

Warnstorfia (Bryopsida, Calliergonaceae) in the Iberian Peninsula

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(Received 5 February 2004, accepted 18 November 2004)

Abstract – A revision of *Warnstorfia* Loeske from the Iberian Peninsula has been undertaken based on examination of two hundred and four herbarium specimens. The following species are recognized for the Spanish bryological flora: *W. exannulata* (Schimp.) Loeske, *W. fluitans* (Hedw.) Loeske and *W. sarmentosa* (Wahlenb.) Hedenäs. *W. exannulata* is confirmed in Portugal and Andorra and *W. fluitans* is excluded from the checklist for Portugal and Balearic Islands.

All specimens determined in Iberian herbaria as *Drepanocladus aduncus* var. *asturicus* (Renauld) Riehm., *D. exannulatus* subfo. *falcifolius* Moenk., *D. exannulatus* var. *alpinus* (Grav.) Wijk & Margad. and *D. fluitans* var. *falcatus* (C.E.O. Jensen) G. Roth, have been re-identified as *Warnstorfia exannulata*.

Warnstorfia exannulata is common in the mountainous areas of the Eurosiberian and Mediterranean Regions of the northern and central part of the Iberian Peninsula, in three distinct areas: Pyrenees, Iberian-Atlantic Ranges (Galician-Portuguese Massif, Cantabrian Range, and Central Range), and Sierra Nevada (south Spain), although it is very rare in the latter. *W. fluitans* and *W. sarmentosa* are rare as both have higher moisture requirements than *W. exannulata*. Their distribution is limited to the mountains of the Eurosiberian Region of Spain, from the Cantabrian Range to the Pyrenees, where there is a strong Atlantic influence. The threats to *Warnstorfia* populations in the Iberian Peninsula are analyzed.

INTRODUCTION

The genus *Warnstorfia* Loeske includes large to medium-sized plants that are associated with aquatic and oligotrophic habitats. Traditionally, the genus has been placed in the family *Amblystegiaceae* G. Roth but circumscription of this family and the genera within it has been problematic. Recent molecular studies (Vanderpoorten *et al.*, 2002a, b) indicate that *Warnstorfia* should be included in the *Calliergonaceae* (Kanda) Vanderpoorten *et al.*

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Four taxa of *Warnstorfia* are included in the checklist of Spanish mosses (Casas, 1991): *W. sarmentosa* (Wahlenb.) Hedenäs (as *Calliargon sarmentosum* (Wahlenb.) Kindb.), *W. exannulata* (Schimp.) Loeske var. *exannulata*, *W. exannulata* var. *purpurascens* (Schimp.) Tuom. & T. J. Kop. and *W. fluitans* (Hedw.) Loeske. Two species occur in Andorra: *W. fluitans* and *W. exannulata* (Casas, 1986), and four taxa have been recorded in Portugal: *Hypnum fluitans* var. *alpinum* Schimp. (Leresche & Levier, 1880), *Warnstorfia fluitans*, *W. exannulata* and *W. exannulata* var. *purpurascens* (Machado, 1931).

Warnstorfia fluitans has been widely reported from the Iberian Peninsula (as *Hypnum fluitans* Hedw.) in Asturias (Durieu de Maisonneuve, 1836), the Pyrenees (Jeanbernat & Renault, 1885; Spruce, 1849), Cuenca (Röll, 1897), the Central Range (Leresche & Levier, 1880; Luisier, 1910; Casares & Beltrán Bigorra, 1912), Pontevedra (Casares, 1915), Salamanca (Luisier, 1924), the Sierra Nevada (Colmeiro, 1889; Höhnelt 1895), the Algarve (Solms, 1868) and Mafra (Machado, 1931). *Hypnum fluitans* var. *rotae* (De Not.) Sanio and *H. fluitans* var. *purpurascens* Schimp. were reported from the Pyrenees (Jeanbernat & Renault, 1885), and *H. fluitans* var. *alpinum* Schimp. occurs in the Serra da Estrela (Leresche & Levier, 1880) and the Pyrenees (Jeanbernat & Renault, 1885). *Warnstorfia sarmentosa* was reported in Spain by Geissler (1979) for the first time.

Most specimens of *Warnstorfia* from the Iberian Peninsula were collected between 1835-1970 and they have not been revised since then. In view of the numerous monographic studies of this genus, mainly during the last 30 years (Hedenäs, 1993, 2000, 2003; Janssens, 1983; Kanda, 1976; Tuomikoski & Koponen, 1979; Ochyra, 1998), and because an Iberian bryophyte flora is necessary, a revision of *Warnstorfia* collections in the Iberian Peninsula is urgently needed.

The main aim of this work has been to revise the collections of *Warnstorfia* from the Iberian Peninsula (Andorra, Portugal, Spain) and Balearic Islands, in order to determine which species occur in the area, their taxonomic status, ecology and distribution, and to verify their regional threat status.

MATERIAL AND METHODS

Collections of *Warnstorfia* from the Iberian Peninsula and Balearic Islands kept at the main herbaria in Spain (ARAN, BCB, FCO, GDAC, MAMUSCI, MACB, MAF, MUB, PAMP, SALA, SANT, VAB, VIT), Portugal (LISU, PO), France (PC), and Switzerland (G) were examined. A total of 204 specimens were studied.

Species descriptions are based on Iberian material. Habitat descriptions are based on field observations made by the authors and label information from herbarium specimens. The morphology of the peristome and spores of *Warnstorfia fluitans* has been studied using Scanning Electron Microscopy (SEM).

Bryophyte nomenclature follows Crosby *et al.* (1999). Nomenclature for vascular plants and syntaxa follows Rivas-Martínez *et al.* (2002). Names of authors are abbreviated according to Brummitt & Powell (1992).

RESULTS

A new identification key and updated descriptions together with distributional and ecological data of the Iberian species of *Warnstorfia* constitute the main results of this study.

