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Marcin Nobis; Jagiellonian University, Kraków, Poland; https://orcid.org/0000-0002-1594-2418

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RESEARCH PAPER

The genus *Selaginella* P. Beauv. (Selaginellaceae, Lycopodiopsida) in Poland: The occurrence of three species as a result of the historical material verification

Ewa Szczęśniak [1*], Edyta M. Gola [2], Wojciech J. Szypuła [3]

[1] Department of Botany, University of Wrocław, Kanonia 6/8, 50-328, Wrocław, Poland
[2] Department of Plant Developmental Biology, University of Wrocław, Kanonia 6/8, 50-328 Wrocław, Poland
[3] Department of Pharmaceutical Biology, Faculty of Pharmacy, Medical University of Warsaw, Banacha 1, 02-097 Warsaw, Poland

* Corresponding author. Email: ewa.szczesniak@uwr.edu.pl

Abstract

Two species of the *Selaginella* genus have been noted in Poland up to date, i.e., *S. selaginoides* and *S. helvetica*. The first species occurs in the Western Carpathians and the Western Sudetes. However, its Sudeten sites are less numerous than previously reported. The second species was one of the rarest elements in Polish flora. Two populations were reported in Silesia (SW Poland), but after 1945, the species was not confirmed in nature, and thus currently, it is regarded in Poland as extinct. Its occurrence and locations were given in the literature based on the historical sources, yet without revision of herbarium materials. Our research on *Selaginella* vouchers, collected from the sites in Silesia and primarily identified as *S. helvetica*, showed that only one population represented *S. helvetica*, whereas the second one was identified by us as an alien American species, *S. apoda*. This is the first record of *S. apoda* occurrence in Poland out of cultivation and, historically, the second in Europe. Accordingly, corrected maps of *S. selaginoides*, *S. helvetica* and *S. apoda* distribution in Poland, together with the identification key to the species, are presented.

Keywords

Selaginella apoda; *Selaginella helvetica*; *Selaginella selaginoides*; distribution maps; morphological features; key to species determination

1. Introduction

The genus *Selaginella* P. Beauv. (Selaginellaceae) represents the ancient lineage of vascular terrestrial plants of the class Lycopodiopsida and is the most numerous of all living lycophytes. Typical features of the *Selaginella* species include microphylls (leaf-like structures differing in origin and development from megaphylls (true leaves) of ferns and seed plants), dichotomous branching of shoots and roots, sporangia in terminal spikes (cones), heterospory and endosporic gametophytes (Jermy, 1990). Currently, six or seven subgenera and more than 700 species (PPG I, 2016; Weststrand & Korall, 2016a, 2016b; Zhou & Zhang, 2015; Zhou et al., 2016), found mainly in the tropics, are distinguished. In Europe, there are three native species, i.e., *Selaginella selaginoides* (L.) P. Beauv. ex Schrank & Mart. recorded in the northern part of Europe and in alpine and subalpine zones of mountains; *S. helvetica* (L.) Spring occurring in the temperate zone, and *S. denticulata* (L.) Spring the thermophile limited to the Mediterranean area (Valentine & Moore, 1993). The two latter are closely related species belonging to the taxonomically difficult *S. helvetica* group (Zhang et al., 2021). In addition, two alien taxa have been recorded in Europe, i.e., an African species *S. kraussiana* (Kunze) A. Braun, which is rather common in Atlantic and sub-Atlantic parts of Europe (Global Biodiversity Information Facility, GIBF, 2023; https://www.gbif.org/) and an American species *S. apoda* (L.) C. Morren, recorded in Germany (Meyer, 1970). In Poland, only *S. selaginoides* and *S. helvetica* have been reported up to date (Mirek et al., 2020). The former species occurs in the highest mountains, quite commonly in the Western Carpathians and rarely in the Western Sudetes. *Selaginella selaginoides* was recorded in 17 and four squares of 10 × 10 km ATPOL grids, respectively (Zając & Zając, 2001). However, the number of squares in the Sudetes seems to be overestimated and should be verified, while the Carpathian stands do not raise such

objections. It is a relatively rare species in Poland, partially protected by law, but not included in the Red list of Polish vascular plants (Kaźmierczakowa et al., 2016).

