PhytoKeys 121: 1–12 (2019)
doi: 10.3897/phytokeys.121.32588
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

A new species of perennial *Bromus* (Bromeae, Poaceae) from the Iberian Peninsula

Carmen Acedo[1], Félix Llamas[1]

1 *Research Group Taxonomy and Conservation of Biodiversity TaCoBi, Department of Biodiversity and Environment Management, University of León, E-24071. León, Spain*

Corresponding author: *Carmen Acedo* (c.acedo@unileon.es)

Academic editor: *M. Vorontsova* | Received 20 December 2018 | Accepted 22 March 2019 | Published 24 April 2019

Citation: Acedo C, Llamas F (2019) A new species of perennial *Bromus* (Bromeae, Poaceae) from the Iberian Peninsula. PhytoKeys 121: 1–12. https://doi.org/10.3897/phytokeys.121.32588

Abstract

During a survey of the genus *Bromus* for the ongoing Flora Iberica, *B. picoeuropeanus* **sp. nov.**, a new orophilous species of perennial *Bromus* from Picos de Europa National Park, was found, and it is described and illustrated here. This new species belongs to the *Bromus erectus* complex and differs from the other perennial species of this group occurring in the Iberian Peninsula in its well-developed rhizome, the small innovation leaves and all peduncles and branches shorter than the spikelets. *B. picoeuropeanus* grows on calcareous stony soils associated with dry places. We provide a description and illustrations of the new species and an identification key for the most related European perennial species belonging to the complex.

Keywords

Bromea, *Bromus* subg. *Festucoides*, *Bromus erectus* complex, *Bromus picoeuropeanus*, Cantabrian range, Identification Key, New species, Poaceae, Spain, Taxonomy

Introduction

The genus *Bromus* L. is the only representative of the tribe Bromeae in Southwest Europe. The genus comprises perennial and annual species, and both life forms are distributed throughout the genus. *Bromus* has a characteristic fleshy appendage above

the style insertion, which is pubescent at its apex and persistent in the caryopsis. The taxonomy of this genus is considered troublesome and has been the subject of numerous regional taxonomic revisions (e.g. Smith and Sales 1993; Acedo and Llamas 1999; Saarela 2008), and the main subject of several studies (e.g. Smith 1972; Acedo and Llamas 2001; Saarela et al. 2007; Oja and Zimmermann 2010; Alonso et al. 2014; Alonso 2015). It includes more than 170 species mainly in the Northern hemisphere (Acedo and Llamas 2001; Saarela et al. 2014).

The last revision of the genus *Bromus* L. in the Iberian Peninsula (Acedo and Llamas 1999) included a detailed discussion of its taxonomic history, morphology, anatomy, distribution and other relevant information for the region. Some twenty-five species of *Bromus* occur in the Iberian Peninsula. The Iberian monograph includes only two alien species, *B. catharticus* Vahl and *B. inermis* Leyss., and recently another weedy species was found: *B. sitchensis* Trin. (Acedo, unpublished data), native to northwestern North America. Some taxonomic studies (Oganesian 2004; Tzvelev 1976), the Euro+Med List of Plants (Valdés and Scholz 2006; 2009) or the Flora of Italy (Pignatti et al. 2017), and Flora of Russia (Fedorov 1999) treated the Old World perennial *Bromus* at the generic level as *Bromopsis* (Dumort.) Fourr. However, other authors argue it must be treated as *Bromus* sect. *Bromopsis* Dumort. (Saarela 2008; Naderi and Rahiminejad 2015: 243) or subgenus *Festucoides* (Stebbins 1981; Acedo and Llamas 1999; Alonso, Llamas, Pimentel, and Acedo unpublished data) based on karyological and morphological data, and phylogenetic relationships suggested by molecular nuclear and plastid data regions. This study follows the proposal to split the genus *Bromus* into subgenera.

The European perennials belong to *Bromus* subg. *Festucoides* (Coss. & Durieu) Hackel, which is not monophyletic in its current circumscription (Saarela et al. 2007; Alonso 2015). It comprises between sixty and seventy perennial species, including caespitose or rhizomatous plants, ranging in height from twenty to more than one hundred and fifty centimeters, and growing in diverse terrestrial habitats such as forest, hedges and pastures, etc. In Europe, only a few species are associated with temperate forests (Smith 1981; Acedo and Llamas 1999). In this subgenus, the cross-section of the leaf blade is characterized by soft ribs and numerous primary vascular bundles bound by wide and complete sclerenchyma beams. The narrow spikelets with close parallel sides have glumes which are 1–3(5)-nerved (Acedo and Llamas 1999). The presence or absence of a developed long rhizome is considered an important diagnostic character within the perennial *Bromus*. Its presence is diagnostic for several European and West Asian species of *Bromus* as several authors pointed out in their identification keys (i.e. Tzvelev 1976; Smith 1980; Pignatti et al. 2017). In addition, the presence of a developed rhizome and the presence of tuberous basal internodes are diagnostic in North African taxa belonging to this group (Maire et al. 1955). Several European perennial taxa are caespitose and lack rhizomes (Smith 1980; Pignatti et al. 2017). The European perennials form a morphologically heterogeneous group, including taxa

with broad distributions as well as narrow endemisms that are grouped within several complexes of cytologically and morphologically similar species (e.g. the *Bromus erectus* complex and the *Bromus ramosus* complex). The *Bromus erectus* complex includes perennial species, with old sheaths remaining intact or decaying into parallel fibres, inflorescences with some long branches and/or pedicels, and spikelets erect (Smith 1980, Acedo et al. 2009; Pignatti et al. 2017). The taxonomy of some species or groups was studied in different regions e.g. "*Bromus erectus* Group" in Slovenia (Bačič and Jogan 2001) or the species *B. erectus* along the Cantabrian range and Pyrenean mountains in the Iberian Peninsula (Acedo et al. 2009). The *Bromus erectus* complex includes several endemics and probably some taxa remain undescribed, due to the lack of a global taxonomic revision.

The main objectives of this study are to describe a new species, to differentiate it from its relatives, and to characterize this new taxon.

Materials and methods

Several specimens of perennial *Bromus* were collected during a survey of the genus *Bromus* for the ongoing *Flora Iberica* project. This material was confirmed as a new species after a careful study and comparison with material deposited at JBAG, LEB, FCO, MA, MAF, JACA, SALA, SANT, VIT, representing the full distribution and variability of *B. erectus* Huds. from the Iberian Peninsula as well as specimens belonging to related species (*B. condensatus* Steud., *B. stenophyllus* Link, *B. transsilvanicus* Steud.) and other perennial European species (*B. biebersteinii* Roem. & Schult., *B. moellendorffianus* (Asch. & Graebn.) Hayek, *B. moesiacus* Velen., *B. pannonicus* Kumm. & Sendtn., *B. riparius* Rhemann, *B. tomentellus* Boiss.). In addition, material from several important European Herbaria: C, K, FI, MSNM was studied. We also studied specimens and photographs of types and original material in B, P, and K, including the type specimen of *B. erectus* (Llamas and Acedo 2019, in press). Herbarium acronyms follow Thiers (2018+ continuously updated).

Specimen locality data were recorded in the field or via geo-referencing. We assessed the preliminary conservation status of the new species using our field knowledge, applying the IUCN (2017) criteria and performing a GeoCat analysis (Bachman et al. 2011). The extent of occurrence (EOO) and the area of occupancy (AOO) were estimated using GeoCat. For AOO calculation, a 2 km cell width was used. The information and measurements of the new and closely related species were taken from live and dried herbarium specimens, and from field data. The taxonomic treatment of the genus *Bromus* follows Acedo and Llamas (1999). Measurements and data for the diagnostic characters comparing the new species and *B. erectus* are presented in Table 1, and an identification key is provided to facilitate differentiation from the related European species.

Results – taxonomic treatment

***Bromus picoeuropeanus* Acedo & Llamas, sp. nov.**
urn:lsid:ipni.org:names:60478523-2

Type. Spain. Cantabria: Macizo Oriental de Picos de Europa, Vegas de Ándara: Fuente de la Escalera. 43°12.42'N, 4°42.20'W, [WGS-84], on limestone dry rocky sites, moving by gelifraction, 1869 m alt., 31 August 2011; *C. Acedo, A. Alonso & F. Llamas* CA247.4 (Holotype LEB 121814).

Diagnosis. *Bromus picoeuropeanus* differs from *B. erectus* Huds. (Table 1) in having shorter habit; longer creeping rhizomes; non-cauline leaf blades short and never reaching the inflorescence, flat and similar to the cauline leaves; ligule truncated or round up to 1 mm; panicle 3–5(8) cm, contracted and smaller, with few spikelets, up to 11; all branches shorter than the spikelets; caryopsis thickened, inrolled or plicate, 8–9 mm, shorter than palea. *B. picoeuropeanus* also differs in its preference for stony soils.

Description. Perennial plant with long rhizomes 3–5(7) cm, loosely tufted. Flowering culms up to 40 cm. Culms channeled and glabrous, with glabrous nodes. Extravaginal innovation leaves with short blades, similar to the cauline leaves. Leaf sheaths of cauline leaves glabrous. Old basal leaf sheaths persistent, investing the culm base. Blade of cauline leaves 9–13 cm × 2–3 mm, tapering gradually towards the apex. Ligule membranous and glabrous, short, 0.5–1 mm, apex truncated or rounded, ± lacerated. Panicle 3–4(–8) × 2–3 cm, erect, lax, contracted, with 4–8(11) spikelets, branches slender. Scale of the lower node leaf-like, c. 4 mm, glabrous. Pedicels scabrid with fine antrorse teeth. All branches and pedicels shorter than spikelets. Spikelets 16–22(–25) × 3–5 mm, with two unequal glumes and 4–5(–7) fertile florets, imbricate when young, in maturity the florets slighted separated. Lower florets bisexual, 9–11(–12) mm, oblong, scaberulous toward the apex; upper floret male or sterile, 5–6 mm, lanceolate, glabrous, similar in color and texture to the lower florets. Lower glume 1–veined, narrow, 6–7 mm. Upper glume 3-veined, 7–9 mm. Lemma glabrous, lanceolate, section slightly keeled, 9–11(–12) mm (excluding the awns), 3–5-veined. Apex of the lemma slightly emarginate (sinus approximately 0.1 mm); margin rounded. Awn short, (2.5–) 3–4 (–5) mm, up to 1/3 the lemma length, fine and straight, inserted 1–1.5 mm below the apex. Rhachilla 2–3 mm, scabrid with very fine antrorse teeth. Callus short, glabrous and rounded. Palea linear-lanceolate of similar size or slightly shorter than the lemma, 8–11 × 1–2 mm, with aculeolate keels; wings nearly as wide as the palea body, with smooth border. Lodicules 2, lanceolate to oblong, glabrous, 0.5–1.5 mm long. Stamens 3, with anthers 3.5–4.5 mm long. Caryopsis elliptic, enrolled or plicate at maturity, 7–8 mm, shorter than palea (Fig. 1).

Phenology. Flowering July – August. Fruiting August – September.

Distribution and habitat. *Bromus picoeuropeanus* is endemic to the Iberian Peninsula and occurs in Spain, distributed through the Northern Mountains of the Cantabrian Range (Fig. 2). We collected it in several localities of Picos de Europa National Park, growing in dry rocky areas of limestone moving by gelifraction, and on stony areas at an altitude of 1600–2200 m.