Warnstorfia Loeske, *Verh. Bot. Vereins Prov. Brandenburg* 49 (Abh.): 63. 1907.
Type: *Warnstorfia fluitans* (Hedw.) Loeske.

Drepanocladus sect. *Warnstorfia* (Loeske) Broth. *Die Natürlichen Pflanzenfamilien* I(3): 1034. 1908.

Plants pleurocarpous, green, brownish-yellow, frequently red to red-purple. **Stem** 2-15 cm long, irregularly branched; cross section round with central strand, with or without partial hyalodermis, cortical cells quadrate, in 2-3 layers, with brown, incrassate walls. **Leaves** not or hardly decurrent, imbricate or spreading from stem, oblong-ovate, ovate-lanceolate to linear lanceolate, falcate-secund or straight, plicate or not; margin denticulate or entire at base; costa either single, reaching 1/2 to 2/3 of leaf length, or shorter and double. **Branch leaves** shorter and narrower than stem leaves. **Alar cells** arranged in 1-3 rows, long rectangular to ovoid, hyaline or coloured, sometimes reaching the costa. **Lamina cells** linear-elongate with thin or incrassate walls. **Autoicous** or **dioicous**. **Sporophyte** rare; seta long, flexuose; capsule horizontal, cylindrical, \pm curved, operculum conical; separating annulus absent or not seen. **Peristome** diplolepidious; exostome teeth yellowish; endostome segments keeled and scarcely perforated, arising from a high basal membrane; spores papillose.

Warnstorfia species grow in oligotrophic and mineral peaty soils or submerged in lakes. *Warnstorfia* spp., show considerable phenotypic plasticity in habit, branching, and size that is related to habitat conditions.

1. Stem without hyalodermis. Leaves straight, loosely imbricate, often falcate at branch ends, oblong-ovate, concave, rounded and cucullate at apex, shortly apiculate, margin entire; costa single reaching 2/3 of the leaf, often bifurcated; basal cells near costa strongly incrassate, porose. Alar cells enlarged, inflated and hyaline, forming a transversely triangular group, not or scarcely decurrent, well differentiated from leaf cells at base, not reaching the costa. Plants usually reddish-brown- or red, in fresh material, sometimes yellowish at tips. Dioicous. *W. sarmentosa*

Stem with or without partial hyalodermis. Leaves falcate, falcate-secund or straight in submerged plants, ovate-lanceolate to narrowly lanceolate, suddenly narrowed into a long and acuminate apex, margin plane, usually serrulate at base, sharply serrate to serrulate in the acumen, basal cells near the costa not strongly incrassate, often porose. Alar cells forming a triangular group, not decurrent, sometimes reaching the costa 2

2. Plants brown to black or purple, rarely green or yellowish; stem usually with partial hyalodermis. Leaves ovate-lanceolate or lanceolate; margin denticulate at base and apex. Alar cells well differentiated from the basal lamina cells, forming a group of 1-3 rows of cells, longly rectangular, inflated, hyaline, reaching the costa of the leaf. Dioicous. *W. exannulata*

Plants green-brownish, pale brown, never reddish; stem without hyalodermis. Leaves ovate-lanceolate to linear lanceolate, margin denticulate at apex, denticulate or entire at base. Alar cells scarcely differentiated from the basal lamina cells, forming a transverse, narrowly triangular group of 2-3 rows of rectangular to ovoid hyaline cells that do not reach the costa. Autoicous.
 *W. fluitans*

***Warnstorfia exannulata* (Schimp.) Loeske, *Hedwigia* 46: 310. 1907. Fig. 1.**

Basionym: *Hypnum exannulatum* Schimp., *Bryologia Europaea* 6: 110. pl. 603 (fasc. 57-61 Mon. 34, pl. 23). 1854. **Type:** Germany. Rheinnland-Pfalz: near Kirkel, Jun, s.n. Probable holotype herb. P. Bruch, in BM! according to Hedenäs (2003). [= *Drepanocladus exannulatus* (Schimp.) Warnst. – *D. exannulatus* var. *brachydictyon* (Renauld) G. Roth, nom. illeg. – *Hypnum fluitans* var. *irrigatum* Renauld – *H. fluitans* var. *purpurascens* Schimp. – *Drepanocladus exannulatus* var. *purpurascens* (Schimp.) Herzog – *Warnstorfia exannulata* var. *purpurascens* (Schimp.) Tuom. & T.J. Kop., *Drepanocladus exannulatus* var. *rotae* (De Not.) Loeske].

Shoots 2-12 cm long, irregularly branched, reddish-brown, often purplish, less commonly green or yellowish. **Stem** with central strand conspicuous, 2-3 layers of incrassate, brownish, cortical cells, a partial hyalodermis often present. **Leaves** 2.5(- 5.5) mm long × 0.8(- 1) mm wide, falcate-secund, sometimes straight, ovate-lanceolate, gradually narrowing into a long, acuminate apex; margin denticulate at base and near apex. **Alar cells** large, hyaline, yellow-orange or reddish, strongly inflated, forming a triangular group of 1-3 rows, well differentiated from the basal lamina cells, reaching the costa. **Lamina cells** rectangular, hyaline at base in the margins; median leaf cells 60(- 75) µm long × 7.5 µm wide, longer than basal and apical cells. **Costa** single, 60(- 70) µm wide at base, extending 2/3 way up of leaf. **Dioicous. Sporophytes** not seen in the Iberian collections revised by the authors.

Warnstorfia exannulata has a Circumboreal-Austral distribution, occurring in North America (USA, Canada, North Mexico), South America, Australia, Europe and Africa (Anderson *et al.*, 1990; Hedenäs, 2003). It is considered a helophytic, photophilous and acidophilous species and grows in intermediate mineral-rich fens, in late snow-beds, or sometimes submerged in lakes (Hedenäs, 2000).

