

DISTRIBUTION AND CONSERVATION STATUS OF *Lycopodiella inundata* (L.) Holub IN THE CARPATHIANS

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Abstract. *Lycopodiella inundata* (L.) Holub is a species with a high risk of extinction in many European countries due to the progressive habitat loss. The aim of this paper is to describe the present and former distribution of *L. inundata* in the Carpathian range as well as to assess its threat status in Europe, the Carpathian countries and particularly in Poland.

Keywords: *Lycopodiella inundata*, Carpathians, distribution, conservation status.

Rezumat. Distribuția și statutul de conservare al speciei *Lycopodiella inundata* (L.) Holub în Carpați. *Lycopodiella inundata* (L.) Holub este o specie cu un risc înalt de extincție în multe țări din Europa din cauza pierderii progresive a habitatului ei. Scopul acestei lucrări este de a descrie distribuția prezentă și trecută a speciei *L. inundata* în întreg lanțul Carpatic și de a evalua statutul de conservare al speciei în Europa, în țările lanțului Carpatic și în mod particular în Polonia.

Cuvinte cheie: *Lycopodiella inundata*, Carpați, distribuție, statut de conservare.

INTRODUCTION

Lycopodiella inundata (L.) Holub (syn.: *Lepidotis inundata* (L.) P. Beauv., *Lycopodium inundatum* L.) is a species with a high risk of extinction in many European countries due to the progressive habitat loss. It is a lowland plant, which occurs occasionally in the mountains. In UK, the species is named Marsh Clubmoss and is a species associated with ponds, having as habitat bare peat, trampled, poached ground, on damp but not wet ground (ecotone between dry and wet) (BAP, 2008).

L. inundata is typically found in open areas on damp, acid, sandy or peaty soils, predominantly in depressions within transition mires and bogs, and around the margins of oligotrophic lakes. It often occurs in places where human activities provide disturbance and maintain areas of bare, wet ground e.g. old peat cuttings, sandpits, damp sands exposed to heavy military vehicle use or heavily eroded footpaths. *L. inundata* needs to grow in open and low vegetation and can be easily out-competed by fast-growing and rapidly-spreading pioneer species, and is a mycorrhizal species (arbuscular mycorrhizae) (FUCHS & HASELWANDTER, 2004).

L. inundata is an Atlantic, circumpolar species, with its main range in North America and Europe. Its altitudinal range extends from sea level to 2000 m in North America. In America, it occurs frequently in the east, from Labrador and New Jersey to the Great Lakes, and only sparsely on the western coast. In Europe, *L. inundata* is widely distributed south of the Arctic Circle (including the Azores), except the Mediterranean region and the eastern part of the continent, except Oksko-Donskaya lowland, where it is locally frequent (Fig. 1). To the north, the range of *L. inundata* extends to 67° N, whereas the southern limits are the Rhodope Mountains and Pyrenees. *L. inundata* has isolated localities scattered sparsely east to Caucasus, as well as being listed from Japan and Baikal Lake region (HULTÉN & FRIES, 1986).

The distribution of *L. inundata* is described in *Florae Europaeae* (2016) as: most of Europe (Au Az Br Bu Cz Da Fe Ga Ge Hb He Ho Hs It Ju Lu No Po Rm Rs (N,B,C,W,E) Su), except the Mediterranean region and much of E. Russia (Fig. 1). In Europe its highest localities are at cca 1,500 m in the Alps (ČEŘOVSKÝ & VÁGENKNECHT, 1999).

In Poland, stands of *L. inundata* are scattered mostly in the Pomeranian Lakeland, NE part of Mazovian (district Warszawa), Roztocze, and the Silesian Basin (ZAJĄC & ZAJĄC, 2001). Few mountain populations were found in the Sudeten and Carpathians, but they did not reach altitudes higher than 1,130m. In the Romanian Carpathians, stands of *L. inundata* are scattered in cold and high areas, 800-1,400 m a.s.l., this species is considered a glacial relic in the Romanian flora (POP, 1976; BOȘCAIU, 1989). Stands in Slovak part of the Carpathian range are distributed mostly from 700 to 880 m a.s.l.