The second taxon, *S. helvetica*, was reported only from a few isolated stands in Silesia (SW Poland). It was recorded near Branice and Bliszczyce villages, in meadows along the Opava river (Milde, 1867a), the current country border between the Czech Republic and Poland, and in the castle park in Pszczyna (Schube, 1908). *Selaginella selaginoides* is easily recognizable due to clear diagnostic features such as isomorphic, spirally arranged microphylls, rarely occurring in the genus, while *S. helvetica* belongs to a large group of anisophyllous, dorsoventrally flattened and morphologically similar *Selaginella* species (Weststrand & Korall, 2016a).

Out of continuous range sites of *S. helvetica* in Poland and especially the population in the castle park, where exotic plant species were cultivated, raised a question regarding specimen identification. As the species has not been found in the field after 1945 and is currently considered extinct in Poland (Kaźmierczakowa et al., 2016), only herbarium specimens were available for species identity verification.

The correctness of the species identification is an essential condition for the proper compilation and completeness of both the general list of the flora and the red lists of endangered species as well as is critical for the effectiveness of biodiversity protection (Nowak & Nowak, 2022). The revision of herbarium materials is the only method of verifying the presence and number of sites of extinct species in a given region.

Therefore, the aims of the current research were to validate the species determination of *Selaginella* herbarium materials collected in Poland; verify species sites and distribution, and prepare updated distribution maps of *Selaginella* species collected in Poland. Consequently, a new key to the determination of *Selaginella* species found in the country was constructed.

2. Material and methods

Polish sites of *Selaginella* species were limited to the Carpathians, Sudetes (S Poland) and Silesia region (SW Poland). To validate species determination and verify the list of species collected in Poland, the general Polish herbaria in Kraków (KRAM; KRA) and Warszawa (WA), as well as the regional herbaria collections in Wrocław (WRSL), Opole (OPOL) and Katowice (KTU), were checked.

The diagnostic features analyzed in herbarium specimens included the position of rhizophores as well as the morphology and size of microphylls and strobili. Measurements of lengths and widths of dorsal and ventral microphylls ($n \geq 30$ for a leaf type and a species) and available strobili were performed on the photographs using AxioVision 4.2 (Zeiss, Germany).

The material was verified using keys to species identification (Dostál, 1984; Valentine & Moore, 1993), which include all European native species and taxa introduced and naturalized in European countries. Due to insufficient descriptions and imprecise indication of diagnostic features in these keys, we also used detailed taxa descriptions included in *Flora of North America* (Valdespino, 1993). In addition, vouchers of specimens collected in Poland were compared with the herbarium materials sampled out of Poland in the species' geographical range of distribution.

To verify *S. selaginoides* distribution in Poland, we analyzed available herbarium materials. Special attention was paid to *S. selaginoides* distribution in the Polish Sudetes due to the raised doubts about the number of its sites. Therefore, we additionally analyzed all available historical sources and consulted the cited stands with researchers who currently conduct field studies in this range, and accordingly updated the species distribution map in the Sudetes. For the Carpathian sites, the revision of herbarium materials was also performed.

Distribution maps of all the species occurring in Poland were made in the ATPOL grid of 10 × 10 km (Zając & Zając, 2001). To prepare a global distribution map, the species occurrence data was taken in January 2023 from GBIF using the rgbif package (Chamberlain et al., 2023). Data sets were cleaned with the CoordinateCleaner package (Zizka et al., 2022), and mapped to a hexagon grid with a function to count the points (species occurrence) in a polygon. World distribution maps of the species were prepared in QGIS (2023).

3. Results

During our research, 75 vouchers of *Selaginella* plants collected in current Polish borders were verified. Materials contained 74 sheets of *S. selaginoides* and one described as *S. helvetica* (Appendix 1).