In the Iberian Peninsula, *W. exannulata* occurs in the mountainous areas of the Eurosiberian and Mediterranean Regions. In the Eurosiberian Region, it grows from the low montane to alpine belts (180-2450 m), from the northwestern coasts of Portugal (Estremadura) and Spain (Vigo, La Coruña, Lugo), from the Galician-Portuguese Massif (Tras-Os-Montes and Alto Douro) to the Cantabrian Range (Asturias, León, Lugo, Cantabria, Palencia, Zamora) and the Pyrenees (Huesca, Andorra, Gerona). In the Mediterranean Region, it is limited to the supra-crioromediterranean belts (1330-2200 m) of the high mountains in the Central Range (Guadalajara, Madrid, Ávila, Salamanca, Beira Alta) and the Iberian Range (Burgos, La Rioja, Soria). In the south of Spain, where the weather is warmer and drier, *W. exannulata* occurs rarely in the Sierra Nevada (Granada) between 2600-2900 m (Fig. 2).

In the Iberian Peninsula, *Warnstorfia exannulata* grows in oligotrophic fens, on mineral soil or submerged in lakes or streams, often where there is an anthropogenic influence. It grows in *Caricetalia nigrae* Koch communities (*Scheuzeria-Caricetea nigrae*), associated with *Carex flava* L. subsp. *flava*, *C. nigra* (L.) Reichard, *Anagallis tenella* (L.) L., *Eleocharis uniglumis* (Link) Schult., *Eriophorum angustifolium* Honck., *Juncus filiformis* L., *J. squarrosus* L., *Menyanthes trifoliata* L., *Parnassia palustris* L., *Potentilla palustris* (L.) Scop., *Viola palustris* subsp. *juressi* (Link ex Wein) W.Becker ex Cout., *Wahlenbergia hederaceae* (L.)

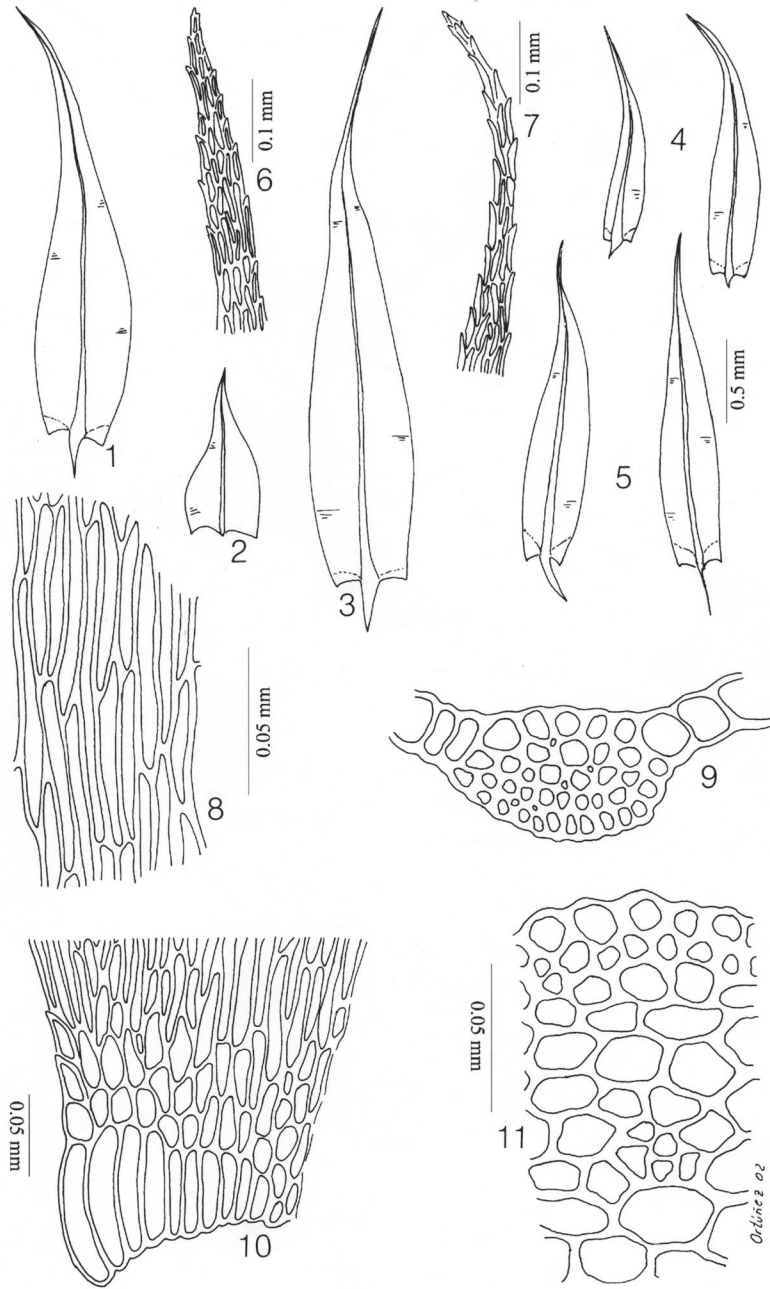


Fig. 1. *Warnstorfia exannulata* (Schimp.) Loeske. 1-3, stem leaves; 4-5, branch leaves; 6-7, apex of stem leaf; 8, midleaf cells; 9, transverse section of the costa at base; 10, alar cells; 11, transverse section of the stem.



Fig. 2. Distribution of *Warnstorfia exannulata* in the Iberian Peninsula.

Rchb., *Sphagnum denticulatum* Brid., *S. flexuosum* Dozy & Molk., *S. compactum* Lam. & DC., *S. palustre* L., *S. teres* (Schimp.) Ångström, *Straminergom stramineum* (Brid.) Hedenäs, *Philonotis fontana* (Hedw.) Brid., *Calliergonella cuspidata* (Hedw.) Loeske.

***Warnstorfia fluitans* (Hedw.) Loeske**, *Hedwigia* 46: 310. 1907. Figs 3-4.

Basionym: *Hypnum fluitans* Hedw., *Species Muscorum Frondosorum* 296. 1801.

