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Drepanocladus turgescens (Bryophyta, Amblystegiaceae) rediscovered in Poland

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Abstract – *Drepanocladus turgescens* is a moss of arctic-alpine distribution, very rare and declining in Central Europe, in the past known in Poland from four relict sites in the small basin area in the central Silesia-Cracow Upland (southern Poland), the only sites of the species in Central Europe outside the Alps. All of them were considered extinct thirty years ago. In May 2011 a new site was discovered in the same upland basin, only a few kilometers from the previous localities. The species occurs quite abundantly in patches of extremely rich-fen (*Caricion davallianae* alliance) of semi-natural origin, mostly in shallow depressions with slightly flowing, spring calcareous water, occasionally drying out.

Arctic-alpine elements / calcareous fens / distribution / Europe / glacial relicts / *Pseudocalliergon* / *Scorpidium* / Silesia-Cracow Upland / Sławków / tundra mosses

Résumé – *Drepanocladus turgescens* est une mousse avec la distribution arctique-alpine, très rare et en fort déclin dans l'Europe Centrale ; en Pologne elle était connue des quatre anciennes localités dans la petite zone du Plateau de Silésie-Cracovie (sud de la Pologne). Ces localités étaient les seules connues en Europe Centrale, en dehors des Alpes, mais elles ont toutes disparu et il y a trente ans qu'elles sont considérées comme éteintes. La nouvelle station de l'espèce a été trouvée au mois de mai 2011, à seulement quelques kilomètres des sites précédents. *D. turgescens* est en nombre dans la végétation du bas-marais alcalin (*Caricion davallianae* alliance) d'origine semi-naturelle, principalement des bassins périodiquement secs, petits et peu profonds, alimentés en eau souterraine, calcaire et à lent débit.

Éléments arctiques-alpins / marais alcalins / distribution / Europe / reliques glaciaires / *Pseudocalliergon* / *Scorpidium* / Plateau de Silésie-Cracovie / Sławków / mousses de la toundra

INTRODUCTION

Drepanocladus turgescens (T. Jensen) Broth. is a distinct species of sect. *Pseudocalliergon* (Limpr.) Broth., which has been classified in various moss genera, such as *Hypnum turgescens* T. Jensen, *Calliergon turgescens* (T. Jensen) Kindb.,

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Pseudocalliergon turgescens (T. Jensen) Loeske and *Scorpidium turgescens* (T. Jensen) Loeske (Hedenäs & Miller, 2014). It is a robust, distinctly golden-green moss, with turgid shoots to 25 cm long and 5 mm in diameter, unbranched or only sparingly branched in one plane. The stem leaves are imbricate to spreading, almost to 3 mm long, broad, strongly concave and apiculate. Externally, it is similar to *Scorpidium scorpioides* (Hedw.) Limpr. from which it differs in having straight leaves with slightly longer and more prominent, single or double costa extending to mid-leaf, small and incrassate alar cells forming indistinct groups in the basal angles and the lack of a stem hyalodermis (Hedenäs, 2003; Porley, 2013).

The species is considered to be an arctic-alpine element that is widely distributed throughout northern Eurasia and North America, with scattered localities farther south, mostly in mountains (Ochyra *et al.*, 1988; Ignatov *et al.*, 2006; Hedenäs & Miller, 2014). Additionally, it is known outside the Holarctic only from the Andes in South America, where it occurs at ca. 4000 m altitude (Churchill *et al.*, 2000; Kuc, 2000). In Europe the species occurs in northern parts of the continent, mainly in the Scandinavian Mountains and in the Baltic area on isles built of limestone, including Gotland, Öland, Saaremaa, Hiiumaa and Pakri Islands (Hedenäs, 2002). In Central and Western Europe the species has been recorded mainly in the Alps (Hedenäs *et al.*, 2003; Meinunger & Schröder, 2007; Ros *et al.*, 2013; Martinčič, 2016; Moose Deutschland, 2016), with only single lowland localities in Britain (Porley, 2013) and Poland (Kuc, 1955, 1956).