Our verification of *S. selaginoides* vouchers confirmed the proper determination of the species. Herbarium specimens collected in the Carpathians came from the Babia Góra Mt., (Beskid Żywiecki range; three vouchers, ATPOL square DG 26), the Gorce Mts. (one voucher, EG 22), the Pogórze Spisko-Gubałowskie range (three vouchers, DG 49, DG 59), the Tatra Mts. (56 vouchers, 51 from the Western Tatra Mts. and one from the High Tatra Mts.; four vouchers had only a general location given; DG 58, DG 59, DG 69, EG 50), the Pieniny Mts. (eight vouchers, EG 32–34) and the Beskid Sądecki range (three vouchers, EG 34, EG 36; Appendix 1). In total, the species sites documented by herbarium materials are located in 11 ATPOL squares of 10 × 10 km. The majority of plants (59 vouchers) was collected in grasslands developed on limestone rocks. Only four sites were located in the alpine belt, and the remaining were sampled in the montane forests zone or in the subalpine zone.

In the case of *S. selaginoides* collected in the Sudetes, all the voucher materials came from sites currently located in the Czech Republic borders. In the literature, the species was reported from the Western and Eastern Sudetes. In the Western Sudetes, *S. selaginoides* was noted in the Izerskie Mts. (one site), and the Karkonosze Mts. (about 13 sites, mostly in the southern part) and in the Eastern Sudetes in the Jeseníky Mts. (about 11 sites, all in the Czech Republic). In the Polish part of the Sudetes, it was reported from six sites, one in the Izerskie Mts. (Wysoki Grzbiet; Milde, 1858; ATPOL square AE 67), which was not confirmed after 1945, and five stands in the Karkonosze Mts. The latter included the site near the tourist path above the Strzecha Akademicka shelter, known from the 19th century (Fiek, 1881; square AE 89), confirmed after 1945 and described as abundant (Šourek, 1969). The next site was discovered in the Mały Śnieżny Kocioł circle, on basalt debris, at 1250 m a.s.l. (Šourek, 1969; square AE 78).