Type: Sweden. O. Swartz s.n. Lectotype G-Hedwig-Schwaegrichen selected by Hedenäs (1993). Isolectotype S! (herb. Swartz n° 2479).

[=*Amblystegium fluitans* (Hedw.) De Not. – *Drepanocladus fluitans* (Hedw.) Warnst. – *Hypnum fluitans* var. *falcatum* Schimp. – *H. fluitans* var. *serratum* Lindb. – *D. fluitans* var. *falcatus* (Sanio ex C.E.O.Jensen) G Roth – *D. fluitans* var. *uncatus* H.A. Crum, Steere & L.E. Anderson – *D. berggrenii* (C.E.O.Jensen) G. Roth].

Shoots 3-16 cm long, irregularly branched, pale brown to yellowish-brown. **Stem** with 2-3 layers of incrassate, brownish, cortical cells, hyalodermis absent, central strand conspicuous. **Leaves** 3.2(-4.5) mm long × 0.6(-0.67) mm wide, usually straight, sometimes falcate; ovate-lanceolate, gradually narrowing to a long, acuminate, often flexuose and twisted apex; margin usually denticulate especially at apex and base. **Alar cells** shortly rectangular to rounded-quadrate, not clearly arranged in rows, forming a diffuse triangular group, intergrading imperceptibly with basal lamina cells, usually not reaching the costa. **Lamina cells**

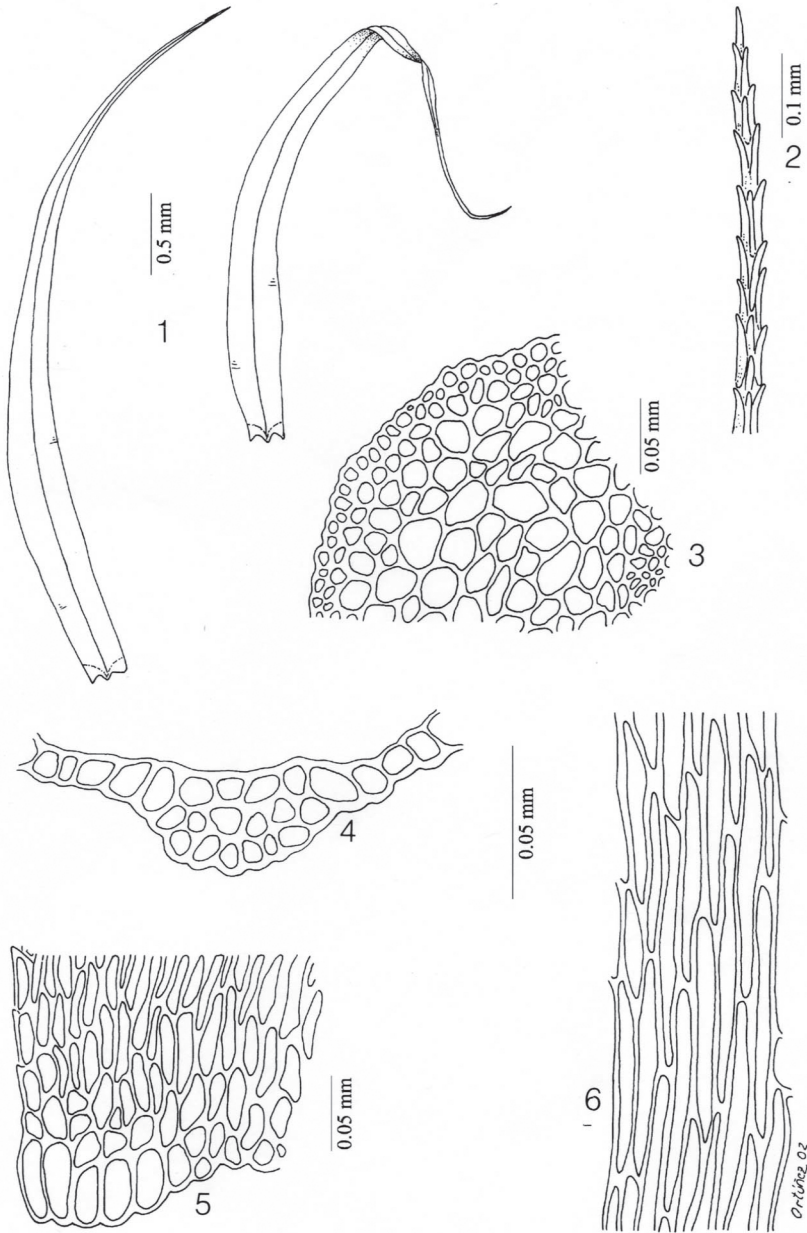


Fig. 3. *Warnstorfia fluitans* (Hedw.) Loeske. **1**, stem leaves; **2**, stem leaf apex; **3**, transverse section of the stem; **4**, transverse section of the costa at base; **5**, alar cells; **6**, middle leaf cells.