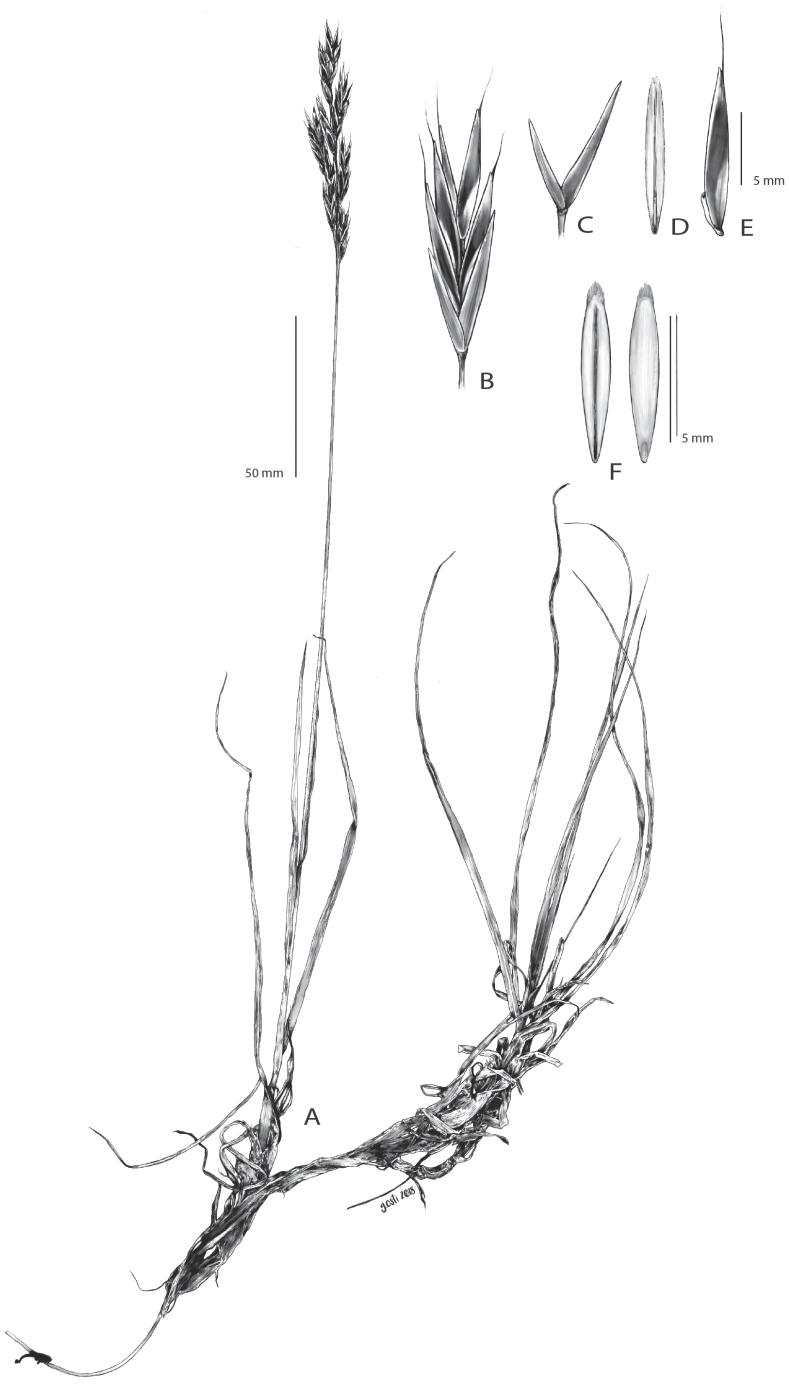

Figure 1. ***Bromus picoeuropeanus***. **A** Habit showing the developed rhizomes, the short basal leaves, and the contracted inflorescence **B** Spikelet with unequal glabrous glumes and five florets **C** Glumes **D** Palea in adaxial view, showing the two adaxial wings **E** Lemma in lateral view (drawn from the holotype) **F** Caryopsis in adaxial and abaxial view (drawn from LEB 121815). Drawings by Ms. Giulia Osti, 2018.

Table 1. Summary of the main taxonomic traits that differentiate *Bromus picoeuropeanus* Acedo & Llamas from *B. erectus* Huds.

	***B. picoeuropeanus* Acedo & Llamas**	***B. erectus* Huds.**
Habit	Loosely tufted	Densely caespitose
Rhizome presence	Rhizomatous	None, or inconspicuous rhizome, caespitose
Height	Up to 40 cm	60–130 cm
Basal and cauline leaf blade	Flat, basal similar to the cauline, 2–3.5 mm wide	The basal narrower (c.1 mm) and longer than cauline (2–3 mm wide)
Ligule	Truncated or rounded, 0.5- 1 mm	Blunt, (0.5)1–2 mm
Panicle in well-developed specimens	Contracted, 3–5(–8) cm length	Spreading, 10–20 cm length
Spikelet number	4–8(–11)	(8)20-30
Spikelet length	16–21 (–25) mm	(15–)20–35(50) mm
Branch length	Shorter than spikelet	Several branches equal to or longer than spikelet
Lower glume length	6–7 mm	7–12 mm
Upper glume length	7–9 mm	(8–)9–14(–15) mm
Fertile lemma length	9–11(–12) mm	(9–)10–15 (–18) mm
Palea length	Similar to lemma	Similar to lemma
Awn length	(2.5–)4.5–5 mm	2.5–6(8) mm
Florets number	(4–)5–7	(5–)7–9
Anther length	3.5–4.5 mm	4.5–8 mm
Caryopsis	Thickened, inrolled shorter than palea 8–9 mm	Thin and almost flat, similar to palea in length

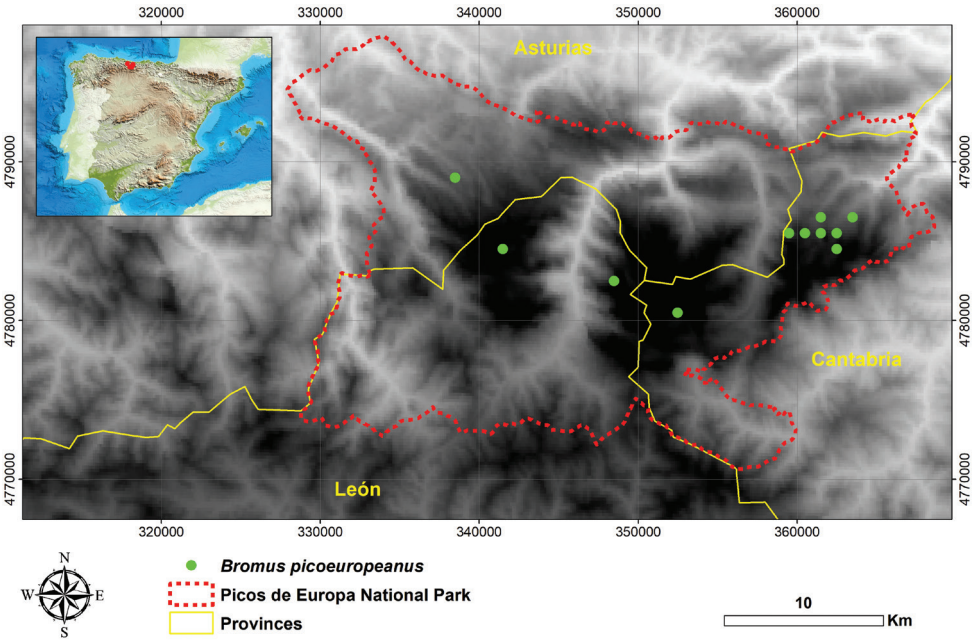

Figure 2. Distribution map representing all the known locations of *Bromus picoeuropeanus*.

Conservation status. *Bromus picoeuropeanus* occurs within the Picos de Europa National Park. Although the IUCN (2017) criterion B thresholds (EOO = 111.51 km^2; AOO = 40.0 km^2) suggest a different category [EN], the species has been evaluated DD (Data Deficient), because further study is needed to assess the risk.

Etymology. The specific epithet is a reference to the Spanish National Park Picos de Europa, where it was collected.

Discussion

Some thirty perennial species belonging to the genus *Bromus* occur in the Euro+Med area (Valdés and Scholz 2006; 2009). Five perennials live in the Iberian Peninsula (Smith 1980; Acedo and Llamas 1999) including the cultivated and naturalized *Bromus inermis* Leyss. extensively cultivated all over the world, the weeds *B. catharticus* Vahl, and *B. sitchensis* Trin., and the native perennial species, *B. benekenii* (Lange) Trim., *B. ramosus* Huds., and *B. erectus*. This last species is the only one known in the Iberian Peninsula belonging to the *B. erectus* complex until now.

The *Bromus erectus* complex is differentiated by its persistent basal sheaths remaining intact or decaying into parallel fibers, and the non-cauline basal leaves typically longer and narrower than the cauline leaves. Its inflorescence is lax, spread or contracted, with erect branches and pedicels, more or less developed, but some of the pedicels longer than the spikelet. The multiflorous spikelet is supported by two subequal or unequal glumes with 1–5 nerves (Smith 1981; Acedo and Llamas 1999; Cope and Gray 2009; Pignatti et al. 2017). Other perennial species have old basal sheaths forming a reticulum as *B. moesiacus* Vell. or *B. riparius*. The complex lacks auricles as opposed to other perennial species having long lanceolate auricles (e.g. *B. biebersteinii*) or diminished auricles (e.g. *B. stenostachyus* Boiss.).

The morphological traits of *Bromus picoeuropeanus* suggest it must be classified within the *Bromus erectus* complex. Among the Iberian perennials, the specimens of *B. picoeuropeanus* are morphologically more similar to the widespread *B. erectus*. The presence of a developed rhizome 3–5(7) cm long (Fig. 1, 3) is a major difference with the remainder of the perennial Iberian taxa. This trait is relevant also in the differentiation of other perennial species such as the nemoral *B. benekenii* and *B. ramosus* (Cope and Gray 2009). There are other European species related to *B. erectus* which have rhizomes: *B. moellendorffianus*, *B. pannonicus*, *B. riparius*, or *B. tomentellus*. All of them, however, have very short rhizomes. The shoot leaf blades of *B. picoeuropeanus* are shorter (Fig. 1) than those of *B. erectus*, which has long and narrow leaves frequently reaching the inflorescence. Leaf hairs are very rare in *B. picoeuropeanus*, even more scarce than in *B. erectus*. In detailed descriptions of *B. erectus*, there is a large range of variability in other characters that are not useful for separating taxa: for instance, some floras (Pignatti et al. 2017) recognized *Bromus longiflorus* Willd. ex Spreng. as having long spikelets with 11–13 florets, which is a variation of *B. erectus*. We have observed that the number of florets is a variable character in several species (Acedo and Llamas

Figure 3. A The preferred habitat of *Bromus picoeuropeanus* in stony and unstable soils, c. 1900 m elevation, where it prefers steep slopes and stony grassland, and disappears when the slope decreases or the pasture becomes denser **B** Detail of the basal part of culms showing the long rhizomes and flat cauline leaves.

1999; Acedo et al. 2009), and the floret number can be sometimes twice or more than its usual number.

While *Bromus erectus* has a wide distribution in most of Europe (except on the Scandinavian peninsula and the adjacent Northeastern countries), *B. picoeuropeanus* is known only in the National Park of the Picos de Europa, a small territory of the Cantabrian range. *B. picoeuropeanus* differs also in its ecological behavior from all the native Iberian perennial species. *B. benekenii* and *B. ramosus* occur in nemoral habitats and *B. erectus* mainly in mesophyllous meadows. *B. picoeuropeanus*, by contrast, occurs in stony and rocky places.

