities: Obedska bara near Kupinovo – UTM DQ25; Deliblato (Konstantinova bara, Vrelo) – UTM EQ06; Kovin (Crna Bara) – UTM DQ95, Novi Sad (Ratno ostrvo) – UTM DR11; Srbobran – UTM DR04; Bač (Mostonga) – UTM CR62; Kač–Novi Sad – UTM DR11; Negotinski rit – UTM FP29; Veliki Štrbac (Pecka bara) – UTM FQ03; Majdanpek (Debeli lug) – UTM EQ71; Blačko jezero lake – UTM EN29 and Semeteško jezero lake – UTM DN79. However, STOJŠIĆ & PANJKOVIĆ (2005) stated that the species does not occur at these sites: Deliblato (Konstantinova bara, Vrelo), Novi Sad surroundings (Kač, Ribarsko ostrvo), Bač (Mostonga), Vršački rit, Blace lake, Debeli lug near Majdanpek, Negotinski rit and Veliki Štrbac. During the surveys in the period 2005–2008, the plant was found in new localities: Jegrička – UTM DR32, Stari Begej – Carska Bara – UTM DR51, Bački Monoštor – UTM CR37, CR47, Kraljevac – UTM EQ06 (STOJŠIĆ & PANJKOVIĆ 2005); Zasavica (Vrbovac) – UTM CQ77, CQ87; Zasavica (Skelice) – UTM CQ87, Zasavica (Preseka) – UTM CQ87 (STANKOVIĆ 2006); Krupačko Blato – UTM FN37 (PETROVIĆ & al. 2007) and Beljanska bara – UTM DR14 (DOBRETIĆ & STOJŠIĆ 2008). The last published record refers to Mt Jelica near Čačak – UTM DP45 (NOVOVIĆ & al. 2022). According to the earlier publications cited here, *T. palustris* has been found in twenty 10×10 km UTM squares in Serbia.

New and unpublished chorological data in Serbia (Fig. 2C): Banat: Deliblatska peščara sands, Grebenac, UTM EQ17 (leg. SOŠKA, Th., sub *Nephrodium thelypteris*, 18 June 1923, BEOU s.n.); Deliblatska peščara sands, Majur bara, UTM EQ06 (leg. STEVANOVIĆ, V., 16 Sep 1998, BEOU 13065); Šumadija: Lazarevac, Čibutkovića (Ogradjeno jezero lake), UTM DQ40 (leg./det. LAKUŠIĆ, D., sub *Dryopteris*?, 26 June 1998, rev. VUKOJIČIĆ, S., BEOU 8465); C Serbia: Kraljevo, Bogutovačka spa (the entrance of Lopatnica gorge), N 43.681519°, E 20.473922°, UTM DP63, 348 m, Quaternary sediments, marsh community with *Filipendula ulmaria*, *Carex paniculata* and *Typha* sp. (leg. STEVANOVIĆ, V., NIKETIĆ, M., VUKOJIČIĆ, S., TOMOVIĆ, G., 03 May 2004, BEOU 18874); S Serbia: Vranje, Mt Oblik, the lake below the Oblik peak, UTM EN72 (leg. PANČIĆ, J., sub *Nephrodium phegopteris*, 1881, BEOU 159); W Serbia: Užice, Krčagovo, UTM DP05 (leg. SOŠKA, Th., sub *Nephrodium thelypteris*, in paludosis ad pagum Krčagovo, June 1912, BEOU s.n.) (Fig. 2C).

In total, *T. palustris* was recorded in five new 10×10 km UTM squares in Serbia (Fig. 2C). The finding of this species at the locality of Lazarevac (Čibutkovića) is the first record of this fern species in the Šumadija region, while Vranje (Mt Oblik) is

the first known locality of this species in Southern Serbia. In addition, the locality of Užice (Krčagovo) is the second known locality of the species in Western Serbia, while Kraljevo (Bogutovačka spa) is the third known locality in Central Serbia.

Habitat and ecology: At the locality of Kraljevo (Bogutovačka spa), this species was found in a marsh community dominated by *Filipendula ulmaria* (L.) MAXIM., *Carex paniculata* L. and *Typha* sp. In addition, the following species were found at this site with *T. palustris*: *Equisetum palustre* L., *Eupatorium cannabinum* L., *Galium cruciata* (L.) SCOP., *Vicia incana* GOUAN, *Veronica beccabunga* L. and *Mentha* spp. Furthermore, the marsh fern was found at the same locality at the edge of the fen community (*Eriophoretum latifoliae* s.l.).