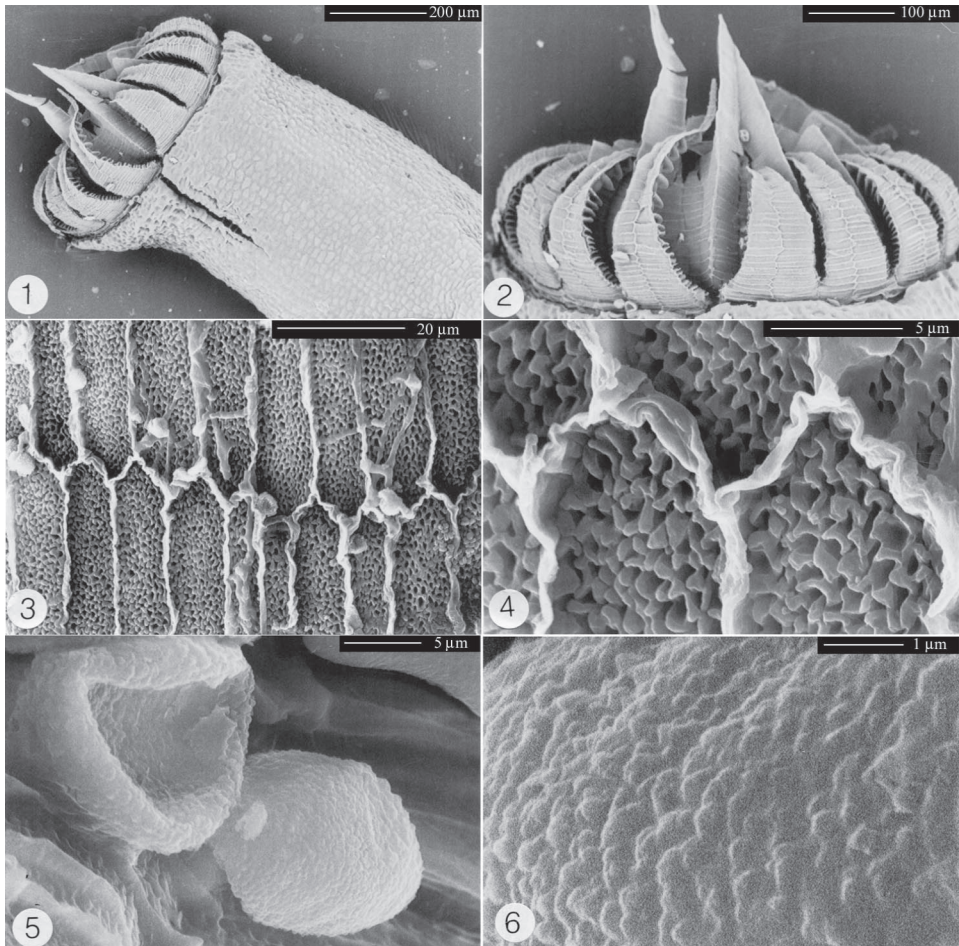


Fig. 4. SEM photographs of *Warnstorfia fluitans*. **1-2**, peristome; **3-4**, details of the outer exostome layer at base; **5**, spores; **6**, detail of the exine of the spores.

longly rectangular, not porose; median leaf cells $87(-25) \mu\text{m}$ long \times $7.5(-8.5) \mu\text{m}$ wide, basal cells $60(-86) \mu\text{m}$ long \times $11(-12.5) \mu\text{m}$ wide. **Costa** single, $45(-60) \mu\text{m}$ wide at base, ending $2/3$ of the way up of the leaf. **Autoicous**. **Sporophytes** with capsule horizontal, cylindrical, \pm curved, operculum conical; peristome diplolepidous; exostome having sixteen robust teeth yellowish, well developed, outer peristomial layer reticulate below and papillose above; endostome well developed, with tall basal membrane striate and finely papillose, segments keeled and perforated above, alternate to exostome teeth; spores $22(-25) \mu\text{m}$, finely papillose.

Warnstorfia fluitans has a bipolar Circumboreal-Austral distribution. It is found in all continents except Antarctica, from the woodland belt up to the alpine one. It grows in a range of mineral-poor and acidic to sometimes nutrient-rich habitats, poor fens, bog pools or depressions in rocks (Hedenäs, 2003).



Fig. 5. Distribution of *Warnstorfia fluitans* (●), *W. sarmentosa* (○) and both taxa (◆), in the Iberian Peninsula

Warnstorfia fluitans is very rare in the Iberian Peninsula. Its distribution is limited to the montane-alpine belts (1350-2300 m) of the Eurosiberian Region from the Cantabrian Range (Palencia, Burgos) to the Pyrenees (Huesca, Lérida) (Fig. 5). It grows in oligotrophic habitats: on peat, in fens and sometimes submerged in small lagoons. *W. fluitans* is associated with *Carex echinata* Murray, *Trichophorum caespitosum* (L.) Hartm., *Potentilla palustris* (L.) Scop., *Viola palustris* L. subsp. *palustris*, *Sphagnum denticulatum* Brid. and *S. flexuosum* Dozy & Molk., belonging to *Caricetalia nigrae* Koch communities (*Scheuzerio-Cariceta nigrae*).

Warnstorfia sarmentosa (Wahlenb.) Hedenäs, *J. Bryol.* 17: 470. 1993. Fig. 6.

Basionym: *Hypnum sarmentosum* Wahlenb. *Fl. Lapp.* 380. 1812. **Type:** Norway. Nordland: Mt. Kronan rear Rörstad, Jun 1807, *Wahlenberg misit s. n.* Lectotype S! (in herb. Swartz) selected by Hedenäs (1993).

[=*Calliergon sarmentosum* (Wahlenb.) Kindb. – *Acrocladium sarmentosum* (Wahlenb.) P.W. Richards & E.C. Wallace – *Sarmentypnum sarmentosum* (Wahlenb.) Tuom. & T.J. Kop.]

Shoots 3-8 cm long, dark red-purple, sometimes yellowish at branch tips. **Stem** without hyalodermis, 2-3 layers of cortical cells with an incrassate reddish-brown wall. **Leaves** 1.8(- 2) mm long × 0.75(- 0.8) mm wide, usually straight, imbricate to patent; oblong-ovate, concave, rounded or shortly acuminate at