In the Carpathians, *L. inundata* usually occurs in associations of *Scheuchzerio-Caricetea* class, especially *Rhynchosporium albae*, *Caricetum limosae* (many populations in the Romanian Carpathians) and *Oxycocco-Sphagnetum* class (SANDA et al., 1993, 2001; KOCZUR, 2014) and waterlogged valleys within raised bog communities (e.g. at Vihorlat in Slovakia). *L. inundata* is commonly associated with *Rhynchospora alba* and *Drosera rotundifolia*.

Localities in the Carpathians might either be relic or of recent origin, since although *L. inundata* has narrow ecological amplitude with a strong preference for nutrient poor situations, this species also has a high dispersive ability facilitating its establishment in suitable sites within the mountains. In some non-mountainous areas, there is evidence that *L. inundata* is spreading into anthropogenic habitats (CIESZKO & KUCHARCZYK, 1999; STEBEL & DROBNIK, 2003).

MATERIAL AND METHODS

A map of the distribution of the species across the Carpathian range was elaborated mostly on the basis of accessible literature data. Some herbarium material from Poland and Romania was also studied. Detailed examination was carried out in the Herbarium of the Institute of Biology Bucharest (BUCA), Herbarium of W. Szafer Institute of Botany of Polish Academy of Sciences in Cracow, Poland (KRAM) and the Herbarium Universitatis Jagiellonicae Cracoviensis (KRA), the biggest Polish collection of the Carpathian flora. In order to verify whether a particular locality was still extant, we used mainly regional “red books” containing relatively recent information (ANDRIJENKO, 1996; ČEŘOVSKÝ & VÁGENKNECHT, 1999; WITKOWSKI et al., 2003; MIREK & PIEKOŚ-MIRKOWA, 2008), together with unpublished data.

To classify stands in terms of their physiographic environment, we used the division of the Carpathians into mesoregions according to KONDRACKI (1978). Categories of threat were based on the IUCN classification scheme for threatened species (IUCN, 1994; 2012).

RESULTS AND DISCUSSION

DISTRIBUTION IN THE CARPATHIANS

In the Carpathians, *L. inundata* is listed from only a few localities, scattered in the Czech Republic, Slovakia, Poland, Ukraine and Romania (WITKOWSKI et al., 2003). However, most populations in the Western Carpathians (from the Podbeskydska pahorkatina, the Tatras and the Kotlina Orawsko-Nowotarska) are considered extinct (Fig. 1; Table 1). In the Eastern Carpathians, *L. inundata* occurs in highly isolated colonies spread from the Bieszczady Zachodnie in the north to Buzău Mountains in the south.