In Poland, *Drepanocladus turgescens* was found at four sites in a small area in the eastern part of the Przemsza river catchment area in the central Silesia-Cracow Upland in the southern part of the country (Kuc, 1955, 1956 as *Scorpidium turgescens*). The species occurred there at the bottom of the small (ca. 100 km^2), intra-upland Bór Biskupi Basin (altitudinal span of sites: 270-315 m), thickly filled by glacial sands (to ca. 50 m layer; an old, duned sandur of the Odra/Saale glaciation, called "Little Desert"). The calcareous mires where the species was found have developed mainly in the spring valleys of the Biała Przemsza river tributaries (Jaworznik, Kozi Bród and Żabnik streams), deeply cutting this sandy plain and draining surrounding prominent limestone and dolomite ridges and plateaux. In combination with the highly specific, cold and humid microclimate of the basin, in fact being a frost pocket, this unusual set of environmental conditions generated the refugium for some rare, mainly mountain and northern species.

Kuc (1964) considered the Przemsza river catchment area as the most important area outside the limit of the last glacial maximum for relictual mosses in southern Poland. *Drepanocladus turgescens* occurred there with many of them, including *Breidleria pratensis* (W.D.J. Koch *ex* Spruce) Loeske, *Cinclidium stygium* Sw., *Drepanocladus trifarius* (F. Weber & D. Mohr) Broth., *Helodium blandowii* (F. Weber & D. Mohr) Warnst., *Meesia triquetra* (L. *ex* Jolycl.) Ångstr., *Paludella squarrosa* (Hedw.) Brid., *Scorpidium scorpioides* and *Tomentypnum nitens* (Hedw.) Loeske). He concluded that these sites were remnants of the arctic tundra which previously existed there for thousands of years.

Two sites with *Drepanocladus turgescens* were proposed for protection as nature reserves for glacial mosses (Szafran & Kuc, 1955; Kuc, 1959), but neither was granted protection. The last time the species was observed, in 1964, was alongside the Jaworznik stream – where there is now an extensive (presently 30 km^2) and deep (ca. 30 m) sand quarry which has rapidly destroyed this area (causing additionally a larger cone of depression). Subsequently, *D. turgescens* was recognized as extinct at all its previously known Polish sites (Ochyra & Baryła, 1988; Stebel *et al.*, 2012; Hodgetts, 2015).

The aim of this study is the description of a new site for *Drepanocladus turgescens* in Poland and to discuss its autecology and the reasons why this is its only site in Central Europe situated outside the mountains.