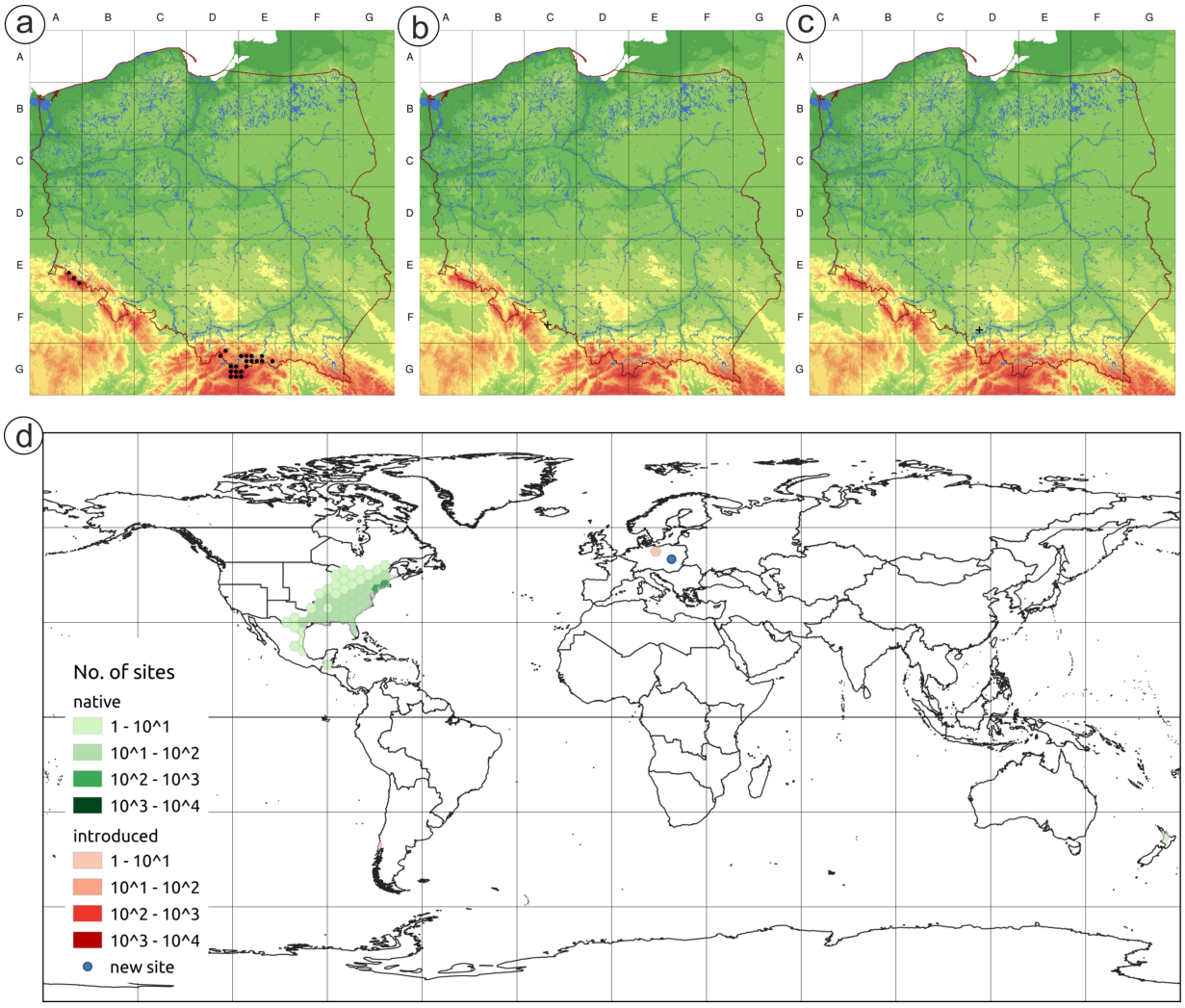

Figure 1 Distribution maps of the genus *Selaginella*. Distribution in Poland: (**a**) *Selaginella selaginoides* (L.) P. Beauv. ex Schrank & Mart.; (**b**) *Selaginella helvetica* (L.) Spring; (**c**) *Selaginella apoda* (L.) C. Morren; (**d**) global distribution map of *Selaginella apoda* (L.) C. Morren.

Currently, both these sites are not confirmed. In the last decades, the species has been recorded only from three sites, located in the ATPOL square AE 89. Two of them, with a very limited number of specimens, were found in the glacial circles of the Wielki Staw pond (B. Wojtuń, M. Malicki, personal information, 2022) and the Mały Staw pond (Krukowski, 2000); these sites have been known since the 19th century (Milde, 1858). The third, new stand was reported in the alpine grasslands in the Kocioł Łomniczki circle (Kwiatkowski, 2006, 2008). In total, all the sites known in the Polish Sudetes are situated in three ATPOL squares. The Sudetes sites were located in the montane forest zone (the Izerskie Mts. and the site near the Strzecha Akademicka shelter) and in the subalpine zone (remaining sites).

The map of *S. selaginoides* distribution in Poland (Zając & Zając, 2001) was updated and is presented in Figure 1a.

In the search for *S. helvetica* in Polish herbaria, only two vouchers (No. 000191 and 000192) collected before 1945 in historical Silesia were found, both in the Herbarium of the University of Wrocław (WRSL). On the sheets, eight samples were present. The first voucher contained three separate shoots and a mature strobilus, collected in Komárov in the Opava river valley. The second one included four clumps of *Selaginella* collected in the castle park in Pszczyna and taken together with mosses and vascular plants (Figure 2a–c).

Both vouchers were supposed to represent the same taxon. Our revision showed that all collected plants belonged to the same subgenus *Stachygynandrum* (P. Beauv. ex Mirb.) Baker, the most numerous within the genus, characterized by mostly ventral rhizophores, dimorphic trophophylls (=vegetative microphylls), and monomorphic sporophylls. However, the comparison of morphological characters of strobili and microphylls clearly disproved their belonging to one species (Figure 2d–k); each voucher represented a different taxon. The main differences concerned the shape of the microphylls, including sporophylls, the size and position of strobili, and the arrangement of megasporangia.