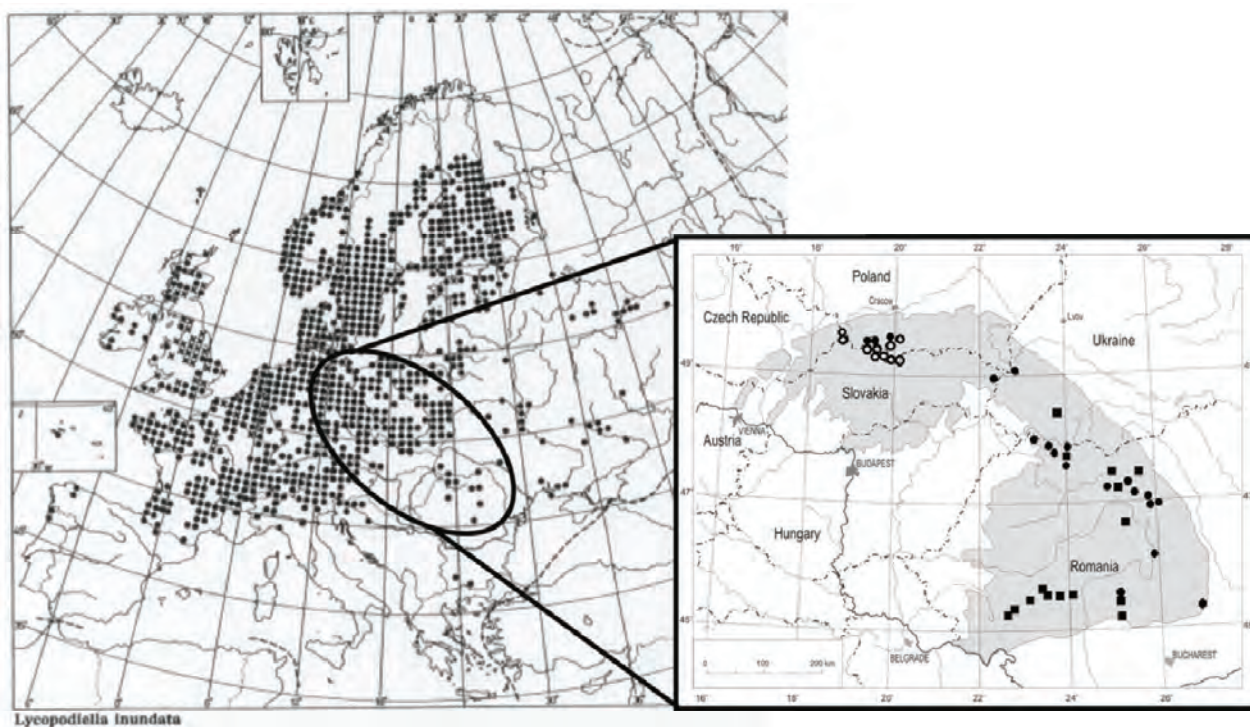


Figure 1. European distribution of *Lycopodiella inundata* (JALAS & SUOMINEN, 1972) and map of localities for *L. inundata* in the Carpathians: ● – extant, ○ – extinct, ■ – probably extant.

In the Polish Carpathians, *L. inundata* was formerly known from two localities in the Tatra Mountains: Toporowy Staw and Polana Molkówka. It was also noted in Gorc and near Ludźmierz in the Orawa-Nowy Targ basin. Despite regular searches, neither locality has been confirmed for many years and must be presumed extinct. After the year 2000 two new localities have been found: in the Orawa-Nowy Targ Basin in the Western Carpathians (KOCZUR, 2014), and Bieszczady Zachodnie in the Eastern Carpathians (KORZENIAK & KALEMBA, 2005).

Lycopodiella inundata is also noted within herbaria for the following localities within Romania, although these records are unconfirmed by later authors with detailed field experience in the respective regions (e.g. BOȘCAIU, 1971; POPESCU, 1975; COLDEA, 1973, 1990; GERGELY & RAȚIU, 1974; ALEXIU, 1998; CIOCĂRLAN, 2009) being probably extinct. The listed localities found in BUCA are not marked in the map: Rodnei Mountains – Ineuț (Grapini 1978); Suhard Mountains – Vârful Omului (Grapini 1973); Călimani Mountains – Tătarca, Zimbru, Strunioru (Grapini 1971, 1979); Gurghiu Mountains – Saca (Grapini 1975); Iezer Mountains – Păpușa, Barbu (Grapini 1975); Lotrului Mountains – Clăbucetu, Sterpu (Grapini 1964); Șureanu Mountains – Bătrâna, Suranele (Grapini 1968); Godeanu Mountains – Corhale, Olanul Mare, Mocârliu, Galbina (Grapini 1960, 1961).

Table 1. List of localities.