Key to the perennial European species similar to *Bromus picoeuropeanus*

1 Plants rhizomatous, laxly caespitose; shoot and cauline leaf-blades similar in width, leaves glabrous, scabrid or distinctly pilose **2**

– Plants without rhizomes or stolons, or inconspicuously rhizomatous, tufted, caespitose; cauline leaf blades wider than the lower, with scattered long (up to 1mm) and patent hairs **6**

2 Leaves flat or slightly involute **3**

– Leaves conduplicate, or setaceous-conduplicate **4**

3 Rhizome long; lemma 9–11(–12) mm, awn 3–5mm; caryopsis slightly thickened, inrolled at maturity, shorter than palea; leaves not auriculate; culms up to 40 cm ..... ***B. picoeuropeanus***

– Rhizome short, forming distinct clumps; lemma long 11–14(–20) mm, awn 5–8 mm; caryopsis almost flat, similar in length to the palea; lower leaves shortly auriculate; culms 50–90(–120) cm ..... ***B. riparius***

4 Leaves and sheaths with long greyish hairs; spikelets 15–20(–25) mm ..... ***B. pannonicus***

– Indumentum of leaves different; spikelets 15–25(–35) mm, awn similar in length to the lemma or slightly shorter..... **5**

5 Leaf sheaths and blades tomentose, covered by dense short and sparse long hairs; lemma 12–18 mm, awn 11–17mm ..... ***B. tomentellus***

– Leaf blades and sheaths glabrous, scarcely scabrid on the veins or distinct pilose, not tomentose; lemma 8–10(–15) mm, awn 7–9 mm..... ***B. moellendorffianus***

6 Leaf sheaths lanate-pubescent, with long and tangled hairs; the lower sheaths fibrous; panicle denser; lemma 8–9 mm..... ***B. condensatus***

– Leaf sheaths not lanate-pubescent, the lower sheaths persistent, remaining intact when dead; panicle lax, lemma > 9 mm **7**

7 Glumes subequal, florets strongly overlapped, for ¾ of their length by the floret below; panicle spread..... ***B. erectus***

– Glumes markedly unequal; florets only slightly overlapped by the apex of the floret below..... **8**

8 Lower sheaths densely pubescent; lemma 13–18 mm, longer than the upper glume; awn up to one half of lemma length..... ***B. stenophyllus***

– Sheaths glabrous or with few scattered long (c. 1 mm) hairs; lemma short, c. 10 mm, similar in length to the upper glume; awn similar to lemma length..... ***B. transsilvanicus***

Other *Bromus picoeuropeanus* specimens examined

Asturias: Vegarredonda, 43°14.44'N, 4°59.42'W, 1983, July 28, limestone, 1800 m alt., *H.S.Nava* s.n. (FCO 14203). **Cantabria: Canal de Jenduda**, 43°9.88'N, 4°48.88'W, 20 July 2008, 1810 m alt., *C.Acedo* & *F.Llamas* (v.v.); **Canal de San Carlos**, 43°12.70'N, 4°41.56'W, 6 August 1983, 1718 m alt., *H.S.Nava* s.n. (FCO 14201); **Canto La Concha**, 43°13.13'N, 4°40.81'W, 6 August 1983, 1660 m alt., *H.S.Nava* s.n. (FCO 14196); **Majada de la Redondal**, 43°12.52'N, 4°43.41'W, 3 August 1983, 1800 m alt., *H.S.Nava* s.n. (FCO 14200); **Mancondiu**, 43°12.96'N, 4°42.47'W, 6 August 1983, 1900 m alt., *H.S.Nava* s.n. (FCO 14199); **Pozo de Ándara**, 43°12.67'N, 4°43.80'W, 3 August 1983, 1730 m alt., *H.S.Nava* s.n. (FCO 14202); **Samelar**, 43°12.54'N, 4°41.90'W, 1 August 2007, 1700 m alt., *C.Acedo & F.Llamas* (v.v.); **Vegas de Ándara**: Fuente de la Escalera, 43°12.42'N, 4°42.20'W, 31 August 2011, 1869 m alt., *C.Acedo, A.Alonso & F.Llamas* CA247.1 (LEB121812); ibidem CA247.2 (LEB 121810); ibidem CA247.3 (LEB 121811); ibidem CA247.4, (LEB 121814); ibidem CA247.5 (LEB 121813); 50m East of the Fuente de la Escalera, 43°12.43'N, 4°41.99'W, 1 October 2017, 1886 m alt., *V.Ezquerra & C. Frey s.n.* (LEB 121815); Camino hacia Fuente de la Escalera, 43°12.46'N, 4°42.01'W, 1

October 2017, 1860, *V.Ezquerra & C.Frey* (v.v.), sink holes, 43°12.66'N, 4°42.25'W, 1 October 2017, 1789, *V.Ezquerra & C.Frey* (v.v.), road margin, 43°12.70'N, 4°42.24'W, 1 October 2017, 1787 m alt., *V.Ezquerra & C.Frey* (v.v.). **León. Carbayal**, 43°11.82'N, 4°57.11'W, 7 July 1983, 1800 m alt., *H.S.Nava* s.n.(FCO 14198); **Las Colladinas**, 43°10.84'N, 4°51.76'W, 22 July 1983, 2170 m alt., *H.S.Nava s.n.* (FCO 14197).

Acknowledgments

This research was partially supported by the Spanish Ministerio de Ciencia e Innovación, and Spanish Ministerio de Economía y Competitividad under Flora Iberica X (CGL2014-52787-C3-2-P/BOS), GrassModels (CGL2012-39953-C02-02), and Pooide (CGL2009-12955-C02-02) projects. The authors give many thanks to the curators of all the herbaria consulted, and would like to thank herbaria B, C, JBAG, LEB, FCO, FI, JACA, K, MA, MAF, MSNM, P, SALA, SANT, and VIT, and researchers who provided material from public or personal collections and provided loans and access to collections, although in some cases it was not included in this study. Thanks to Víctor Ezquerra and Carlos Frey for collecting the fruiting specimens in the locus classicus; Ms. Giulia Osti for drawing the holotype; Estrella Alfaro Ph.D. (LEB) for improving the distribution map, and Mrs. Amelia Llamas for proofreading the paper. Many thanks to the reviewers Martin Röser and Jeffery Saarela, and the communicating editor Maria Vorontsova for suggestions to improve the manuscript.

References

Acedo C, Llamas F (1999) The genus *Bromus* L. (Poaceae) in the Iberian Peninsula. Phanerogamarum Monographiae, Vol. 22. J. Cramer, Berlin and Stuttgart, 293 pp.

Acedo C, Llamas F (2001) Variation of micromorphological characters of lemma and palea in the genus *Bromus* (Poaceae). Annales Botanici Fennici 38: 1–14. https://www.jstor.org/stable/23726828

Acedo C, Molina A, Llamas F (2009) Variación morfológica de *Bromus erectus* Huds., en el eje pirenaico-cantábrico. Significado taxonómico. In: Llamas F, Acedo C (Eds) Botánica Pirenaico-Cantábrica en el siglo XX. Área de publicaciones. Universidad de León, León, 123–144.

Alonso A (2015) Multi-Genomic evolution, ancestral reconstruction, dating, and design of microsatellites in the tribe Bromeae (Pooideae, Poaceae). PhD Thesis, University of León, Spain, 302 pp.

Alonso A, Bull RD, Acedo C, Gillespie LJ (2014) Design of plant-specific PCR primers for the ETS region with enhanced specificity for tribe Bromeae and their application to other grasses (Poaceae). Botany 92(10): 693–699. https://doi.org/10.1139/cjb-2014-0062

Bachman S, Moat J, Hill A, de la Torre J, Scott B (2011) Supporting Red List threat assessments with GeoCAT: Geospatial Conservation Assessment Tool. ZooKeys 150: 117–126. https://doi.org/10.3897/zookeys.150.2109

Bačič T, Jogan N (2001) Multivariate morphometric study of the *Bromus erectus* group (Poaceae-Bromeae) in Slovenia. Phyton, Annales Rei Botanicae 41(2): 295–311.

Cope T, Gray A (2009) Grasses of the British Isles. B.S.B.I. Handbook No. 13. Botanical Society of the British Isles, London, 83–85, 434–479.

Fedorov A (1999) Flora of Russia, the European part and bordering regions. Vol. 1. AA Balkema, Roterdam, Brookfield, 237–254.

IUCN (2017) Guidelines for using the IUCN red list categories and criteria. Version 13. Prepared by the standards and petitions subcommittee. Downloadable from http://www.iucnredlist.org/documents/RedListGuidelines.pdf

Llamas F, Acedo C (2019) Typification of eight current and seven related names, and a new section in the genus *Bromus* (Bromeae, Pooideae, Poaceae). PhytoKeys 119.

Maire R, Guinochet M, Faurel L (1955) Flore de l'Afrique du Nord, Vol. 2. P. Lechevalier, Paris, 395 pp.

Naderi R, Rahiminejad MR (2015) A taxonomic revision of the genus *Bromus* (Poaceae) and a new key to the tribe Bromeae in Iran. Annales Botanici Fennici 52(3–4): 233–248. https://doi.org/10.5735/085.052.0316

Oganesian ME (2004) *Bromopsis gabrielianae* (Poaceae) a new species from Southern Armenia. Flora, Rastitel'nost' i Rastitel'nye Resursy Armyanskoi SSR 15: 11–13.

Oja T, Zimmermann K (2010) Genetic variation of *Bromus hordeaceus s. lato* (Poaceae) over its core distribution range. Annales Botanici Fennici 47(3): 161–174. https://doi.org/10.5735/085.047.0301

Pignatti S, Guarino R, La Rosa M (2017) Flora d'Italia. Vol. 1. Edagricole. Bologna, 679–694.

Saarela JM (2008) Taxonomy of *Bromus* (Poaceae: Pooideae: Bromeae) sections *Bromopsis*, *Bromus*, and *Genea* in British Columbia, Canada. Journal of the Botanical Research Institute of Texas 2(1): 323–372.

Saarela JM, Peterson PM, Keane RM, Cayouette J, Graham SW (2007) Molecular phylogenetics of *Bromus* (Poaceae: Pooideae) based on chloroplast and nuclear DNA sequence data. Aliso 23(1): 450–467. https://doi.org/10.5642/aliso.20072301.35

Saarela JM, Peterson PM, Valdés-Reyna J (2014) A taxonomic revision of *Bromus* (Poaceae: Pooideae: Bromeae) in México and Central America. Phytotaxa 185(1): 1–147. https://doi.org/10.11646/phytotaxa.185.1.1

Smith PM (1972) Serology and species relationships in annual bromes (*Bromus* L. sect. *Bromus*). Annals of Botany 36 (1969): 1–30.

Smith PM (1980) *Bromus* L. In: Tutin TG, Heywood VH, Burgues NA, Moore DM, Walter SM, Webb DA (Eds) Flora Europaea Vol. 5. Alismataceae to Orchidaceae (Monocotyledones). Cambridge University Press. Cambridge, 182–189.

Smith PM (1981) Ecotypes and subspecies in annual brome-grasses (*Bromus*, Gramineae). Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 102(1/4): 497–509.