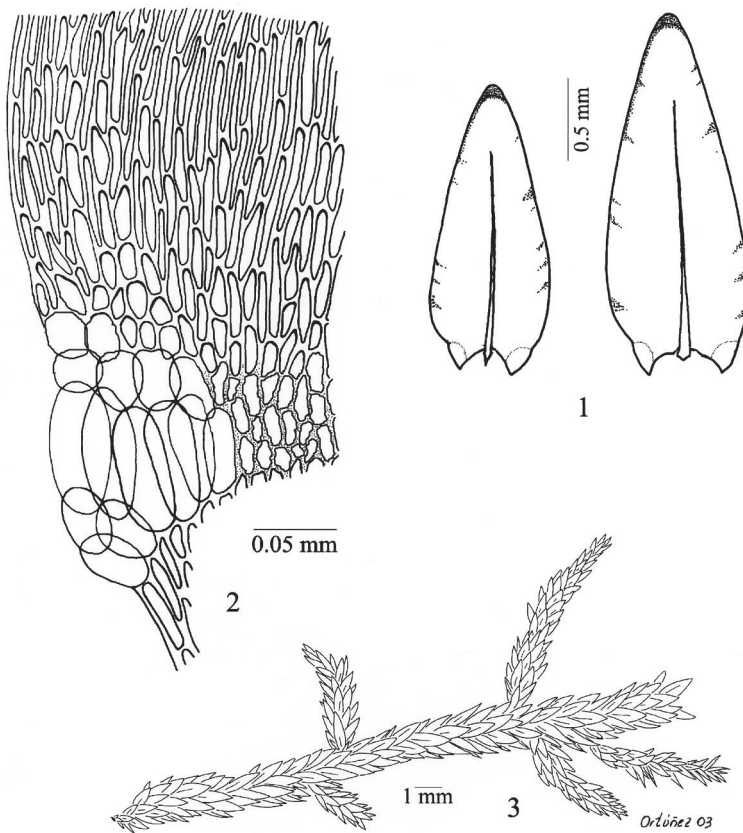


Fig. 6. *Warnstorfia sarmentosa* (Walenhb.) Hedenäs. **1**, stem leaves; **2**, alar cells; **3**, habit.

apex; margin usually entire; costa single, long, often forked, ending near apex. **Lamina cells** with porose and thick walls; basal cells porose, with strongly incrassate walls, 30(–55) μm long \times 12(–15) μm wide; mid-leaf cells 65(–82) μm long \times 10(–15) μm wide. **Alar cells** inflated, hyaline cells \pm gradually becoming strongly incrassate near costa, forming distinct decurrent auricles. **Dioicous**. **Sporophytes** not seen in the revised Iberian collections.

Warnstorfia sarmentosa is distributed in North America, North and Central Europe, Asia, Africa, South America, Australia (Düll, 1984; Hedenäs, 2003) and Antarctica (Ochyra, 1998). It is an ombrophilous helophytic to hygrophytic species, which grows in intermediately mineral-rich fens, around or in late snowbeds and sometimes submerged in lakes (Hedenäs, 2000).

This species is very rare in the Iberian Peninsula. It is absent in Portugal, while in Spain it is restricted to the north, where it occurs in the montane to sub-alpine belts (1000–1850 m) of the Cantabrian Range (Palencia), the Basque Mountains (Navarra) and the Pyrenees (Lérida), where there is a humid climate (mean annual rainfall > 1500 mm) (Fig. 5). *Warnstorfia sarmentosa* grows in permanently wet habitats, preferring oligo-minerotrophic fens, but also sometimes occurs on irrigated soils. It is associated with *Pinguicula vulgaris* L., *Narthecium ossifragum*

(L.) Huds., *Vaccinium myrtillus* L., *Trichophorum caespitosum* (L.) Hartm. subsp. *caespitosum*, *Calypogeia fissa* (L.) Raddi, *Lophocolea bidentata* (L.) Dum. var. *bidentata*, *Marsupella sphacelata* (Gieseke ex Lindenb.) Dum., *Scapania undulata* (L.) Dum., *Sphagnum angustifolium* (C. Jens. ex Russow) C. Jens and *S. compactum* DC., belonging to *Caricetalia nigrae* Kock communities (*Scheuzerio-Caricetea nigrae*).

DISCUSSION AND CONCLUSIONS

Warnstorfia exannulata in the Iberian Peninsula exhibits a considerable variation in habit, size and branching pattern, variation that seems to depend on habitat conditions. The morphological variation exhibited by *W. exannulata* had led to the erroneous identification of many samples as either *Drepanocladus aduncus* or *W. fluitans* (see Annex II). However, these three taxa are readily distinguished. *Warnstorfia fluitans* is an autoicous species and has alar cells that are scarcely differentiated from the basal lamina cells. In contrast, *W. exannulata* and *D. aduncus*, are dioicous and have alar cells that are clearly differentiated from the basal lamina cells. *Warnstorfia exannulata* and *D. aduncus* can be distinguished by the leaf margin: *W. exannulata* has a denticulate leaf margin whereas *D. aduncus* has leaves with an entire margin at the base.

This study has demonstrated that the following taxa should be excluded from the Bryological Flora of the Iberian Peninsula, since all have been re-identified as *Warnstorfia exannulata*. The specimens previously identified as these taxa are indicated below each.

D. aduncus* var. *asturicus (Renauld) Riehm.

(**Granada:** Sierra Nevada, Laguna de las Yeguas, leg. R. Maire 1925, PC).

Drepanocladus exannulatus* subfo. *falcifolius Moenk.

(**Asturias:** Puerto de Tarna, FCO 2547, 2544).

Drepanocladus exannulatus* var. *alpinus (Grav.) Wijk & Margad.

(**Huesca:** Ibón de Bachimaña, PC (herb. Bizot n° 13928)).

Drepanocladus fluitans* var. *falcatus (C.E.O. Jensen) G. Roth

(**Pontevedra:** Vigo, MA-Musci 8306, 9710).

Hypnum fluitans var. *purpurascens* Schimp., *D. exannulatus* var. *purpurascens* (Schimp.) Herzog, *W. exannulata* var. *purpurascens* (Schimp.) Tuom. & T. J. Kop., *D. exannulatus* var. *rotae* (De Not.) Loeske, *Hypnum fluitans* var. *irrigatum* Renauld, *Warnstorfia exannulata* var. *brachydictyon* (Renauld) G. Roth, are synonyms of *W. exannulata* (Schimp.) Loeske, according to Hedenäs (1993).

The voucher named as *Amblystegium sarmentosum*, (Asturias: Valle del Pas, MA-Musci 12656) is *Warnstorfia exannulata*.