MATERIAL AND METHODS

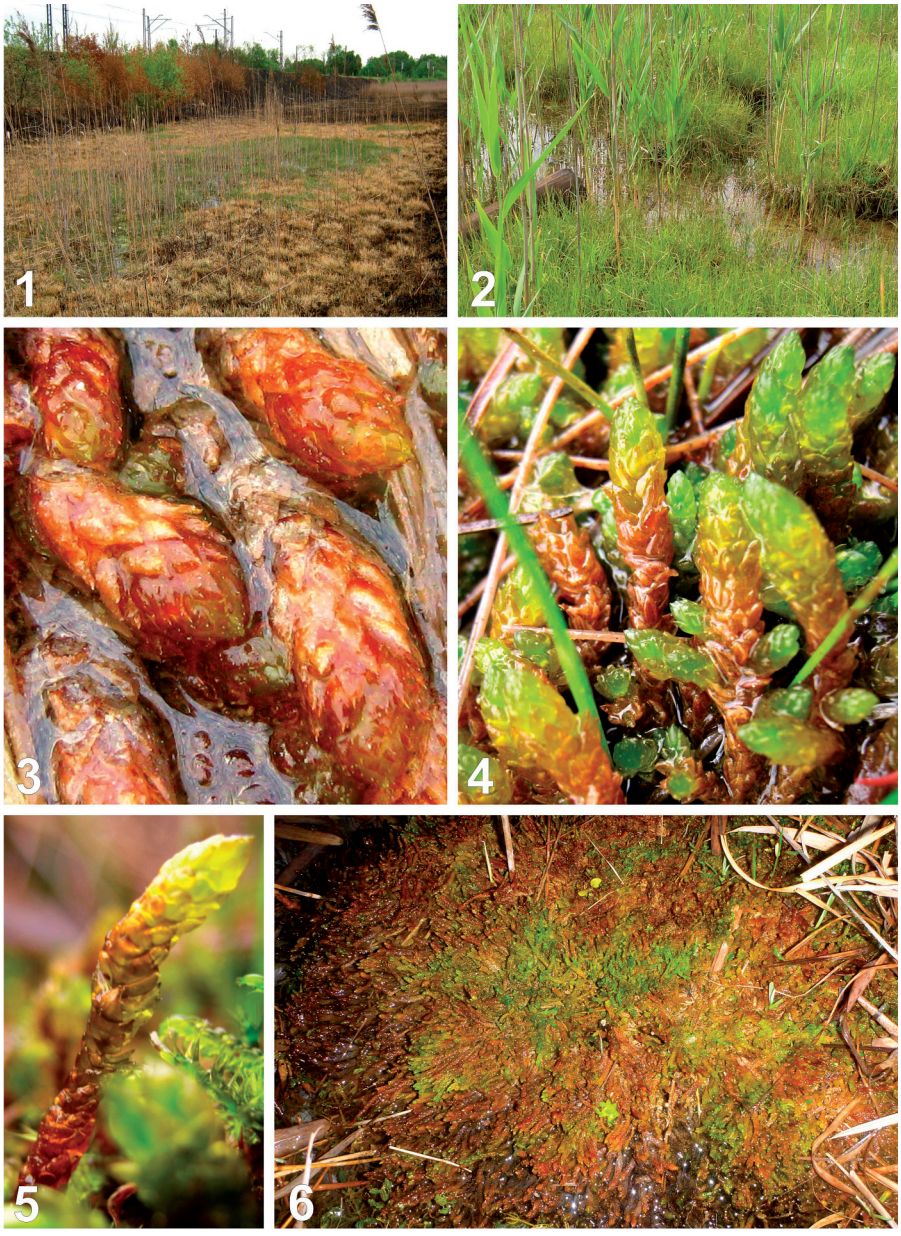
The site of *Drepanocladus turgescens* in Sławków was unexpectedly found during to delete or front size should be change; in accepted manuscript "during a survey" survey of charophytes in the central Silesia-Cracow Upland (Krajewski, 2012). It has been regularly investigated from 2011 to 2016. Water samples (1 L), after preservation by addition of 1 mL of H_2SO_4, were analyzed in the Biological and Chemical Research Centre Laboratory, University of Warsaw. pH and electrical conductivity (EC) values were measured in the field (Elmetron CPC-401). Values of Ca^{2+}, K^+ and Na^+ ions were determined using a flame spectrophotometer, total Fe was measured using the rhodanate method, PO_4^{3-} using the molybdate method and calculated to P_t, N-NH_4^+ using Nessler's method (Hermanowicz *et al.*, 1999). The vegetation associated with *D. turgescens* was investigated in 10 plots each of 1 m^2. Names for plants correspond with that proposed by the Muséum National d'Histoire Naturelle (2016). Syntaxonomy follows Bardat *et al.* (2004).

RESULTS

In May 2011, I observed a puzzling moss near the railway station in Sławków in the same sandy Bór Biskupi Basin and then I assumed it was an atypical *Scorpidium scorpioides*. Unfortunately, no material was collected for microscopic examination and herbarium. I revisited this site in the next year but the pools with this moss were dried up owing to the very dry summer. Finally, the next visit of this site in May 2013 was successful and I collected the plants which I determined as *Drepanocladus turgescens*. My determination was confirmed by Dr. P. Pawlikowski (Warsaw), and Prof. Dr. R. Ochyra (Kraków). Thus, the species considered to be extinct in this area was rediscovered in a new site situated on the northern border of the basin with Triassic, dolomitic limestone hills, around 5 km north of the former but now destroyed sites.

Specimens examined: S Poland, Silesia-Cracow Upland, Sławków, small spring fen alongside railway embankment, lat. 50°17'27"N, long. 19°22'43"E, alt. 288 m, *leg. et det. Ł. Krajewski*, 12.05.2013 (WA, conf. P. Pawlikowski; KRAM B-228361, conf. R. Ochyra; Ochyra (2013): 62).

Drepanocladus turgescens was found in an anthropogenic habitat, in fen in an excavated shallow (0.5-1 m deep), but wide (around 10 m) draining ditch (Fig. 1), dug probably before 1885 when the adjacent Dąbrowa Górnicza-Dęblin railway was opened. The moss grew both in the pools with shallow, slightly flowing mineral-rich spring water (pH: 6.98-7.85; median 7.08; $n = 23$), (EC: 1050-2020 µS/cm (median 1354 µS/cm; $n = 43$), Ca^{2+}: 131 mg/l, Fe_t: 0.141 mg/l, Na^+: 103 mg/l, K^+: 15.4 mg/l, N-NH_4^+: 0.23 mg/l, P_t: 0.03 mg/l) and on their margins with extremely rich fens. The measured values of EC, Ca^{2+} and Na^+ ions are notably high and unique, not