Smith PM, Sales F (1993) *Bromus* L. sect. *Bromus*: Taxonomy and relationship of some species with small spikelets. Edinburgh Journal of Botany 50(2): 149–171. https://doi.org/10.1017/S0960428600002535

Stebbins GL (1981) Chromosomes and evolution in the genus *Bromus* (Graminae). Botanische Jahrbücher für Systematik 102(1–4): 359–379.

Thiers B (2018) [continuously updated] Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/ [Accessed 9 February 2017]

Turland NJ, Wiersema JH, Barrie FR, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Kusber WH, Li DZ, Marhold K, May TW, McNeill J, Monro AM, Prado J, Price MJ, Smith GF (Eds) (2018) International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. Regnum Vegetabile 159. Koeltz Botanical Books, Glashütten. https://doi.org/10.12705/Code.2018

Tzvelev NN (1976) Grasses of the Soviet Union. Vol.1, Leningrad, Nanka. [English translation 1983, New Delhi, Oxonion Press, 298–343]

Valdés B, Scholz H (2006) The Euro+Med treatment of Gramineae – A generic synopsis and some new names. Willdenowia 36(2): 657–669. https://doi.org/10.3372/wi.36.36202

Valdés B, Scholz H (2009) with contributions from Raab-Straube E von, Parolly G, Poaceae (pro parte majore). Euro+Med Plantbase – the information resource for Euro-Mediterranean plant diversity. http://www.emplantbase.org/home.html [Accesed July 2018]

PhytoKeys 121: 13–28 (2019)
doi: 10.3897/phytokeys.121.33927
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

A new striking and critically endangered species of *Nasa* (Loasaceae, Cornales) from North Peru

Tilo Henning[1], Rafael Acuña Castillo[2,3], Eric Frank Rodríguez Rodríguez[4], Luis Felipe García Llatas[5], Maximilian Weigend[2]

1 *Freie Universität Berlin, Botanischer Garten Botanisches Museum, Königin-Luise Str. 6-8, 14195 Berlin, Germany* **2** *Nees Institut für Biodiversität der Pflanzen, Rheinische Friedrich-Wilhelms-Universität Bonn, Meckenheimer Allee 170, 53115, Bonn, Germany* **3** *Universidad de Costa Rica, Escuela de Biología, Apdo. Postal: 11501-2060 San Pedro de Montes de Oca, Costa Rica* **4** *Herbarium Truxillense (HUT), Universidad Nacional de Trujillo, Jr. San Martín 392, Trujillo, Perú* **5** *Servicio Nacional de Áreas Naturales Protegidas por el Estado (SERNANP), Calle Diecisiete 355, San Isidro-Lima, Perú*

Corresponding author: *Tilo Henning* (HenningTilo@web.de)

Academic editor: *Y. Mutafchiev* | Received 18 February 2019 | Accepted 27 February 2019 | Published 24 April 2019

Citation: Henning T, Acuña Castillo R, Rodríguez Rodríguez EF, García Llatas LF, Weigend M (2019) A new striking and critically endangered species of *Nasa* (Loasaceae, Cornales) from North Peru. PhytoKeys 121: 13–28. https://doi.org/10.3897/phytokeys.121.33927

Abstract

Nasa angeldiazioides **sp. nov.** is described and illustrated. The species is restricted to two forest remnants on the western slope of the northern Peruvian Andes (Dept. Lambayeque) where it is found in the undergrowth of primary forest. The new taxon shows a unique leaf morphology in the family Loasaceae. Molecular and morphological data show that the new species belongs to the *Nasa triphylla* group. Since the relic forests of the north-western Andes are increasingly threatened by the effects of climate change, i.e. droughts and wildfires, the new species already faces imminent extinction.

Resumen

Se describe e ilustra la especie inédita *Nasa angeldiazioides* **sp. nov.** Esta especie está restringida a dos remanentes de bosque de la vertiente occidental de los Andes del norte del Perú (Depto. Lambayeque), donde se la encuentra en el sotobosque de bosques primarios. *Nasa angeldiazioides* muestra una morfología foliar única en la familia Loasaceae. Tanto la evidencia morfológica como la molecular muestran que esta nueva especie pertenece al grupo de *Nasa triphylla*. Dado que los bosques relictos de los Andes noroccidentales del Perú se encuentran cada vez más amenazados por los efectos del cambio climático, como lo son las sequías e incendios forestales más frecuentes, esta nueva especie podría estar enfrentando una extinción inminente.

Keywords
Loasaceae, Peru, Laquipampa, *Nasa*, Lambayeque, Amotape-Huancabamba-Zone, narrow-endemic, Chiñama, *Angeldiazia*, new species

Introduction

Loasaceae Juss. and its largest genus *Nasa* Weigend (97 spp.) constitute a prime example for the challenges botany faces today when trying to assess Andean phytodiversity. *Nasa* has been recognised as the most speciose genus in the family since its segregation from *Loasa* Adans. (Weigend 1997, 2006; Weigend et al. 2006a) and as the result of ongoing taxonomic and systematic research based on numerous field collections and the study of extensive herbarium material. Almost two thirds of the species and numerous subspecies were described during the last two decades (Weigend 2000a, b, 2001, 2004; Rodríguez 2008; Henning and Weigend 2011; Henning et al. 2011). The increasingly longer intervals between new discoveries suggest that the majority of suitable habitats have been sampled and that the alpha-taxonomy may be approaching completion. However, this taxonomic research, fundamental for every conservation effort, has become a race against time in recent years. Unfortunately, botanical sampling, as the crucial basis for subsequent conservation of Andean biotopes – even if funding is available – usually follows the expanding human activities throughout most of Latin America and across all relevant altitudinal levels (Feeley and Silman 2011; Oliveira et al. 2016). Agricultural and mining activities, as well as urban sprawl, have become an immense threat, especially for the hyperdiverse mosaic landscapes and habitats within the Andes and their biota (Weigend et al. 2005, 2006b). Moreover, in recent years, the impact of climate change has been strongly affecting the region and, amongst other effects, has led to severe droughts, even in evergreen high Andean cloud forest, resulting in tremendous wildfires (Mutke et al. 2017) that destroyed numerous forest remnants, especially on the western slopes of the Andes. The relic forests in this area are home to a number of micro-endemics (Weigend et al. 2005, 2006b), many of which would be potentially extinct or critically endangered (Rodríguez and Weigend 2006). An unknown number of taxa awaits formal scientific description, as is the case in other biodiversity hotspots worldwide (Joppa et al. 2011).

The latest taxonomic additions to Loasaceae in general and *Nasa* in particular, have consequently either been discovered in remote areas that were botanically sampled only recently, often following new road cuttings (e.g. *Nasa tulipadiaboli* T.Henning & Weigend, three subspecies of *Nasa rugosa* Killip, Henning et al. 2011; *Nasa kuelapensis* Weigend, Weigend and Rodríguez 2003) or have been revealed by evaluation of herbarium material from poorly sampled localities (e.g. *Nasa pascoensis* Weigend, Weigend 2000b, *Nasa callacallensis* Weigend & E.Rodr. Weigend and Rodríguez 2002). Conversely, the taxon here described has been discovered in a relatively well known and already (at least nominally) protected area in north Peru: the Refugio de Vida Silvestre Laquipampa (D.S. N°045-2006-AG). The Pacific coast and Chiclayo, the fourth biggest city of Peru, are only 50–60 km away in a straight line (Fig. 1).

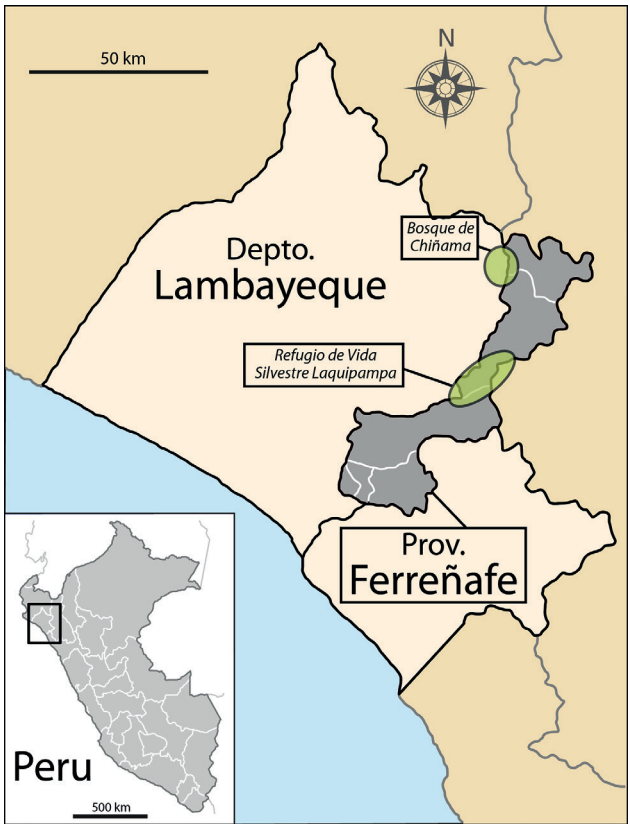

Figure 1. Map of the known localities of *Nasa angeldiazioides*.

The surprising discovery of a conspicuous macrophyte in this area, reveals that there is significant undersampling, even in readily accessible, recognised biodiversity-rich areas of northern Peru. The lack of knowledge of biodiversity may have dire consequences for its survival as recent incidents tragically demonstrate. Contrary to our expectations, governmental monitoring and protection – given the relative proximity to major cities – could not prevent a series of wildfires in several protected areas in northern Peru, as a result of poor agricultural burning practices during a drought in 2016 (Novoa and Finer 2017). The Laquipampa Wildlife Refuge suffered a major wildfire in the "La Pescadera" sector in November 2016, with a reported loss of 20 hectares of protected forest and additional 70 hectares of buffer forest (La República, Nov/18/2016). The fires mostly raged in areas covered with dry, scrub vegetation some 5.5 km away from the much more humid, shady and less seasonal habitat in which the new *Nasa* is found.

Although detailed information on the extent of the damage varies, it is clear that even areas within official conservation programmes remain virtually unprotected when it comes to drought-promoted and human-induced wildfires.

The habitat, to which the new species is endemic, lies well in the Amotape-Huancabamba Zone (AHZ) in southern Ecuador and large parts of northern Peru

(for details see: Weigend 2002, 2004). This floristic region is an important centre of biodiversity and a hotspot of endemism (Berry 1982, Ayers 1999, Weigend 2002) as repeatedly demonstrated for several plant groups (Weigend et al. 2005; Struwe et al. 2009; Deanna et al. 2018) and, in particular, for Loasaceae (Dostert and Weigend 1999; Weigend 2004; Henning and Weigend 2009a). The new taxon described here underlines the importance of this region in terms of phytodiversity and showcases the exceptional morphological divergence even between closely allied taxa in this region.