The occurrence of *Warnstorfia fluitans*, in Asturias (Durieu de Maissonneuve, 1836), Cuenca (Röll, 1897), the Central Range (Leresche & Levier, 1880; Luisier, 1910), Pontevedra (Casares, 1915), Salamanca (Luisier, 1924), Sierra Nevada (Colmeiro, 1889; Höhnelt, 1895) and Algarve (Solms, 1868), could not be confirmed as these specimens were not found in the herbaria revised by the authors. Furthermore, we have made several extensive and intensive searches in the Galician-Portuguese Massif, the Iberian Range, the Central Range and the Sierra Nevada and its surroundings and did not find this species.

The presence of *Warnstorfia fluitans*, *W. sarmentosa* and *W. exannulata* in Spain is confirmed. *W. exannulata* is also present in Portugal and Andorra. These species grow in wet and oligotrophic-minerotrophic habitats (peat, fens, springs, near lakes or submerged in them), in *Scheuzerio-Caricetea nigrae* communities, in mountainous areas under a humid ombroclimate (mean annual rainfall exceeds 1500 mm) mainly in the northern half of the Iberian Peninsula.

Warnstorfia fluitans and *W. sarmentosa* are both rare. The two species have higher moisture requirements than *W. exannulata*, and their distribution is limited to two disjunct areas of the Eurosiberian Region of Spain (the Cantabrian Range and the Pyrenees), which have a strong Atlantic influence (Fig. 5).

Warnstorfia exannulata is the most common species. It occurs across a wide altitudinal range and under a range of different environmental conditions. It grows in mountains with a more continental climate, i. e. cold winters and dry summers, in northern and central parts of the Iberian Peninsula, from 1200 to 2450 m. Occasionally, it appears in coastal areas in the northwestern part of the Iberian Peninsula, in thermo-mesotemperate belts from 180 to 800 m. It is very rare in the south where there is a warmer and drier bioclimate in summer and it has only been recorded from the Sierra Nevada (Granada), between 2800-2900 m (Fig. 2).

This revision shows that the Iberian populations of *Warnstorfia* are at the southwestern margin of the genus range, which corresponds to the Holarctic region.

Warnstorfia species are not considered to be threatened in Europe (Schumacker & Martiny, 1995) and they are not included in the IUCN World Red List of Bryophytes (IUCN, 2000).

In the Iberian Peninsula these taxa grow in highly specific habitats (*Sphagnum* bogs, oligotrophic fens, on mineral soils or submerged in lakes or streams). Recent changes in wetlands management and in agricultural practices are threatening and destroying these habitats. Reserves of fresh water are decreasing, and the desertification of the ground is advancing. Moreover, due to the macroclimatic xerophytic conditions in the Mediterranean Region and the sparsely scattered and fragmented distribution of the remaining wetlands, these communities are at risk. Only special protection of the Iberian wetlands can prevent the decline of *Warnstorfia* species as well as other wetland mosses. For these reasons, we think that these taxa deserve special attention given the importance of the habitats in which they occur and the value of these species as bio-indicators.

Acknowledgements. We would like to thank the directors and curators of all the herbaria listed above for the loan of the specimens. We wish to express our gratitude to L. Hedenäs, B. O'Shea and M. Carine for helpful comments on the manuscript, and also thank to the former for confirming the identity of some specimens. This research has been funded by the Spanish Ministry of Science and Technology, Grant n°. PB98-0792. Some of the type specimens were revised during the visit of G. O. to the Swedish Museum of Natural History funded by the HIGH LAT RESOURCE under the EC-funded IHP programme.

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ANNEX I. SPECIMENS REVISED

Only one specimen from each province is cited. The coordinates of the locality in U.T.M. (10 × 10 km), collector name, date and acronym of the Herbarium are given for all the specimens. A list of all the examined specimens for this work is deposited in MACB Herbarium and can be consulted upon request to the authors.

Warnstorfia exannulata (Schimp.) Loeske

ANDORRA. 31TCH72, Serra Tristaina, Estany de Mes Amunt 2100 m, leg. E. Fuertes & G. Oliván, 2001, MACB79085

SPAIN: Ávila: 30TUK06, Sierra de Gredos, Refugio de la Mira 1650 m, leg. M. Pottier-Alapetite 1943, PC. **Asturias:** 29TQH06: près laguna Arbas 1750 m, leg. Durieu 1835, PC.

Burgos: 30TVM395, Quintanar de la Sierra, Peñas Albas 1500 m, leg. P. Montserrat 1950, BCB4534. **Cantabria:** 30TUN66, Puerto de Riófrio 1750 m, leg. J. Muñoz 1988, FCO 933.

Gerona: 31TDH50, Baixa Cerdanya, Maranges, near Malniu lake 2450 m, leg. C. Casas 1958, BCB 15897. **Granada:** 30SVG60, Sierra Nevada, Laguna de la Yeguas, leg. A. Casares 1913, MA-Musci 9702. **Guadalajara:** 30TVL65, Macizo de Ayllón, pr. Cardoso de la Sierra, leg.

J. M^a Herranz, 1999 MUB9687. **Huesca:** 31TCH01, Vallivierna, leg. M. L. López 1998, MUB11045. **La Coruña:** 29TNH67, Curtis near Santiago de Compostela, leg. P. & V. Allorge 1927, PC. **La Rioja:** 30TWM25, Fuentes del Iregua, leg. Zubía 1914, MA-Musci

3672-2. **León:** 30TUN06: Lago Ausente, leg. P. & V. Allorge 1934. **Lérida:** 31TCH31, Parque Nacional d'Aiguestortes, d'Amitges, stany Bards 2390 m, leg. E. Fuertes & M. Acón 2000, MACB 78842. **Lugo:** 29TPJ13, Entre Vivero y Ferreira, leg. P. & V. Allorge 1927, PC.