Dorsal microphylls in specimens collected in the Opava river valley (WSRL 000192) were broadly ovate, with obtuse or broadly acute apices, (0.9–)1(–1.6) mm long and (0.5–)0.6(–0.7) mm wide. Ventral (lateral) microphylls were of a similar shape but slightly bigger, (1.3–)1.5(–2.0) mm long and

Figure 2 Features of the herbarium specimens; (**a**) herbarium specimens of *Selaginella helvetica* (L.) Spring from the Opava river valley (WSRL 000192); (**b**) herbarium specimens of *Selaginella apoda* (L.) C. Morren, signed as *S. helvetica*, from Pszczyna (WSRL 000191); (**c**) one of samples of *S. apoda*; (**d**) close up of the *S. helvetica* shoot with dorsal microphylls; (**e**) close up of the *S. apoda* shoot with dorsal microphylls; (**f**) strobilus of *S. helvetica*; (**g**) typical strobilus of *S. apoda*, with keels of sporophylls pointed by arrows; (**h**) the longest observed strobilus of *S. apoda*, visible two rows of megasporangia on the ventral side of strobilus; (**i**) sporophyll of *S. apoda*, with pointed the vascular bundle and significant keel; (**j**) habit of the *S. apoda* shoot, visible short horizontal strobili at the tips of branchlets; (**k**) silhouettes of dorsal and ventral microphylls of analyzed specimens, and *S. apoda* (for reference, WSRL 51330). Scale bars: d, e, g, i = 1 mm; f, h, j = 5 mm; k = 500 µm.

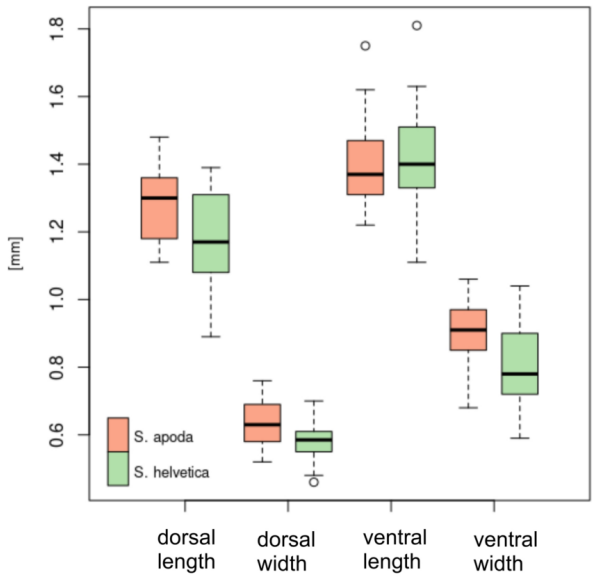

Figure 3 Comparison of microphyll sizes in analyzed specimens of *Selaginella helvetica* (L.) Spring and *Selaginella apoda* (L.) C. Morren.

(0.6–)0.8(–1.0) mm wide (Figure 2k; Figure 3). Margins of all trophophylls were slightly dentate. The only strobilus present in the voucher was 5.2 cm long, lax, with megasporangia located along the entire axis. All features are typical to *S. helvetica* (compare the key below).

Samples collected in the castle park in Pszczyna (WSRL 000191) differed in morphology from the previously described material (Figure 2d–k). Dorsal microphylls were narrowly cordate, acuminate to cuspidate, dentate, (1.1–)1.3(–1.5) mm long and (0.5–)0.6(–0.8) mm wide, whereas ventral microphylls were broad, ovate to slightly cordate, broadly acute to apiculate, (1.2–)1.4(–1.8) mm long (Figure 2k; Figure 3). Numerous horizontal strobili were present in these samples (Figure 2j), although some of them were immature. Strobili were tetragonal, small, (2.1–)3.5–5(–5.2) mm long, and one reached 9.1 mm; with two to 14 megasporangia arranged only in two ventral rows. In one sample, we found 14 well-preserved strobili and ca. 10 immature or damaged ones. In addition, sporophylls had a significant keel (Figure 2g,i). The characters presented above are typical of *S. apoda* and not of *S. helvetica*. *Selaginella apoda* is a new taxon in Poland. Accordingly, the distribution maps of both species in Poland (Figures 1b,c) and the updated map of *S. apoda* global distribution (Figure 1d) are shown.

In summary, our revision clearly proved that the voucher WSRL 000192 represents *S. helvetica*, whereas the voucher WSRL 000191 is *S. apoda*, a new find for Poland.