The traditional subdivision of *Nasa* into four Series (*Alatae*, *Carunculatae*, *Grandiflorae* and *Saccatae* – Urban and Gilg 1900) remains useful to coarsely characterise the morphology, growth form and appearance of a species; however these divisions do not seem to agree with clades retrieved by molecular studies (Weigend et al. 2004; Weigend and Gottschling 2006). *Nasa* series *Saccatae*, to which the taxon here described would have been assigned, has turned out to be a highly unnatural group defined on the basis of plesiomorphic characters (annual to subperennial herbs with tilt revolver flowers and contrastingly coloured nectar scales with small, erect apical wings: Weigend 1997; Weigend and Gottschling 2006). Ongoing molecular work has, however, repeatedly retrieved some monophyletic clades within the polyphyletic *Saccatae*, namely the *N. stuebeliana* (Urb. & Gilg) Weigend, *N. poissoniana* (Urb. & Gilg) Weigend and *N. triphylla* (Juss.) Weigend groups (Weigend and Gottschling 2006; Acuña et al. in prep.). The latter, although recently revised using copious herbarium material (Dostert and Weigend 1999), has already been subject to a taxonomic expansion (Henning and Weigend 2009a). This is not surprising, as it is one of the most widespread clades, present from northern Peru in the south to northern Venezuela (*Nasa triphylla* subsp. *papaverifolia* (Kunth) Weigend) and Mexico (*Nasa* '*triphylla*' subsp. *rudis* (Benth.) Weigend) in the north. Most of the taxa (16 out of 22 species and subspecies) have been found in the Amotape-Huancabamba zone (Dostert and Weigend 1999; Henning and Weigend 2009a). Typically, one or two taxa of the *Nasa triphylla* species group grow in each relic forest of the western slopes of the AHZ Andes (Weigend 2002). For example, *Nasa humboldtiana* (Urb. & Gilg) Weigend subsp. *glandulifera* T.Henning & Weigend and *N. humboldtiana* subsp. *subtrifoliata* T.Henning & Weigend, were described from the opposite margins of the so-called "Bosque de Kañaris", the largest of these forest fragments, to northeast to the Refugio de Vida Silvestre Laquipampa (Henning and Weigend 2009a). *Nasa pteridophylla* Weigend & Dostert subsp. *geniculata* Weigend & Dostert and *N. humboldtiana* subsp. *obliqua* Dostert & Weigend, are endemic to the "Bosque de Monte Seco", another neighbouring relic forest, towards the southeast, in the Department Cajamarca (Dostert and Weigend 1999).

Materials and methods

Collection locality

The Refugio de Vida Silvestre Laquipampa was established in 2006 and spans an area of 8330 hectares on the western slope of the Cordillera Occidental between 500 and

2500 m a.s.l. It is located in the Department Lambayeque, Province Ferreñafe close to the border with Department Cajamarca. The reserve is mainly covered by seasonally dry tropical forest, with increasingly humid conditions towards the mountain ridges (SERNANP 2018 http://www.sernanp.gob.pe/laquipampa).

Plant material

The material studied was obtained from the collection locality and is preserved in HUT (Thiers 2018). Stereomicroscopes and light microscopes were used for its study.

Molecular methods

Total DNA was extracted from silica gel or herbarium preserved material of 68 species and subspecies of Cornales, using the CTAB method (Doyle and Doyle 1987). We analysed sequences from four plastid regions: *trn*L–*trn*F, *mat*K, the *trn*S–*trn*G intergenic spacers and the *rps*16 intron. These have proved to be informative to infer the phylogenetic relationships in Loasoideae (Weigend et al. 2004; Hufford et al. 2005; Weigend and Gottschling 2006; Acuña et al. 2017). Sequences were newly generated for this study or for previously published research by our working group (Acuña et al. 2017, 2018; Henning et al. 2018). These were combined in a single matrix with 4 partitions. There is full overlap for the markers except *mat*K, that was not amplified for *Nasa formosissima* Weigend and *Cevallia sinuata* Lag. The partial *mat*K sequence of the latter was obtained from GenBank. (Hufford et al. 2005). Outgroups were selected based on Xiang et al. (2011) and APGIV (2016). The species *Cornus peruviana* J.F.Macbr., *Fendlera rupicola* Engelm. & A.Gray, *Hydrangea oerstedii* Briq. and *Nyssa talamancana* Hammel & N.Zamora were selected as distantly related outgroups. The respective GenBank accession numbers for all sequences are shown in the Suppl. material 1. Amplification, sequencing and alignment protocols followed Acuña et al. (2017).

Phylogenetic reconstructions were carried out, employing Maximum Likelihood (ML) in RAxML v. 8.1.X (Stamatakis 2014), included in RAxMLGUI v. 1.5b1 (Silvestro and Michalak 2012) and Bayesian Inference (BI) in MrBayes 3.2.6 (Huelsenbeck and Ronquist 2001) in the CIPRES Science Gateway (Miller et al. 2010). Based on the Akaike information criterion, FindModel (source: http://hcv.lanl.gov/content/sequence/findmodel/findmodel.html), which implements Posada and Crandall's (2001) Modeltest, selected GTR+Γ as the substitution model that fits the nucleotide dataset. Following Xiang et al. (2011), *Cornus peruviana* was chosen to root the trees. The statistical support for the nodes was assessed by 1000 ML thorough bootstrap replicates in 100 runs. The BI analyses were conducted in four independent runs with one cold and three heated chains; the Markov chain had a length of 10 million generations, sampled every 1000 generations. After convergence was assessed in Tracer 1.5 (Rambaut and Drummond 2014), the first 2.5 million generations were discarded as burn-in.

Results

Taxonomic treatment

Nasa angeldiazioides **T.Henning, R.H.Acuña, E.Rodr., L.García-Llatas & Weigend, sp. nov.**
urn:lsid:ipni.org:names:60478524-2
Figs 2A–E, 3

Type. Peru: Dept. Lambayeque, Provincia Ferreñafe, Distrito Incahuasi, "Refugio de Vida Silvestre Laquipampa", ruta Piedra Parada, April 2015, *L. F. García Llatas 333* (Holotype: HUT, Isotypes: HUT)

Diagnosis. *Nasa angeldiazioides* is similar to *N. bicornuta*, *N. pteridophylla* and *N. urens* but differs in having strongly amplexicaul leaves, sessile to amplexicaul prophylls on the pedicels and flowers with white petals and dark red nectar scales. The unique interrupted bipinnatisect leaves with rounded leaflet apices distinguish *N. angeldiazioides* from all other taxa of *Nasa* and Loasaceae as a whole.

Description. Annual herb 30–50 (–110) cm tall. Stem subterete to weakly grooved, 3–9 mm thick at base, pale green with dispersed darker green streaks and dots and whitish protuberances; set with scattered yellowish setae 1–1.5 mm long and covered with medifixed t-shaped hairs, 0.1–0.3 mm. Adventitious roots present in the L-shaped stem base. Leaves alternate, petiolate below (petiole to 10–15 mm), amplexicaul above sometimes with decurrent base, sessile in between; glabrescent; lamina oblong to widely rhomboidal in outline, (80-) 150–280 (-310) mm long and (25-) 60–220 (-280) mm wide (the petiolate leaves smaller than the sessile ones), pinnate at the base and apex, bipinnatisect in the central part, dissected nearly to midvein, central pinnae subpinnatisect, lobules narrowly-oblong; apex acuminate; abaxial surface covered with short, prostrate, yellowish glochidiate hairs, 0.05–0.1 mm and scabrid hairs 0.2–0.3(-0.5) mm along the veins; adaxial surface covered with few scabrid hairs 0.2–0.3 mm long (never on the veins), venation pinnate. Inflorescences of 2–5 terminal or axillary monochasial branches each 10–20 cm long, with (3-) 5–10 (-15) pendent flowers per branch. Flowers borne opposite to an amplexicaul upper leaf, bracts sometimes recaulescent, simple, ovate, margin dentate, sessile, (10-) 15–30 (-33) long and (6-) 10–17 (-25) mm wide, pedicel often provided with a single, ovate, sessile to amplexicaul prophyll, (15-) 20–25 mm long and 12–15 mm wide. Flowers pentamerous, pedicels 30–50 mm, green at the upper half, basally brownish, appearing dessicated, calyx covered densely with scabrid hairs (0.5–0.7 mm) and sparse glochidiate hairs (0.1–0.2 mm), tube conical, 4 × 3 mm, calyx lobes ovate acuminate, 7 × 4 mm, densely covered with scabrid hairs on back. Petals spreading to slightly reflexed, white, deeply cymbiform, cucullate, 15–23 mm long, 5 mm wide and 9–10 mm deep, base green, unguiculate and abruptly widened into two small triangular teeth 2 mm from base, these bent towards the centre of the petal, almost touching each other and leaving only a narrow gap for the stamens, adaxial

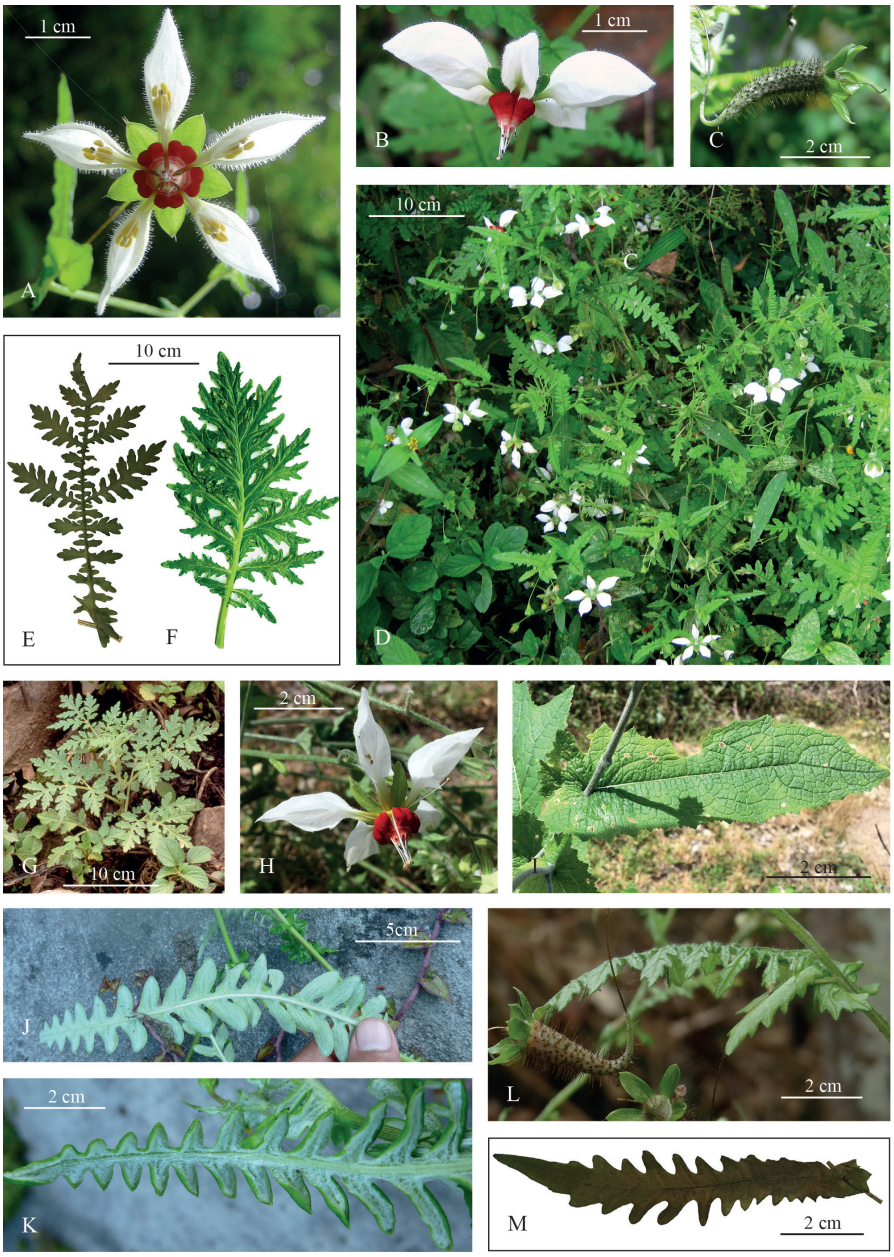

Figure 2. Morphology of *Nasa angeldiazioides* (**A–E, L, M**) and similar taxa (**F–K**). **A** Flower, frontal view **B** Flower, lateral view **C** Capsule, lateral view, note the thin, curved pedicel **D** General habit of several flowering plants in their natural habitat, Bosque de Chiñama **E** Mature basal leaf **F** Mature leaf of *Nasa urens* **G** Young plant of *N. pteridophylla* **H** Flower of *Nasa formosissima*, lateral view **I** Amplexicaul bract of *N. formosissima* **J, K** Leaves of *Angeldiazia weigendii*, abaxial surface, note the overall shape and the ampexicaul leafbase visible in the background **L** Bract, prophyll and capsules of *Nasa angeldiazioides* **M** Lowermost bract of *N. angeldiazioides*, outlined from a specimen photograph. (Credits: photographs **A, B, D** B. Esquerre-Ibañez **J, K** Mario Zapata).