Figs 1-6. Site of rediscovered *Drepanocladus turgescens* in Sławków (Poland). **1.** View (after burning, 17.05.2011). **2.** Habitat (5.07.2011). **3.** Floating specimens (17.05.2011). **4.** Slightly branched shoots from the pool margin (12.05.2013). **5.** One of the dispersed individuals in the moss layer of the fen (24.04.2016). **6.** Circular patch built by the species (17.04.2015).

recorded in the any other upland fen. The layer of peat is very thin (with massive calcite precipitation) and almost absent in some pools (having a bed of red Permian clays, forcing water to the surface; Kaczmarek *et al.*, 1995). The species is locally abundant in the middle part of the excavated trench (Fig. 2), occupying an area around 5 × 50 m. The floating specimens are turgid and the largest (Fig. 3), sometimes coated in a crust of lime, rarely creating its own, round carpets in depressions with water (Fig. 6), indicating a long time of growing and vegetative propagation. At the pool margins the individuals are smaller (Fig. 4), the thinnest occur in a moss layer that is not inundated, where the erect shoots appear sparsely in small groups among other bryophytes (Fig. 5). Only sterile specimens were found.

DISCUSSION

The species probably occurred in this region earlier and colonized the ditch dug in an old fen, because *Drepanocladus turgescens* is easily propagated vegetatively by buds falling from the shoots (Miller, 1985). Spring fens previously developed, when the calcareous outflows (in the base of the Muschelkalk cuesta) were blocked by aeolean sands. A formed dune is visible around 100 m west of the excavation. It is likely that this happened during the Late Glacial and early Holocene period, when dune forming processes were active in the basin (Szczepanek & Stachowicz-Rybka, 2004). In this area also an old drainage system is only just visible as shallow, overgrown ditches. This is the reason for the contemporary peat-muck soil and dominance of *Molinion caeruleae* W.Koch 1928 meadows. Only overgrowing patches of natural fens now occur there (100-200 m from the excavation), still with such plants as *Carex davalliana* Sm., *C. pulicaris* L., *Comarum palustre* L., *Epipactis palustris* (L.) Crantz, *Eriophorum angustifolium* Honck., *E. latifolium* Hoppe, *Fissidens adianthoides* Hedw., *Menyanthes trifoliata* L., and *Philonotis fontana* (Hedw.) Brid., but without *D. turgescens*. Kuc (1956, 1959) recorded some glacial mosses in Sławków, but all in the Biała Przemsza valley, ca. 1.5-2 km to S, SE of the newly discovered site of *D. turgescens*. He did not report *D. turgescens* from Sławków and he investigated probably only fens in the river valley (he proposed there the nature reserve "Miodawa Druga").

The pools with *D. turgescens* sometimes dry up in summer (e.g. in 2012 and 2015), such as the sites in alvars (bare limestones, polished by ice sheets; Hedenäs 2002). The continuous presence of depressions with open water and exposed bare soil, favourable for *D. turgescens*, seem to depend on the activity of wild boars, as observed several times. The species does not occur in the uppermost part of the excavation (dammed, with extremely high fluctuations of water level (ca. 0-50 cm), less mineralised: EC: 652-976 µS/cm; pools dominated by *D. lycopodioides* (Brid.) Warnst.), and in the lowest part, transitioning into a reservoir of stagnant and deeper water (flow dammed by a crossing road; in areas where charophytes are abundant; Krajewski (2012): site no. 26 "Sławków-Miedawa").

Many notable vascular plants co-exist in the excavated trench with *Drepanocladus turgescens*, including *Carex davalliana*, *C. dioica* L., *C. lepidocarpa* Tausch., *C. pulicaris*, *Eleocharis quinqueflora* (Hartm.) O. Schwarz, *Epipactis palustris*, *Equisetum variegatum* Schleich. *ex* F. Weber & D. Mohr, *Liparis loeselii* (L.) Rich., *Malaxis monophyllos* (L.) Sw., *Pinguicula vulgaris* L. f. *bicolor* (Nordst. *ex* Hartm.) Neuman, *Tofieldia calyculata* (L.) Wahlenb. and *Utricularia minor*