The ecological preferences of this species are consistent with those reported for other parts of its range and are based on previously published data from Serbia. Thus, this species is known to occur in wetlands, damp ditches, on the banks of ponds, on alluvial deposits along riverbanks and lake coasts and in swamp forests (VUKIĆEVIĆ 1992, TZONEV & al. 2023). It occurs at altitudes between 10 m and 1400 m a.s.l. (KAVAK 2014). In Bulgaria, this species occurs in the community *Thelypterido palustris-Phragmitetum australis* (TZONEV & al. 2023). Published data indicate that this species inhabits wetlands in riparian forests and marshes (the communities *Alnetum glutinosae*, *Fraxino-Ulmetum effusae* and *Scirpo-Phragmitetum*) in Serbia (VUKIĆEVIĆ 1992). *Thelypteris palustris* is significant because of its relict character, and the plant communities it forms can be considered relict. In the community *Thelyptero-Phragmito-Salicetum cinerae*, described in Serbia, the marsh fern is a sub-edificator and differential species growing in shallow waters and more open places (JANKOVIĆ 1997).

Conservation status and threats: *Thelypteris palustris* is currently classified as a strictly protected species at the national level (SL. GLASNIK RS 2010–2016). However, considering the distribution and population size of this species in Serbia, we believe that the species needs to be protected with a lower level of protection than the existing one. This species is listed as Least Concern (LC) in the IUCN Red List of Threatened Species (KAVAK 2014). It has the same status (LC) in the European Red List of Lycopods and Ferns (GARCÍA CRIADO & al. 2017).

The main factors threatening this species in Serbia are changes in the hydrological regime of habitats and habitat destruction. However, KAVAK (2014) found that this species is threatened throughout its range by grazing, water pollution, agricultural development in wetlands, drainage, dam construction and afforestation.

3.4. *Phegopteris connectilis* (MICHX.) WATT –
Beech Fern (Fig. 5)

Synonym: *Polypodium connectile* MICHX.,
Thelypteris phegopteris (L.) SLOSS.

General distribution: The species occupies boreal and temperate parts of Eurasia and North America (SMITH 1990, VUKIĆEVIĆ 1992). The species is widespread throughout Europe, except in the southern parts, where it is rather rare (TUTIN & al. 1993). It belongs to the circum-Holarctic disjunct boreal-temperate floristic element. In the Balkans, it is distributed in Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Serbia, Bulgaria and Greece (POWO 2023b).

Distribution in Serbia (Fig. 2D): Until 1992, only two localities of this species were known: Mts Šar planina (Kobilica) – UTM DM96 and Golija (Dukića stream, Paljevaci) – UTM DN49 (GAJIĆ 1989, VUKIĆEVIĆ 1992).

New and unpublished records (Fig. 2D):
W Serbia: Mt Jelova Gora, Vojnička stena (Tatalija river), N 43.957616°, E 19.775821°, UTM DP06, 830 m, sericitic quartzites, mixed beech forest (leg./det. VUKOJIĆIĆ, S., Aug 2021, BEOU 80119); Mt Jelova Gora, Sremoš (Tatalija river), N 43.953008°, E 19.796024°, UTM DP06, 855 m, metamorphosed quartz conglomerates and breccias, mixed beech forest (leg./det. VUKOJIĆIĆ, S., 24 July 2021, BEOU 80136); Mt Jelova Gora, below Bujadnjača towards Tatalija river, N 43.944956°, E 19.793598°, UTM DP06, 910 m, metamorphosed quartz conglomerates and breccias, the clearing within beech forest (leg./det. VUKOJIĆIĆ, S., Aug 2022, BEOU 68600); Mt Golija, Ostatija, Gradište (Milojevsko brdo), N 43.361134°, E 20.394997°, UTM DP50, 940 m, phyllite-micaschist, mixed beech forest (leg. VUKOJIĆIĆ, S., KABAŠ, E., LAZAREVIĆ, P., VELJIĆ, M., 19 May 2021, det. VUKOJIĆIĆ, S., BEOU s.n.); Mt Tara, Mitrovac, Crveni potok, UTM CP76, c. 1100 m, Quaternary sediments, ass. Piceo-Abieto-Fagetum s.l. (leg./det. STEVANOVIĆ, V., sub *Thelypteris phegopteris*, 26 June 1990, BEOU 1297/90); E Serbia: Mt Stara planina, Dojkince village (Arbinje), UTM FN49, sandstone (leg. TOMOVIĆ, G., ZLATKOVIĆ, B., sub *Thelypteris phegopteris*, 27 July 1998, BEOU 11648);

Metohija: Mts Šar planina, Orman peak, UTM EM07 (leg. RUDSKI, I., sub *Dryopteris phegopteris*, 16 July 1930, BEOU s.n.); Mts Šar planina, Orman peak, Donji Orman, UTM EM07 (leg. RUDSKI, I., sub *Nephrodium phaegopteris*, 16 July 1930, BEOU s.n.); Mts Šar planina, Gine vode – Mekuš bor – Careve livade, UTM DM96, 1900 m (leg. STEVANOVIĆ, V., sub *Thelypteris?*, 24 June 1997, det. VUKOJIĆIĆ, S., BEOU 7372) (Fig. 2D).