Figure 3. *Nasa angeldiazioides*. **A** Flowering shoot **B** Mature leaf **C** Flower **D** Petal **E** Calyx lobe **F** Nectar scale, abaxial view **G** Staminode, lateral view **H** Capsule, lateral view. Drawing prepared by L. García (**D–H**), T. Henning (**A, B**) and R. Acuña (**C**).

surface set with scattered scabrid (0.2–0.3 mm) and uniseriate short glandular (3–7 cells) (0.3–0.7 mm) hairs; abaxial surface set with scattered glochidiate (0.1–0.2 mm) and uniseriate short glandular (3–7 cells) (0.3–0.7 mm) hairs. Nectar scales dark red at the base (sacs), white towards the neck and wings, with triangular back, much nar-

rowed above, 7–8 × 4 mm, base incurved, back with two conspicuous, globose nectar sacs about 2 mm in diameter, scale back with 4–5 transversal calli, neck thickened and slightly recurved, laterally protracted into two small erect wings 1 mm long and 0.5 mm wide. Staminodia 9–10 mm long, base slightly dilate, filiform above, papillose, yellowish. Stamens in epipetalous fascicles of 12–15 each, filaments 8–10 mm, white, anthers 0.3 mm long and wide, yellow. Ovary inferior, with three parietal placentae and numerous ovules. Fruit a capsule, horizontal to semi-erect due to the sigmoid pedicel that elongates postflorally, capsule narrowly clavate, slightly curved, purplish, opening with 3 apical valves.

Discussion

Affinities

Nasa angeldiazioides adds even more morphological diversity to highly diverse *Nasa*. In previous taxonomic works (Weigend et al. 1998; Weigend 2004; Henning and Weigend 2009b, 2011; Henning et al. 2011), the enormous variability in almost all aspects of plant morphology found in this genus has been demonstrated. *Nasa* has evolved an incredible range of characteristics in concert with habitat-exploitation and pollinator recruitment, including different life history, growth form, leaf shape, indumentum, inflorescence morphology and floral architecture characters. As a result, major clades within *Nasa* have few or no evident morphological apomorphies, but are rather defined by unique combinations of characters that individually can also occur in other, distantly related taxa. The assignment of species to one of these groups is usually possible, based on morphological traits, especially regarding growth form, phyllotaxis, leaf blade division and details of flower morphology. The species described here, however, presents some challenges in this regard and an allocation to a major clade would have been tentative without molecular evidence.

Nasa angeldiazioides shares the presence of amplexicaul bracts, with several species of the *Nasa stuebeliana* group (e.g. *N. formosissima* Fig. 2H, I, Weigend and Rodríguez 2003), but also with individual taxa of other clades. The white petals in combination with dark red nectar scales (Fig. 2A, B) are found in a range of "Saccatae" species, sometimes in combination with a narrowed neck and several transversal calli, e.g. in *Nasa picta*, a taxonomically isolated but geographically widespread species in northern Peru, sister to the compound leaved *Nasa venezuelensis* (Steyerm.) Weigend + *Nasa triphylla* groups (Weigend and Gottschling 2006, this study). Superficially similar deeply dissected leaves are found in *Nasa urens* (Fig. 2F), but the pattern of leaf subdivision is more similar to what is found in species of the *Nasa triphylla* group. Overall, the thin, angular pedicels (esp. in fruit (Figs 2C, 3A), clavate capsules (Figs 2C, 3H) and especially the deeply divided leaves (Figs 2E and 3B) indicate a close affinity to *Nasa pteridophylla* (Fig. 2G) and *Nasa bicornuta*. Despite the close overall similarity, the peculiar type of leaf subdivision with interrupted bipinnatisect leaves with rounded leaflet apices is unique in *Nasa* and indeed the entire Loasaceae.

Molecular placement

Plastid molecular data, clearly show that this new species belongs to the *Nasa triphylla* group and is closely related to *Nasa pteridophylla* and *N. humboldtiana* (Fig. 4). Morphological and ecological similarities also seem to confirm that these three taxa are phylogenetically very close. The new species, like *Nasa pteridophylla*, has ovate-acuminate sepals and semi-erect capsules, it is found on the Pacific slope of the Amotape Huancabamba Zone and grows in the understorey of low elevation, seasonally dry forests (Dostert and Weigend 1999). Most importantly, *Nasa pteridophylla*, *N. humboldtiana* and the new species, all have very characteristic medifixed t-shaped trichomes that are, as far as we know, virtually restricted to this small clade within *Nasa triphylla* species group (cf. Henning and Weigend 2009a).

Etymology

The epithet refers to a recently described monotypic genus of Asteraceae from the same area, *Angeldiazia weigendii* M.O.Dillon & Zapata (Dillon and Zapata 2010). The latter species has an extremely peculiar leaf morphology: deeply pinnatisect, amplexicaulous leaves with rounded leaflet apices, i.e. leaves that in the living state look extremely similar to the upper leaves and bracts of the new species here described (Figs 2J–M, 3A).

Phenology

The species was first reported by Santos Llatas Quiroz in May 2007 in the Bosque de Chiñama. Luis Felipe García Llatas collected the species in the Laquipampa Wildlife Refuge in March 2013 in sterile condition (specimen not deposited in a herbarium) and then in April 2015 with flowers and fruits (type collection deposited in HUT). An additional sighting from the Bosque de Chiñama by Boris Esquerre-Ibañez reported full flowering plants in June 2014 (B. Esquerre-Ibañez photographic evidence, no specimen).

The life-cycle of this taxon is strongly linked to the precipitation seasonality and its corresponding inter-annual variation. Annual plant development is mostly affected by the amount of precipitation during the growing season in February and March. Flowering time coincides with other annual taxa of the group in that area, which is typically starting with the end of the rainy- and beginning of the dry season. The length of the flowering period in turn is proportional to the intensity of summer rains during the dry season and can last between some weeks to up to three months depending on overall humidity. Accordingly, fruiting plants can be found from May onwards.

Distribution and ecology

So far, this species is known only from Laquipampa and the neighbouring Bosque de Chiñama (Fig. 1), another, smaller forest fragment towards the northeast (B. Esquerre-

Figure 4. Maximum likelihood tree based on a plastid combined dataset (*mat*K, *rps*16, *trn*L-*trn*F, *trn*S-*trn*G). ML bootstrap support values are indicated above branches and Bayesian posterior probabilities are indicated below; only values above 50 and 0.5, respectively are shown. *Nasa angeldiazioides* is marked by a grey rectangle.

Ibañez, pers obsv.). All known specimens are from the type locality in the Refugio de Vida Silvestre Laquipampa (Figs 2C, L), the population from the Bosque de Chiñama is so far only documented photographically (Figs 2A, B, D). The taxon inhabits forest edges and clearings of seasonally dry forests from 1500–2000 m elevation. It can be found in shady areas, on rocky, but humus rich soils. The species may tolerate some degradation of its habitat in areas of secondary forest or roadsides, but so far has only been collected in primary forest.

The associated arboreal and shrubby species that allow the development of shady, humid microclimates and soils rich in decaying plant matter are the "Pasallo" (*Eriotheca ruizii* (K. Schum.) A. Robyns, Malvaceae) that, at the time of the collections, show fresh foliage and provide shade to many herbaceous species around, as well as *Clusia* sp. (Clusiaceae), *Bauhinia weberbaueri* Harms (Fabaceae), *Tecoma* sp. (Bignoniaceae) and "San Pedro" (*Trichocereus pachanoi* Britton & Rose, Cactaceae). The accompanying ombrophile herbaceous taxa include *Cranichis* sp. (Orchidaceae), *Callisia monandra* (Sw.) Schult. & Schult. f. (Commelinaceae), *Dioscorea* sp. (Dioscoreaceae), *Commelina* sp. (Commelinaceae) and *Oxalis* sp. (Oxalidaceae).

No pollinator observations are available for this species, but based on flower morphology, it likely falls into the group of taxa predominantly pollinated by rather specialised short-tongued bees (Weigend and Gottschling 2006; Henning et al. 2018).

Preliminary conservation status

Nasa angeldiazioides has only been reported from two relic forests in close proximity whose areas occupy less than 200 km^2. Given the relatively easy accessibility and the comparatively good knowledge of the floristic inventory of the region in general, it is rather unlikely that vast populations have been overlooked in adjacent areas. Furthermore, this taxon is found as part of the undergrowth flora of otherwise intact primary forests. Unlike closely related taxa that are frequently found in open, disturbed situations, such as roadsides or field margins (*N. pteridophylla*, *N. bicornuta*) or in the undergrowth of secondary vegetation and for example, coffee plantations (*N. humboldtiana* subspp.), *N. angeldiazioides* seems dependent on native vegetation and is incapable of thriving in habitats that are subject to change caused by human activities. Due to its very restricted known range, small populations (L. García Llatas, B. Esquerre-Ibañez, pers. obs.) and the serious environmental threats (wildfires, deforestation, agriculture) that the whole north-western slope of the Western Cordillera of Peru faces, we consider this species as Critically Endangered (CR B1a,biv), according to the IUCN threatened species assessment guidelines (IUCN 2001, 2017).

Additional specimens examined

Although reported twice from the Bosque de Chiñama, the taxon has so far only been collected in Laquipampa. Only the type collection from 2015 is deposited in the Herbario de la Universidad Nacional de Trujillo (Herbarium Truxillense, HUT).

Acknowledgements

Thanks are due to Boris Esquerre-Ibañez (Chiclayo) for sharing information and photos of the new species from the Bosque de Chiñama and Michael O. Dillon and Mario Zapata for providing photos of the leaves of *Angeldiazia weigendii*. Esteban Jiménez (USJ) and Barry Hammel (MO) provided access to valuable material or accompanied us in the field. We acknowledge support by the German Research Foundation and the Open Access Publication Fund of the Freie Universität Berlin.

References

Acuña R, Fließwasser S, Ackermann M, Henning T, Luebert F, Weigend M (2017) Phylogenetic relationships and generic re-arrangements in 'South Andean Loasas' (Loasaceae). Taxon 66(2): 365–378. https://doi.org/10.12705/662.5

Acuña R, Chinchilla IF, Weigend M (2018) An unusual disjunction in Loasaceae: Central American *Chichicaste grandis* is nested in Brazilian Aosa. Phytotaxa 365(3): 273–287. https://doi.org/10.11646/phytotaxa.365.3.5

APGIV (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society 181(1): 1–20. https://doi.org/10.1111/boj.12385

Ayers T (1999) Biogeography of *Lysipomia* (Campanulaceae), a high elevation endemic: An illustration of species richness at the Huancabamba Depression, Peru. Arnaldoa 6: 13–28.