L. Two strongly calciphilous charophytes occur abundantly: *Chara aculeolata* Kütz. and *C. vulgaris* L. (Krajewski, 2012: site no. 25 – "Sławków PKP"). The bryophytes correspond with those from northern European sites of *D. turgescens* (Hedenäs, 2002), and among them there are present: *Aneura pinguis* (L.) Dumort., *Calliergonella cuspidata* (Hedw.) Loeske, *Campylium stellatum* (Hedw.) Lange & C.E.O. Jensen, *Cratoneuron filicinum* (Hedw.) Spruce, *Drepanocladus lycopodioides*, *D. polygamus* (Schimp.) Hedenäs, *D. sendtneri* (Schimp. *ex* H.Müll.) Warnst., *Fissidens adianthoides*, *Palustriella falcata* (Brid.) Hedenäs, *Ptychostomum pseudotriquetrum* (Hedw.) J.R. Spence & H.P. Ramsay and *Scorpidium cossonii* (Schimp.) Hedenäs. Additionally, I also recorded *Palustriella commutata* (Hedw.) Ochyra, *Pellia endiviifolia* (Dicks.) Dumort., *Preissia quadrata* (Scop.) Nees and *Sanionia uncinata* (Hedw.) Loeske.

The associated flora represents generally the *Caricion davallianae* Klika 1934 alliance and this is identical to the *Caricetalia davallianae* Braun-Blanquet 1949, reported for the species by Dierßen (2001). Some species are typical for petrifying springs, also tufa deposition has been noted in some sites. In Sweden, *Cratoneuron filicinum*, *Drepanocladus lycopodioides, D. turgescens* and *Palustriella* spp. are considered as indicators of extremely rich fens (Rydin *et al.*, 1995).

However, none of the relict glacial mosses recorded by Kuc (1955, 1956) with *D. turgescens* was found, despite it was considered the rarest of them in all Poland (Ochyra *et al.*, 1988). The relictual character of the southern European sites of *D. turgescens* is well recognised because the species was much more widespread during the past glaciations and in the late Pleistocene and early Holocene (Dickson, 1973; Frahm, 2012), as well as in Poland (Ochyra *et al.*, 1988).

In the Silesia-Cracow Upland some northern fen mosses appear as the pioneers, like the relict vascular plants. They inhabit the waterlogged bottoms of large sand quarries (the most notable: *Drepanocladus lycopodioides*, *Helodium blandowii*, *Cladium mariscus* and *Utricularia bremii*; Krajewski, 2011, 2012; Krajewski & Płachno, 2015; Krajewski *et al.*, 2015). This phenomenon seems to be strictly related to their previous occurrence in the adjacent natural localities (or even in the same places, destroyed gradually by excavating), that have now vanished under the industrial landscape. This is the reason for the survival of *D. turgescens*.

CONCLUSIONS

The small anthropogenic spring fen in Sławków is the most spectacular example of spontaneous survival of a relict moss in the Silesia Cracow-Upland and in Poland. After more than 100 years of existence this fen represents a magnificent remnant hotspot of regional biodiversity of calciphilous fen species. This is a result of the exceptional synergistic action of many factors: the initial proximity of alkaline fen with a unique flora, the stable supply of calcareous groundwater, the presence of impermeable clays rich in calcite in the substrate, and optimal microclimate. This sensitive and fragile arrangement is unparalleled in the lowlands of Central Europe.

Following the IUCN (2012) criteria, *Drepanocladus turgescens* should now be listed in Poland as CR (critically endangered), criteria: A2abce, B1ab (i,ii,iii,iv) + B2ab (i,ii,iii,iv). In 2011 the site was only found after burning and an increase in abundance of *Phragmites australis* (Cav.) Trin. *ex* Steud. is being observed, so the survival prospects of *D. turgescens* in Sławków are tenuous. Nevertheless, it seems

that the population of *D. turgescens* has remained relatively stable in recent years. The water level and chemical proprieties of the spring water could be easily changed as a result of railway maintenance and because of the proximity of a brickworks. The site is formally protected as Natura 2000 site and recently has been extensively used as a horse pasture. However, additional active conservation measures are strongly recommended, not only for *in situ* removal of the expansive reed beds, but also for attempts to introduce *D. turgescens* in the others similar upland fens, as successfully implemented for *Cochlearia polonica* E. Fröhlich (Ochyra & Baryła, 1988), another unusual endemic species of springs in sandy basins of the Silesia-Cracow Upland, but extinct in all its known primeval sites.

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