In total, *P. connectilis* was recorded in five new 10×10 km UTM squares in Serbia (Fig. 2D). The finding of *P. connectilis* on Mt Stara planina is the first record of this species in the region of Eastern Serbia. The locality on Mt Tara (Mitrovac) is the northwesternmost, whereas the locality on Mt Stara planina (Dojkince village, Arbinje) is the easternmost limit of the species' distribution in Serbia.

Habitat and ecology: *Phegopteris connectilis* was found mainly on rocky places in beech forests and mixed beech-spruce, beech-fir and beech-fir-spruce forests at new localities in Serbia (Mts Jelova Gora, Golija and Tara). Its populations were found usually on steep slopes and in shady places where water constantly flows over rocky sections. The following accompanying taxa were frequently found at the new localities (Mts Jelova Gora and Golija) with *P. connectilis* in Serbia: *Rubus caesius*, *Fagus sylvatica*, *Valeriana officinalis* L., *Oxalis acetosella* L., *Aruncus dioicus* (WALTER) FERNALD, *Polypodium vulgare* L., *Impatiens noli-tangere* L. and some liverworts (*Marchantia* sp. and *Conocephalum* sp.). Newly recorded populations were found mostly



Fig. 5. *Phegopteris connectilis* (MICHX.) WATT (Mt Jelova Gora; photo S. VUKOJIĆIĆ).

on various siliceous bedrock types as well as on Quaternary sediments, at altitudes between 830 m and 2000 m a.s.l.

The ecological preferences of this species at the new localities in Serbia correspond to its habitat and ecological requirements in other parts of its range and at already known localities in Serbia. Many studies indicate that this species occurs in hilly and mountainous areas (up to 2300 m a.s.l.), in shady places in deciduous and coniferous forests of oak and beech/fir or spruce, or on sheltered rocky banks with steep slopes (VUKIĆEVIĆ 1992, PAGE 1997, CHRISTENHUSZ & al. 2017c). According to VUKIĆEVIĆ (1992), in Serbia this species has been recorded in various deciduous and coniferous communities of the alliances Fagion silvaticae and Vaccinion-Piceion.

Conservation status and threats: *Phegopteris connectilis* is currently classified as a strictly protected species at national level (SL. GLASNIK RS 2010–2016). The species has been classified as Least Concern on the IUCN Red List of Threatened Species (CHRISTENHUSZ & al. 2017c) and on the European Red List of Lycopods and Ferns (GARCÍA CRIADO & al. 2017).

According to our observations, the factors threatening this species in Serbia are the following: changes in the hydrological regime of habitats, deforestation, widening of roads and construction of infrastructure. According to CHRISTENHUSZ & al. (2017c), there are no significant threats to the populations of this species on a global scale.

4. Conclusion

In this paper, chorological data on four fern taxa in Serbia are presented. For this purpose, all available sources were used: field investigations, literature sources and herbarium collections. For the first time, a distribution map of the newly discovered species *Athyrium distentifolium* (alpine lady-fern) in Serbia was provided. The results show that the studied fern taxa are actually more widespread in the studied region than previously assumed. The most abundant taxa in terms of the number of 10×10 km UTM squares are *Thelypteris palustris* (25 grid cells) and *T. limbosperma* (13), while the taxa occurring in a smaller number of squares are *A. distentifolium* (4) and *Phegopteris connectilis* (7). Although three of the studied taxa (*T. limbosperma*, *T. palustris* and *P. connectilis*) are listed as strictly protected at the national level, it is concluded that *T. limbosperma* and *T. palustris* should be protected in Serbia with a lower level of conservation than the strictly protected taxa. In contrast, *P. connectilis* and *A. distentifolium* should be given the status of strictly protected species in Serbia,

considering their small number of localities and small population size. This study highlights the importance of siliceous bedrock types and Quaternary sediments as important substrates for the growth and survival of the studied fern species, which should be taken into account when planning their conservation. Further studies are needed to determine the detailed chorological and ecological preferences of these fern species on the territory of Serbia and to organize their appropriate conservation.

Acknowledgements and funding

The authors thank the editor and anonymous reviewers for their useful suggestions and comments on a previous version of the manuscript.

This work was supported by the Science Fund of the Republic of Serbia, grant number 7750112 – Balkan biodiversity across spatial and temporal scales – patterns and mechanisms driving vascular plant diversity (BalkBio-Drivers), and by the Ministry of Education, Science and Technological Development of the Republic of Serbia (grant numbers 451-03-47/2023-01/ 200178 and 451-03-47/2023-01/200383).

Conflicts of interest

The authors declare no conflict of interest.

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(Received 21 Mar 2023, accepted 5 Apr 2023)