Berry PE (1982) The systematics and evolution of *Fuchsia* sect. Fuchsia (Onagraceae). Annals of the Missouri Botanical Garden 69(1): 1–198. https://doi.org/10.2307/2398789

Deanna R, Barboza GE, Carrizo-García C (2018) Phylogenetic relationships of *Deprea*: New insights into the evolutionary history of physaloid groups. Molecular Phylogenetics and Evolution 119: 71–80. https://doi.org/10.1016/j.ympev.2017.11.001

Dillon MO, Zapata M (2010) *Angeldiazia weigendii* (Asteraceae, Senecioneae), a new genus and species from northern Peru / *Angeldiazia weigendii* (Asteraceae, Senecioneae), un género y especie nuevo del norte del Perú. Arnaldoa 17: 19–24.

Dostert N, Weigend M (1999) A synopsis of the *Nasa triphylla* complex (Loasaceae), including some new species and subspecies. Harvard Papers in Botany 4: 439–467.

Doyle JJ, Doyle JL (1987) A rapid DNA isolation procedure for small quantities of fresh leaf tissue. Phytochemical Bulletin 19: 11–15.

Feeley KJ, Silman MR (2011) Keep collecting: Accurate species distribution modelling requires more collections than previously thought. Diversity & Distributions 17(6): 1132–1140. https://doi.org/10.1111/j.1472-4642.2011.00813.x

Henning T, Weigend M (2009a) Two novel and critically endangered subspecies of *Nasa humboldtiana* (Loasaceae) from Peru. Botanische Jahrbücher 127(4): 473–488. https://doi.org/10.1127/0006-8152/2009/0127-0473

Henning T, Weigend M (2009b) Systematics of the *Nasa poissoniana* group (Loasaceae) from Andean South America. Botanical Journal of the Linnean Society 161(3): 278–301. https://doi.org/10.1111/j.1095-8339.2009.01006.x

Henning T, Weigend M (2011) Two new species of *Nasa* (Loasaceae) from Andean South America. Phytotaxa 26(1): 1–8. https://doi.org/10.11646/phytotaxa.26.1.1

Henning T, Rodríguez E, Weigend M (2011) A revision of the *Nasa ranunculifolia* group (*Nasa* ser. Grandiflorae pro parte, Loasaceae). Botanical Journal of the Linnean Society 167(1): 47–93. https://doi.org/10.1111/j.1095-8339.2011.01164.x

Henning T, Mittelbach M, Ismail SA, Acuña R, Weigend M (2018) A case of behavioural diversification in male floral function – the evolution of thigmonastic pollen presentation. Scientific Reports 8(1): 14018. https://doi.org/10.1038/s41598-018-32384-4

Huelsenbeck JP, Ronquist F (2001) MRBAYES: Bayesian inference of phylogenetic trees. Bioinformatics (Oxford, England) 17(8): 754–755. https://doi.org/10.1093/bioinformatics/17.8.754

Hufford L, McMahon MM, O'Quinn R, Poston ME (2005) A phylogenetic analysis of Loasaceae subfamily Loasoideae based on plastid DNA sequences. International Journal of Plant Sciences 166(2): 289–300. https://doi.org/10.1086/427477

IUCN (2001) IUCN Red List Categories and Criteria. Version 3.1. Prepared for the IUCN Species Survival Commission. Gland, Switzerland and Cambridge, IUCN, ii + 33 pp.

IUCN Standards and Petitions Subcommitee (2017) Guidelines for using the IUCN Red List categories and criteria. Version 13. Prepared by the Standards and Petitions Subcommitee. https://cmsdocs.s3.amazonaws.com/RedListGuidelines.pdf [Accessed: 29.01.2019]

Joppa LN, Roberts DL, Myers N, Pimm SL (2011) Biodiversity hotspots house most undiscovered plant species. Proceedings of the National Academy of Sciences of the United States of America 108(32): 13171–13176. https://doi.org/10.1073/pnas.1109389108

La República (2016) Lambayeque: Incendio forestal afecta 20 hectáreas del Refugio de Vida Silvestre Laquipampa. https://larepublica.pe/sociedad/822819-lambayeque-incendio-forestal-afecta-hectareas-del-refugio-de-vida-silvestre-laquipampa [Accessed 13.02.2019]

Miller MA, Pfeiffer W, Schwartz T (2010) Creating the CIPRES Science Gateway for inference of large phylogenetic trees. In: 2010 Gateway Computing Environments Workshop (GCE). New Orleans, LA, USA: IEEE, 1–8. https://doi.org/10.1109/GCE.2010.5676129

Mutke J, Böhnert T, Weigend M (2017) Save last cloud forests in western Andes. Nature 541(7636): 157. https://doi.org/10.1038/541157e

Novoa S, Finer M (2017) Update – Fires Degrade 11 Protected Areas in northern Peru. MAAP: 52. https://maaproject.org/2017/northern-fires-update/ [Accessed 14.12.2018]

Oliveira U, Paglia AP, Brescovit AD, deCarvalho CJB, Silva DP, Rezende DT, Leite FSF, Batista JAN, Barbosa JPPP, Stehmann JR, Ascher JS, de Vasconcelos MF, De Marco Jr M, Löwenberg-Neto P, Dias PG, Ferro VG, Santos AJ (2016) The strong influence of collection bias on biodiversity knowledge shortfalls of Brazilian terrestrial biodiversity. Diversity & Distributions 22(12): 1232–1244. https://doi.org/10.1111/ddi.12489

Posada D, Crandall KA (2001) Selecting the best-fit model of nucleotide substitution. Systematic Biology 50(4): 580–601. https://doi.org/10.1080/10635150118469

Rambaut A, Drummond AJ (2014) Tracer v.1.6. http://tree.bio.ed.ac.uk/software/tracer

Rodríguez E (2008) *Nasa weigendii* (Loasaceae: Loasoideae) una nueva especie del Perú. Arnaldoa 15: 21–29.

Rodríguez E, Weigend M (2006) Loasaceae endémicas del Peru. Revista Peruana de Biología. Número especial 13: 391–402.

Servicio Nacional de Áreas potegidas por el Estado (2018) Laquipampa. http://www.sernanp.gob.pe/laquipampa [Accessed 14.12.2018]

Silvestro D, Michalak I (2012) raxmlGUI: A graphical front-end for RAxML. Organisms, Diversity & Evolution 12(4): 335–337. https://doi.org/10.1007/s13127-011-0056-0

Stamatakis A (2014) RAxML version 8: A tool for phylogenetic analysis and post-analysis of large phylogenies. Bioinformatics (Oxford, England) 30(9): 1312–1313. https://doi.org/10.1093/bioinformatics/btu033

Struwe L, Haag S, Heiberg E, Grant JR (2009) Andean speciation and vicariance in neotropical *Macrocarpaea* (Gentianaceae-Helieae). Annals of the Missouri Botanical Garden 96(3): 450–469. https://doi.org/10.3417/2008040

Thiers B (2018, continuously updated) Index Herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/ [Accessed 14.12.2018]

Urban I, Gilg E (1900) Monographia Loasacearum. Nova Acta Academiae Caesareae Leopoldino-Carolinae Germanicae Naturae Curiosorum 76: 1–368.

Weigend M (1997) *Nasa* and the conquest of South America: Systematic rearrangements in Loasaceae Juss. PhD Thesis, Ludwig-Maximilians Universität München, Germany.

Weigend M (2000a) Loasaceae No. 132. In: Andersson L, Harling G (Eds) Flora of Ecuador 64. Berlings Skogs AB, Trelleborg, 1–92.

Weigend M (2000b) A revision of the Peruvian species of *Nasa* ser. Alatae (Loasaceae). Nordic Journal of Botany 20(1): 15–31. https://doi.org/10.1111/j.1756-1051.2000.tb00727.x

Weigend M (2001) Loasaceae. In: Bernal R, Forero E (Eds) Flora de Colombia 22. Universidad Nacional de Colombia, Bogota, 1–100.

Weigend M (2002) Observations on the biogeography of the Amotape-Huancabamba zone in northern Peru. Botanical Review 68(1): 38–54. https://doi.org/10.1663/0006-8101(2002)068[0038:OOTBOT]2.0.CO;2

Weigend M (2004) Four new species of *Nasa* ser. Alatae (Loasaceae) in the Amotape-Huancabamba zone of Peru. Novon 14: 134–146.

Weigend M (2006) Validating subfamily, genus and species names in Loasaceae (Cornales). Taxon 55(2): 463–468. https://doi.org/10.2307/25065594

Weigend M, Gottschling M (2006) Evolution of Funnel-Revolver Flowers and Ornithophily in *Nasa* (Loasaceae). Plant Biology 8(1): 120–142. https://doi.org/10.1055/s-2005-873034

Weigend M, Rodríguez E (2002) Las especies arbustivas de *Nasa* ser. Grandiflorae en el Norte de Peru, con la descripción de una especie nueva de la Abra del Barro Negro (Callacalla), Dpto. Amazonas. Arnaldoa 9: 7–20.

Weigend M, Rodríguez E (2003) A revision of the *Nasa stuebeliana* group [*Nasa* ser. Saccatae (Urb. & Gilg) Weigend, Loasaceae] with notes on morphology, ecology and distribution. Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 124(4): 345–382. https://doi.org/10.1127/0006-8152/2003/0124-0345

Weigend M, Rodríguez E, Dostert N (1998) *Nasa insignis* y *Nasa glangulosissima* (Loasaceae: Loasoideae), dos nuevas especies con hojas peltadas del norte de Perú. Arnaldoa 5: 151–157.

Weigend M, Gottschling M, Hoot S, Ackermann M (2004) A preliminary phylogeny of Loasaceae subfam. Loasoideae (Angiospermae: Cornales) based on trnL (UAA) sequence

data, with consequences for systematics and historical biogeography. Organisms, Diversity & Evolution 4(1–2): 73–90. https://doi.org/10.1016/j.ode.2003.12.001

Weigend M, Rodríguez E, Arana C (2005) The relict forests of northwest Peru and southwest Ecuador. Revista Peruana de Biología 12: 185–194.

Weigend M, Dostert N, Henning T, Schneider C, Rodríguez E (2006a) Validating Valid publication for 101 species and subspecies names of the genera *Nasa* and *Aosa* (Loasaceae: Cornales). Revista Peruana de Biología 13: 71–84. https://doi.org/10.15381/rpb.v13i1.1766

Weigend M, Dostert N, Rodríguez E (2006b) Bosques relictos de loa Andes peruanos: Perspectivas económicas. In: Moraes M, Øllgaard B, Kvist LP, Borchsenius F, Balslev H (Eds) Botánica Económica de los Andes Centrales. La Paz, Universidad Mayor de San Andrés, 130–145.