Key to distinguishing *Selaginella* species collected in the wild in Poland

1. Plants not dorsoventrally flattened; isophyllous, microphylls spirally arranged (Figure 4) . . . . . *S. selaginoides*

1*. Plants dorsoventrally flattened; anisophyllous, two rows ventral (lateral) and two rows of dorsal microphylls, dorsal microphylls smaller than ventral (Figure 3) 2

2. Strobili on erected, single or dichotomously branched peduncles, cylindrical, lax, (2–)3–5 cm long, 3–5 mm wide, with many megasporangia inserted throughout the length of strobilus, not limited to specific rows, sporophylls without keels; dorsal microphylls broadly ovate, with obtuse or broadly acute apices, ventral (lateral) microphylls similar in shape but bigger, margins of both types of microphylls entire or slightly dentate . . . . . *S. helvetica*

2*. Strobili on tips of the secondary branches, horizontal, tetragonal, 0.2 to 1.5 (2) cm long, and ca. 1 mm wide, with megasporangia limited to two ventral rows, sporophylls strongly keeled; dorsal microphylls ovate to narrowly cordate, their apices acuminate to cuspidate, ventral (lateral) microphylls broadly ovate, slightly cordate to broadly lanceolate, broadly acute to apiculate, margins of both types of microphylls dentate . . . . . *S. apoda*

4. Discussion

Selaginella selaginoides is the only representative of the genus *Selaginella* still present in Poland. However, its current condition is different in the Carpathians and the Sudetes. In the Polish Carpathians, it is not considered endangered, and therefore it was not included in the regional red list (Mirek & Piękoś-Mirkowa, 2008). In the Sudetes, the majority of *S. selaginoides* sites were located in the Jeseníky Mts. and in the southern slopes of the Karkonosze Mts., both in the Czech Republic; in that country, the species is limited to the Sudetes (Kaplan et al., 2019) and is classified as vulnerable (Grulich & Chobot, 2017). In the Polish Sudetes (Kącki et al., 2003; Szczęśniak, 2008), as well as in the whole range of the Karkonosze Mts. (Štursa et al., 2009), it is critically endangered. Considering the degree of the threat in the Sudetes, the species should be included in the Polish red list. However, because of the condition and abundance of the Carpathian population the risk of extinction is rather low. Therefore, the NT (Near Threat) category, according to the IUCN, seems to be appropriate (IUCN, 2023).

In the ATPOL map of species distribution (Zając & Zając, 2001), *S. selaginoides* was shown in four squares in the Sudetes (AE 78, 79, 89, BE80). However, according to our verification, the taxon should be limited to three squares, i.e., AE 67, 78, 89 (Figure 1a). Moreover, in the Carpathians, the number of ATPOL squares slightly increased. These differences comparing the species distribution published in ATPOL (Zając & Zając, 2001) may result from incorrect translations of historical geographical names, and thus wrong placement on the map. The other reason could be the more precise location of the sites in the ATPOL square grid due to nowadays-advanced technical possibilities; this is of great importance for sites at the edges of squares.

Selaginella helvetica was one of the rarest elements of Polish flora, reaching the northeastern distribution limit in this part of Europe. Therefore, the species caught the interest of botanists, and it was included in Polish red books of vascular plants (Baryła, 1993, 2001; Parusel, 2014). However, the correctness of the species identification was not verified up to date.

Specimens collected in 1857 in Komárov by T. Hain (WSRL 000192) belonged to the population observed in the Opava river valley. The population was described as growing sparsely

Figure 4 *Selaginella selaginoides* (L.) P. Beauv. ex Schrank & Mart.: (**a**) habit, (**b**) tropophyll, (**c**) sporophyll. Scale bars: 500 µm.