Locality	Physiographic unit	Altitude [m]	Status	References
	Podbeskydska pahorkatina		Extinct	ČEŘOVSKÝ & VÁGENKNECHT, 1999
Zajacovci	Beskid Żywiecki		Extant	ČEŘOVSKÝ & VÁGENKNECHT, 1999
Rabčické hory	Beskid Żywiecki	813	Extant	KOTULA, 1889-1890; ČEŘOVSKÝ & VÁGENKNECHT, 1999;
Spálený Grúnik	Beskid Żywiecki	880	Extant	DÍTĚ et al., 2001
	Babia Góra		Extinct	ZAPAŁOWICZ, 1878 (Herbarium KRAM)
Sucha Hora	Kotlina Orawsko-Nowotarska	810	Extinct	KOTULA, 1889-1890; BERNÁTOVÁ & MAJZLANOVÁ, 1982
Ludźmierz	Kotlina Orawsko-Nowotarska	620	Extinct	LUBICZ-NIEZABITOWSKI, 1922
Puścizna Wielka	Kotlina Orawsko-Nowotarska	673	Extant	KOCZUR, 2014
Toporowy Staw	Zapadne Tatry	1130	Extinct	KOTULA, 1889-1890
Polana Molkówka	Zapadne Tatry	980	Extinct	LILIENFELDÓWNA & WILCZYŃSKI, 1912 (Herbaria: KRA, KRAM)
Poręba Wielka	Gorce		Extinct	ŻMUDA, 1908 (Herbarium KRAM)
Dolina Wołosatki	Bieszczady Zachodnie	775	Extant	KORZENIAK & KALEMBA, 2005
Podstávka	Vihorlat	740	Extant	ČEŘOVSKÝ & VÁGENKNECHT, 1999
	Gorgany		Probably extant	ANDRIJENKO, 1996; WITKOWSKI et al., 2003
Tinovul Vlășchinescu, Firiza; Blidari	Gutâi-Oaş Mountains		Probably extant	NYÁRÁDY 1941 (Herbarium BUCA); SCHNEIDER 1969 (Herbarium BUCA); GRINȚESCU & NYÁRÁDY 1952; COLDEA et al., 1997 (Herbarium BUCA); COLDEA, 2000 (Herbarium BUCA); CIOCĂRLAN 2009; WITKOWSKI et al., 2003
Mlaștina Izvoarele, Tăul Hoteni, Desești, Giulești	Maramureș County		Probably extant	GRINȚESCU & NYÁRÁDY, 1952; COMAN, 1961 (Herbarium BUCA); ȚOPA, 1961 (Herbarium BUCA); ȘERBĂNESCU, 1963 (Herbarium BUCA); POPESCU, 1969 (Herbarium BUCA).
Grintieșu, Muntele Ceahlău spre Duruitoarea, Budacu	Bistriței Mountains		Probably extant	GRINȚESCU & NYÁRÁDY, 1952, 1966 (Herbarium BUCA); PAPP, 1954 (Herbarium BUCA); DOLTU, 1952 (Herbarium BUCA); GRAPINI, 1976, 1978 (Herbarium BUCA); CIOCĂRLAN, 2009
Rarău	Rarău Mountains		Probably extant	PAPP, 1924, 1953, 1960 (Herbarium BUCA); RĂCLARU, 1970
Vatra Dornei, Petriceanca	Suceava County		Probably extant	ȚOPA, 1934 (Herbarium BUCA); MITITELU et al., 1988
Tușnad, Lacul Sfânta Ana	Harghita County		Probably extant	BAUMGARTEN, 1827 (Herbarium BUCA); GRINȚESCU, 1952 (Herbarium BUCA).
Boteni	Argeș County		Probably extant	GRINȚESCU, 1915 (Herbarium BUCA); GRINȚESCU & NYÁRÁDY, 1952; CIOCĂRLAN, 2009
Cercul Dobrinului, Varful „Deasupra Dumitresei”	Gilău Mountains		Probably extant	GRINȚESCU & NYÁRÁDY, 1952; CIOCĂRLAN, 2009
Cățiașu	Buzău Mountains		Probably extant	CIOCĂRLAN, 2009.

In Romania, there have as yet been no recent comprehensive field surveys of the distribution of *L. inundata*, even within those localities where several authors have noted its presence in different years. It is thus impossible to confirm the continued survival of *L. inundata* in such sites, where it might well recently have become extinct due to negative impacts (anthropogenic or natural).

The assessment of conservation status of *Lycopodium* spp. from Romania according with Article 17 of Habitats Directives (MIHĂILESCU et al., 2015), highlighted that all the species belonging to the genus *Lycopodium* are distributed in alpine bioregion of Romania. No *L. inundata* localities has been confirmed for Romania. In the Romanian Carpathians, *L. inundata* is pointed only in three localities (OM 2387/2011) as rare species growing in bogs: in Maramureș county (ROSCI0089 Gutâi - Creasta Cocoșului and ROSCI0124 Maramureșului Mountains) and Covasna County (ROSCI0242 Tinovul Apa Roșie). Following the assessment of *Lycopodium* spp. in Romania (MIHĂILESCU et al., 2015), the main threats are the habitat loss and degradation. In 2015, we could not find *L. inundata* on the territory of Tinovul apa Roșie, thus we cannot confirm or infirm the existence of the species in this area; the species might still exist but in very small populations distributed on small areas.