Madrid: 30TVL22, Sierra Guadarrama, Laguna de los Pájaros 2100 m, leg. F. Beltran 1912, MA-Musci 9708, 9703, 9312. **Navarra:** 30TW86, Monte Gartzaga, pr. Leiza, 1.100 m leg. J. Arraiza 1984, PAMP 3272. **Palencia:** 30TUN66: Pozo de Curavacas 1750, leg. E. Fuertes

1996, MACB 66210. **Pontevedra:** 29TNG16: Vigo, La Ramallosa, leg. L. Bescansa 1913, MA-Musci 9710; **Salamanca:** 30TTK77, Navacarros, Garganta del Oso, leg. M. J. Elías 1983, SALA648. **Soria:** 30TWM15: Sierra de Urbión, Laguna Negra 1700 m. leg. C. Casas 1974, MAF2400. **Zamora:** 29TPG77, Laguna del Moncalvillo 1950 m, leg. J.J. Aldasoro 1993; MA-Musci 19157.

PORTUGAL: Beira Alta: 29TPE16, Serra da Estrela, leg. Pereira Coutinho 1848 LISU 55001. **Tras-Os-Montes e Alto Douro,** 29TNF25: Foz de Douro leg. I. Newton 1887, LISU 55005, PO 3253B. **Estremadura:** 29SMD71: Mafra, leg. E. Mendes 1947, LISU 158310.

Warnstorfia fluitans (Hedw.) Loeske

SPAIN: Burgos: 30TVN48, Lunada, 1350 M, *pr.* Espinosa de los Monteros, *leg.* P. Heras 1988, VIT11202. **Huesca: 31TCH01**, Vall de Llauset, Montanuy, 2300m, *leg.* I. Aizpuru, ARAN 1543. **Lérida: 31TCH22**, Vall d'Arán, between Estany Mort and Estany Garguills 2200 m, *leg.* E. Ballesteros 1986, MACB **Palencia: 31TUN66**, submerged in lagoons, surroundings of Pozo de Curavacas, 1750 m, *leg.* E. Fuertes & M. Acón 2003, MACB.

Warnstorfia sarmentosa (Walenh.) Hedenäs

SPAIN: Lérida: 31TCG99, Baixa Cerdanya, dels Estanys de la Pera a Llés 1850 m, *leg.* M. Brugués *et al.* 1999, BCB53000. **Navarra: 30TXN36**, Roncesvalles 1000 m, *leg.* and *data* unknown, MA-Musci 12657 p.p. **Palencia: 30TUN65**, Curavacas *supra* Vidrieros 1400 m, *leg.* P. Geissler 1978, G (Herb. P. Geissler 2972)

ANNEX II

Sites excluded of taxa erroneously identified as:

Warnstorfia fluitans (Hedw.) Loeske

SPAIN: Ávila, 30TUK06: Sierra de Gredos, Laguna del Cervunal, MACB 12264 is *Warnstorfia exannulata*; *ibidem*, Prado de las Pozas, MACB 11265 is *W. exannulata*. **Asturias: 29TQH23**, Laguna de Arbas, FCO 2548, VAB 2501, PC, is *W. exannulata*. **Cantabria: 30TUN86**, Tres Mares, *pr.* Polaciones, MA-Musci 16543 is *W. exannulata*. **Granada: 30SVG70**, Sierra Nevada, MA-Musci 9702, 12618, 12620, is *W. exannulata*. **Huesca: 30TYN23** *supra* Balneario de Panticosa, PC is *W. exannulata*; 31TBH63 Ibón de Pinara, VIT 28240 is *Sanionia uncinata*. **La Coruña: 29TNH67**, Curtis, PC is *W. exannulata*. **La Rioja: 30TWM25**, Fuentes del río Iregua, MA-Musci 3672-2, is *W. exannulata*; **León: 29TQG07**, Laguna de las Truchas, MA-Musci 18718, 12885, is *Warnstorfia exannulata*; **30TUN06**, Lago Ausente, PC is *W. exannulata*. **Lugo: 29TPJ13**, between Vivero and Ferreiro, PC is *W. exannulata*. **Madrid: 30TVL12**, Sierra de Guadarrama, Laguna de Peñalara, MA-Musci 9703; *ibidem*, Altos de San Juan, MA-Musci 8307; **30TVL22**, Laguna de los Pájaros, MA-Musci 9708, all them are *W. exannulata*.. **Mallorca: Palma de Mallorca, MAF 1918**, is *Amblystegium riparium*. **Navarra: 30TXN75**, valle de Belagua, PAMP3057, is *Brachythecium* sp. **Sevilla: 30STG61**, Isla Mayor del Guadalquivir, MAF 52 is *Amblystegium riparium*. **Zamora: 29TPG87**, Porto, Laguna de Salcillo, MA-Musci 18776 is *W. exannulata*; *ibidem*, Galende, MA-Musci 16547 is *W. exannulata*. **Zaragoza: 30TXL06**, Cascadas del Monasterio de Piedra is *D. aduncus*, MAF 54. **Vizcaya: Übernaga**, MA-Musci 3735 is *Fontinalis hypnoides* Hartm. subsp. *duriei* (Schimp.) Warnst.

PORTUGAL: Beira Alta: 29TPE16, Serra da Estrela, LISU 55003, 55004, 55006, 55007, 55008, 176066, 176247, 176237, 176124, 176033, 176378, 175911 is *W. exannulata*. **Tras-Os-Montes e Alto Douro: 29TNF96**, Serra do Marao, LISU 55009, is *W. exannulata*; *ibidem* LISU55005, PO3253B is *Drepanocladus aduncus*. **Estremadura, 29SMD71**, Mafra, LISU 158312, is *W. exannulata*; Monção, LISU158311 is *Hygrohypnum ochraceum*.

Hypnum fluitans var. *irrigatum* Renaud

SPAIN: La Rioja: 30TWM92, Logroño, Monasterio, MA-Musci 3736 is *Rhynchostegium riparioides*.

Amblystegium revolvens (Sw.) De Not.

SPAIN: Navarra: 30TXN36, Roncesvalles, MA-Musci12657 is *Warnstorfia sarmentosa*.