(Milde, 1867a). However, no information about the number of fertile shoots and the effectiveness of generative propagation were given. In herbarium materials, only one well-developed strobilus was included. Along the Opava river, the species was recorded in two subpopulations, one in the current borders of the Czech Republic, and the other one, at the opposite bank of the river, in the current borders of Poland. The Czech location was in a flooded meadow on the bank of Moravice (germ. *Mora*, *Mohra*), a tributary of the Opava river, in Komárov near Opava, the town (*Kommerau bei Troppau*; Fiek, 1881; Milde, 1867a). The other subpopulation was recorded near Krnov, in meadows on the bank of the Opava river, near Branice and Bliszczyce villages (*Branitz und Bleischwitz bei Jägerndorf*; Schube, 1903), but in later literature was always given as two separate sites, named after the villages. However, Milde described this subpopulation as three occurrences in meadows in the Opava river valley near Branice and Bliszczyce, between the towns of Opava and Krnov (*in den Auen der Oppa bei Branitz und Bleischwitz (zwischen Troppau und Jägerndorf*), *wo sie an den 3 Standorten sparsam vorkommt*; Milde, 1867a). Unfortunately, it was not noted how far they were apart from each other, and thus whether they could be considered as two or three sites, or as three occurrences within one site. Here, the species grew also in meadows, on exposed soil of the old mole mounds. These plants were verified by Julius Milde (Milde, 1867a), the German pteridologist with a very wide knowledge of the vascular spore plants, the author of keys to their identification (Milde, 1865, 1867b). This species identification did not raise any objections, and its correctness was confirmed during our revision of the herbarium materials. Although the verified material was collected from the Czech subpopulation, it should be considered representative of the entire population, including sites near Branice and Bliszczyce.

One issue needs to be addressed. At that time, the southern bank of the Opava river belonged to Austrian Silesia (currently in the Czech Republic), whereas the northern bank of the river was in Prussian Silesia (currently in Poland). Milde (1867a) emphasized that the first site (in Komárov) was located in Austrian Silesia, but the others (near Branice and Bliszczyce) were in Prussian Silesia. However, the latter sites were designated within an administrative unit *kreis Jägerndorf* (Austrian Silesia), not *kreis Leobschütz* (Prussian Silesia; Schube, 1903), what may suggest a section of the Opava river valley between these villages, but on the southern bank (the present Czech side). To make it more complicated, on the Czech side, there is a grange, which in the past belonged administratively to the village of Branice. Moreover, Schube (1908) stated that *S. helvetica* found in Pszczyna was a new species for Prussian Silesia (*Neu für Preuss.-Schlesien*, l.c.). This suggested that all sites in the Opava river valley were situated in the current borders of the Czech Republic, and thus it further implies that the species did not occur in the current borders of Poland. Although an unequivocal determination of these sites' location is currently impossible, given that Milde exchanged letters with the discoverer of all the sites, Milde's opinion on the location of the subpopulation near Branice and Bliszczyce in Prussian Silesia seems to be conclusive (Milde, 1867a).

In Polish literature after 1945, two other localities of *S. helvetica* were mentioned, not documented by herbarium materials, and erroneously referring to the 19th-century German floristic data. The first location, in Strzelniki near Lewin Brzeski (Sendek, 1986), was the mistranslation of the German name Jägerndorf, which currently is Krnov in the Czech Republic. Furthermore, there is no record of the species from Jägerndorf in the German data; this location was given as the name of the administrative unit, in which the species occurred (*kreis Jägerndorf*; Schube, 1903). The second site, in the Karkonosze Mts. (Parusel, 2014), was also a result of a misunderstanding of German data. Milde noted that many years ago *S. helvetica* was allegedly found near the

Podgórna river waterfall in Przesieka (Karkonosze Mts., Western Sudetes), but he explicitly stated this site as a mistake or even a deception (*Vor vielen Jahren sollte Selaginella helvetica am Hain-Falle in Schlesien entdeckt worden sein; doch war es damals offenbar auf eine Täuschung abgesehen*; Milde, 1867a).

The other voucher, verified during our studies, contained plants collected in the castle park in Pszczyna and identified by Kirchner as *S. helvetica* (Schube, 1908). At that time, it was the only dorsoventrally flattened species included in keys to the identification of the vascular spore plants in this part of Europe, although the occurrence of the similar alien species, *S. apoda*, was already noted near Potsdam (Magnus, 1878). The site in Pszczyna raised doubts about its naturalness (Baryła, 2001), but the identity of the species has not been questioned. Parusel (2014, 2016) examined the herbarium specimens from Pszczyna, and repeated the erroneous identification; moreover, he assessed the site as probably natural, emphasizing the similarity of habitats in which the species was observed in Pszczyna to those in the Opava river valley. Our revision of the voucher specimens indisputably excluded such an identification. Thus, three occurrences of *S. helvetica* in the Opava river valley remain the only ones recorded in the area of Poland.