THREAT STATUS

In Europe, *Lycopodiella inundata* is considered rare and declining throughout much of its range. It is principally threatened by habitat loss through urbanisation development, drainage of habitats, cessation of traditional management practices such as peat cutting and grazing, and the associated successional changes. Nitrate and phosphate pollution, causing increased growth of competitive vegetation, may be also an important factor. *L. inundata* is a species with high conservation priority throughout Central Europe, where it has more than 1/3 of its whole European range

(SCHNITTLER & GÜNTHER, 1999). In the twentieth century, *L. inundata* lost over 70% of its former range in Britain (Plant Life, 2008), where is now designated nationally scarce (STEWART et al., 1994). Due to drainage, peat industry and habitat fragmentation, *Lycopodiella inundata* has disappeared from more than a half of its recorded localities in Slovakia, the Czech Republic (ČEŘOVSKÝ & VÁGENKNECHT, 1999) and Ukraine, especially in the east and north (ANDRIJENKO, 1996).

Among Carpathian countries, *L. inundata* is critically endangered in Austria and Slovakia, endangered in the Czech Republic and Ukraine, vulnerable in Poland and Germany (although in some regions endangered), out of threat only in Hungary (SCHNITTLER & GÜNTHER 1999; WITKOWSKI et al., 2003; ZARZYCKI & SZELAĞ, 2006). In Romania, its threat status is not quite clear: OLTEAN et al. (1994) and DIHORU & DIHORU (1994) classified *L. inundata* among the lower risk category, whereas BOȘCAIU et al. (1994) stated that it could be considered unthreatened, and DIHORU & NEGREAN (2009) even do not take it into account in their red book. In 2013, SÂRBU et al., identify *L. inundata* as synonym of *Lycopodium inundatum* and describe the species as being rare in the oligotrophic swamps and bogs from spruce forests areas, as glacial relict in Romanian Flora, belonging to Alliance *Rhynchosporion albae* and Class *Oxycocco-Sphagnetea*. Interpreting the Romanian Natura 2000 habitats (GAFTA & MOUNTFORD, 2008), the species belong to habitat 7150 Depressions on peat surfaces of the *Rhynchosporion*.

In the Polish Carpathians, where *L. inundata* is known to exist at only two locations, it is considered critically endangered (MIREK & PIĘKOŚ-MIRKOWA, 1992). The same category of threat it has in the Ukrainian and Slovak Carpathians (KRICSFALUSY & BUDNIKOV, 2007; TURIS et al., 2014). All of four extant populations in Slovak Carpathians are small and endangered by process of natural succession (DÍTĚ et al., 2001), with continuing decline in number of mature individuals, locations and area of occurrence, and for this reason facing an extremely risk of extinction.

Measures taken at the European level for all *Lycopodium* species (including *Lycopodiella*) (Annex V) are governed by the Habitats Directive 92/43/EEC, which is designed to maintain or restore, at favourable conservation status, natural habitats and species of wild flora of Community interest. This directive states that if, in the light of the surveillance provided for in Article 11, Member States deem it necessary, they shall take measures to ensure that the taking in the wild of specimens of species of wild *Lycopodium* as well as their exploitation is compatible with their being maintained at a favourable conservation status.

CONCLUSION

Due to its exacting environmental requirements and increasing disturbance from natural and/or anthropogenic causes (including climatic change in the last decade), *Lycopodiella inundata* is considered rare and declining throughout much of its range. Within the Carpathian range the loss of stands is particularly noticeable in the Western part and yet unknown in the southern part. We suppose that the traditional management, maintained in the Eastern and Southern Carpathians may play a significant role in the survival of the species. Populations in confirmed sites are small, and thus more vulnerable to any disturbance, and in many other sites there is considerable doubt as to whether *L. inundata* survives or not. Restoration and/or conservation of its habitat require comprehensive and far-reaching measures.

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