Based on the herbarium materials, we identified the specimens collected in Pszczyna as an American species, *S. apoda*. These plants were collected in 1907 in the park meadow near the castle, the main residence of Hans Heinrich XV von Hochberg, the Duke von Pless. At that time, the castle was surrounded by a vast English park. *Selaginella* grew there in large numbers (*in grosser Menge*; Schube, 1908). As we observed in the herbarium materials, plants were vigorous and produced numerous strobili with well-developed spores. The abundance of the site and the number of shoots in the voucher suggest that this population probably lasted for more than one season, but apart from this surmise, there is no published data on this site. The American *S. apoda* species was, and still is, a popular ornamental plant cultivated in greenhouses, bottle gardens, and others; however, little is known about its naturalization in Europe. The only confirmed historical site of *S. apoda* in Europe was reported in 1878, in Pfaueninsel near Potsdam (currently in Berlin), Germany. The species was noted only on lawns, and not entered the natural meadows, possibly due to lawn mowing (Magnus, 1878), which eliminated the competition of higher plants. The population survived ca. 100 years (Meyer, 1970). However, in 2014, the population did not exist on this site, and no other information about the long-term stable species presence in Germany was available (Hand & Buttler, 2014). The site in Pszczyna is the first record of *S. apoda* occurrence in Poland and the second certain occurrence of the species out of cultivation in Europe.

The distribution map of *S. apoda*, generated based on the GBIF database (2023), presents several sites of this species in Europe. However, they mostly refer to preserved materials with the coordinates of the herbaria in which they are deposited. Two sites are unverifiable as they represent personal observations without deposited materials. Some sites in the GBIF database were not included in the map due to the lack of coordinates. The most interesting was voucher No. 50887 deposited in WRSL with specimens collected 10.07.1900 in Madeira, Ribeira de S. Luzia (Portugal) by J. Bornmüller and designated as *S. apus* Spring (synonym of *S. apoda*; GBIF No. 1707151102). However, after the revision, we found that collected *Selaginella* plants belonged to the subgenus *Gymnogynum* (P. Beauv.) Weststrand & Korall, which excluded *S. apoda*, and the specimens were identified as an African species *S. kraussiana* (Kunze) A. Braun. Out of the geographical range, *S. apoda* was also recorded in South America, in some sites along Corral Bay near the town of Valdivia (Chile). For the first time, it was observed in 1975 (Hausenstein et al., 1981) and was still present in 2002 (GBIF, 2023). The species was cultivated in the botanical garden of the Universidad Austral de Chile, and possibly, it escaped from the cultivation (Hausenstein et al., 1981).

To summarize, our studies showed that before 1945 in Poland, three *Selaginella* species were present: two native, i.e., *S. selaginoides* and *S. helvetica*, and one alien, *S. apoda*. In Poland, *S. selaginoides* and *S. helvetica* are known from fossils from the Augustovian Interglacial, characterizing the cold periods with subarctic climate and indicating the lack of full forest cover (Lindner et al., 2004; Stachowicz-Rybka, 2005). The first species is still present in Poland; however, it is rarer in the Western Sudetes than previously presented in the Polish literature. *Selaginella helvetica* was probably native to our flora and is also treated as a native element in the Czech flora (Kaplan et al., 2019). However, it is not known how stable the population was in the Opava river valley. Thus, it is difficult to conclude whether it was a permanent or ephemeral element in Polish flora. *Selaginella apoda* is an alien element. There is no information on its population persistence in Pszczyna. However, as there was only a single note on its occurrence, it should be classified as a casual alien (Pyšek et al., 2004) in Poland. Despite vitality, spore production and some resistance of *S. helvetica* and *S. apoda* to low temperatures, none of the discussed Polish populations survived. The sites and their vicinity were checked several times after 1945, but the individuals of *Selaginella* were not found. *Selaginella helvetica* sites in the Czech Republic have also disappeared (Chrtek, 1997; Grulich & Chobot, 2017; Kaplan et al., 2019). Thus natural regeneration of the Polish extinct population seems not to be possible.

5. Supplementary material

Appendix 1. The list of herbarium vouchers of the species *Selaginella* P. Beauv. collected in wild in Poland and deposited in Polish herbaria.

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