Xiang QY, Thomas DT, Xiang QP (2011) Resolving and dating the phylogeny of Cornales – Effects of taxon sampling, data partitions, and fossil calibrations. Molecular Phylogenetics and Evolution 59: 123–138. https://doi.org/10.1016/j.ympev.2011.01.016

Supplementary material 1

List of taxa sampled for the molecular analyses with their respective voucher specimen (herbarium acronyms in parentheses), geographic origins and GenBank accession numbers

Authors: Tilo Henning, Rafael Acuña Castillo, Eric Frank Rodríguez Rodríguez, Luis Felipe García Llatas, Maximilian Weigend

Data type: molecular data

Link: https://doi.org/10.3897/phytokeys.121.33927.suppl1

PhytoKeys 121: 29–41 (2019)
doi: 10.3897/phytokeys.121.33573
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Asclepias speciosa (Apocynaceae, Asclepiadoideae): a rare or unrecognized alien species in Europe?

Zigmantas Gudžinskas[1], Lukas Petrulaitis[1], Egidijus Žalneravičius[1]

1 *Nature Research Centre, Institute of Botany, Žaliųjų Ežerų Str. 49, Vilnius LT-08364, Lithuania*

Corresponding author: *Zigmantas Gudžinskas* (zigmantas.gudzinskas@gamtc.lt)

Academic editor: *Peter Bruyns* | Received 1 February 2019 | Accepted 3 April 2019 | Published 24 April 2019

Citation: Gudžinskas Z, Petrulaitis L, Žalneravičius E (2019) *Asclepias speciosa* (Apocynaceae, Asclepiadoideae): a rare or unrecognized alien species in Europe? PhytoKeys 121: 29–41. https://doi.org/10.3897/phytokeys.121.33573

Abstract

Studies on populations of *Asclepias syriaca* L. in Lithuania revealed the occurrence of a new alien plant species, the North American native *Asclepias speciosa* Torr. (Apocynaceae, Asclepiadoideae), in southern parts of Lithuania – the first report of the latter species in Europe. Interestingly, a thorough analysis of herbarium specimens revealed that *A. speciosa* had first been collected in Lithuania in 1962, but the specimen was misidentified at the time as *A. syriaca*. The newly discovered population of *A. speciosa* occupies mesic grasslands, tall-herb fringe communities and arable field habitats. Sexual reproduction of this species was not recorded; it spreads locally by means of vegetative reproduction. We present here an exhaustive analysis of morphological characteristics and differences between *A. speciosa* and *A. syriaca* and other species of the genus, as well as a key for identification of alien *Asclepias* species in Europe. We predict that the effect of *A. speciosa* on native habitats and communities, and its economic impact, are comparable to those of the highly invasive *A. syriaca*. Although *A. speciosa* currently occurs very rarely as an alien species in Europe, its existence in other regions of Europe is highly probable.

Keywords

alien species, ecology, identification, invasiveness, morphology, naturalization, reproduction

Introduction

The genus *Asclepias* L. s. str. (Apocynaceae, Asclepiadoideae) includes about 120 species native to the Western Hemisphere. Most of the species are distributed in North America and the Caribbean, ten species occur in South America (Woodson 1954; Wilbur

1976; Endress and Bruyns 2000; Agrawal et al. 2009). However, if a broad concept of the genus *Asclepias* is accepted, it would include ca. 400 species distributed in Africa, West Asia, North and South America (Goyder 2009; Chuba et al. 2017). Several species of the genus *Asclepias* have been registered as aliens in other continents, and some of them are invasive (Ping-Tao et al. 1995; Randall 2007; Botta-Dukát 2008).

In Europe, three alien species of the genus *Asclepias* s. str. had been reported so far: *Asclepias curassavica* L., *Asclepias incarnata* L., and *Asclepias syriaca* L. (Arianoutsou et al. 2010; Pyšek et al. 2017). Another two species, *Asclepias fruticosa* L. and *Asclepias physocarpa* (E.Mey.) Schltr., have also been reported as alien naturalized species in several countries of southern Europe (Greuter and Raus 2000; Knees 2000; Arianoutsou et al. 2010; Haeger et al. 2011); however, these species of African and West Asian origin are frequently considered as members of the genus *Gomphocarpus* R.Br. (*Gomphocarpus fruticosus* (L.) W.T.Aiton and *Gomphocarpus physocarpus* E.Mey., respectively) (Goyder and Nicholas 2001; Fishbein et al. 2011). About a dozen *Asclepias* species are cultivated as ornamentals in Europe (Knees 2000). The most widespread and invasive species in some South and Central European countries is *A. syriaca* (Botta-Dukát 2008; Konstantinović et al. 2008; Medvecká et al. 2012; Kelemen et al. 2016; Pergl et al. 2016), whereas *A. curassavica* and *A. incarnata* have been recorded as casuals or locally naturalized aliens in various regions of Europe (Verloove 2006; DAISIE 2009; Arianoutsou et al. 2010). Because of invasiveness and significant negative impact on native habitats, as by the provisions of the Regulation of the European Parliament, EU 1143/2014, and of the Council of 22 October 2014 on Invasive Alien Species, *A. syriaca* was included in the list of alien species of European Union concern (EU 2016/1142, EU 2017/1263).

In an attempt to implement the requirements of Regulation EU 1143/2014, we set out with an extensive study of the distribution, habitats, population structure, and impact of *A. syriaca* on native plant communities in Lithuania, because available information on this species was only fragmentary. Over several decades, *A. syriaca* had been reported to occur at several localities in southern Lithuania, and it has been recognized as a naturalized species (Gudžinskas 1998; Gudžinskas et al. 2018). Revisiting and evaluating the current status of populations at all localities recorded in the literature, in herbaria and other archival sources, was among the aims of this study. On a visit to one of the previously reported localities in the district of Alytus (South Lithuania), we noticed significant morphological differences in the plants compared to *A. syriaca* at other sites in Lithuania. Although herbarium specimens from this locality had been identified as *A. syriaca*, further studies showed that this population represented another species of this genus, *Asclepias speciosa* Torr. Analysis of checklists of alien species and floristic lists of many European countries (Essl and Rabitsch 2002; Verloove 2006; DAISIE 2009; Arianoutsou et al. 2010; Gederaas et al. 2012; Medvecká et al. 2012; Pyšek et al. 2012; NOBANIS 2018) revealed that *A. speciosa* had neither been reported as naturalized nor as a casual alien species.

The aim of this study was to identify reliable morphological characters for distinguishing *A. syriaca* and *A. speciosa* at the vegetative stage and during flowering, to study habitats of *A. speciosa*, and to evaluate the possibilities of its further spread and invasion.

Materials and methods

The population of *A. speciosa* was studied in the environs of the village of Liepakojai, Alytus district, South Lithuania (54°28.51'N, 23°40.86'E). Research on morphological characteristics, flowering, and habitats was performed on 26–28 June and 20 September 2018. For comparison of morphological features, we selected a population of *A. syriaca* located in a similar habitat in the village of Meškučiai, Kaišiadorys district (54°44.88'N, 24°10.09'E). In each population, we studied characters of 30 flowering shoots.

Plants for the study were selected randomly from all over the colony, with a distance of at least 2 m between sampled plants. Stems were cut at ground level with garden shears. Stem height was measured from the soil level to the apex with a precision of 1 cm, using a measuring tape. The number of leaf pairs on the stem was counted, including wilted and fallen leaves. In cases where some of the lower leaves were fallen, their number was determined by leaf scars on the stem. Leaf measurements with a precision of 0.1 cm were taken from the leaf that was situated closest to the middle of the stem. The length and width of the leaf blade, length of the petiole, and diameter of the lowermost inflorescence were measured using a ruler. The length of the leaf blade was measured from the leaf base at the junction with the petiole to its tip, whereas the width of the leaf was measured at its widest point. The number of developed inflorescences on the stem was counted. The diameters of the inflorescences were measured at their middle part and the number of flowers was counted.

We studied the herbarium specimens of *Asclepias* species stored at the Herbarium of the Institute of Botany of the Nature Research Centre (BILAS), Vilnius, Lithuania. Specimens collected during this research were also deposited at the same herbarium.

The significance of differences between the studied characters of *A. speciosa* and *A. syriaca* was tested by applying a 2-sample *t*-test. All calculations were performed using PAST 3.20 (Hammer et al. 2001).

Results

History of records

The studied herbarium specimens revealed that *A. speciosa* was first collected in Lithuania on 10 August 1962 by M. Vincevičiūtė in the Žuvintas mire (Alytus district, South Lithuania); the specimen was identified by V. Galinis as *A. syriaca* (BILAS, 92607). This record was also mentioned by Galinis (1964), with additional information that the plant had been found about 1 km from the nearest settlement, but had not been found in gardens or ornamental plantings in surrounding settlements. The current state of this population is unknown. Most probably it became extinct because of development of the mire habitat. It should be noted that the specimen collected in 1962 was found only recently among collections transferred from the Lithuanian University of Educology of Vilnius, Lithuania, to BILAS. Based on the information provided by

Galinis (1964), the record of *A. speciosa* was erroneously considered as the first record of *A. syriaca* in Lithuania (Gudžinskas 1998).

A new locality for *A. speciosa* was discovered on 24 July 1992 by M. Lapelė in the village of Liepakojai (Alytus district); however, it was also erroneously identified as *A. syriaca* (BILAS, 63179). Just a few days later, *A. speciosa* was collected by Ž. Sinkevičius (BILAS, 87421). More than a decade later, in 2004, a specimen of *A. speciosa* was collected by V. Rašomavičius (BILAS, 76363) and also identified as *A. syriaca*. Therefore, *A. speciosa* has been present in southern Lithuania in the vicinity of the Žuvintas Biosphere Reserve for at least 56 years and at its recently identified locality for at least 26 years.

Habitats and population size

Galinis (1964) reported an abundant population of *A. speciosa* (originally identified as *A. syriaca*) in the mire of Žuvintas, although the exact size of the population was not given. The label of the herbarium specimen of *A. speciosa* collected by M. Lapelė in the vicinity of the village of Liepakojai indicated that plants were abundant, but the size of the colony was not specified. The herbarium label of the specimen collected in 2004 by V. Rašomavičius noted that this species formed a colony; however, once again, the size of the stand and density of the colony were not recorded. During the present study in 2018, the area occupied by *A. speciosa* in the vicinity of the village of Liepakojai was measured. A dense stand of *A. speciosa* in a mesic meadow and at the edge of a woodland (Fig. 1) occupied an area of 230 m^2, whereas in a nearby winter wheat field it formed quite a sparse colony over an area of about 280 m^2. Thus, the total area occupied by *A. speciosa* in 2018 was ca. 510 m^2.

In the tall herb woodland fringe community (Fig. 1), coverage of *A. speciosa* in 2018 was about 60%, with the most abundant native species being *Urtica dioica*, *Aegopodium podagraria*, *Chaerophyllum aromaticum*, and *Anthriscus sylvestris*. In the mesic grassland, the coverage of *Asclepias speciosa* was slightly higher, at about 65%. The most abundant native species in the grassland community were *Geranium pratense*, *Festuca pratensis*, *Phleum pratense*, *Agrostis capillaris*, *Festuca rubra*, *Poa pratensis*, and *Medicago falcata*, though their total coverage was quite small at ca. 25%. In the field with the winter wheat crop, the coverage of *Asclepias speciosa* was about 5% (Fig. 1). Apart from *Triticum aestivum*, which covered about 60% of the field, the most abundant species were *Artemisia vulgaris*, *Chenopodium album*, *Cirsium arvense*, and *Thlaspi arvense*.

Reproduction

Asclepias speciosa flowered abundantly in June 2018 in the studied population in the village of Liepakojai; however, no developed fruits were recorded as by September 2018. Therefore, sexual reproduction was probably absent. The colony survives and expands by vegetative renewal, spreading by long rhizomes.

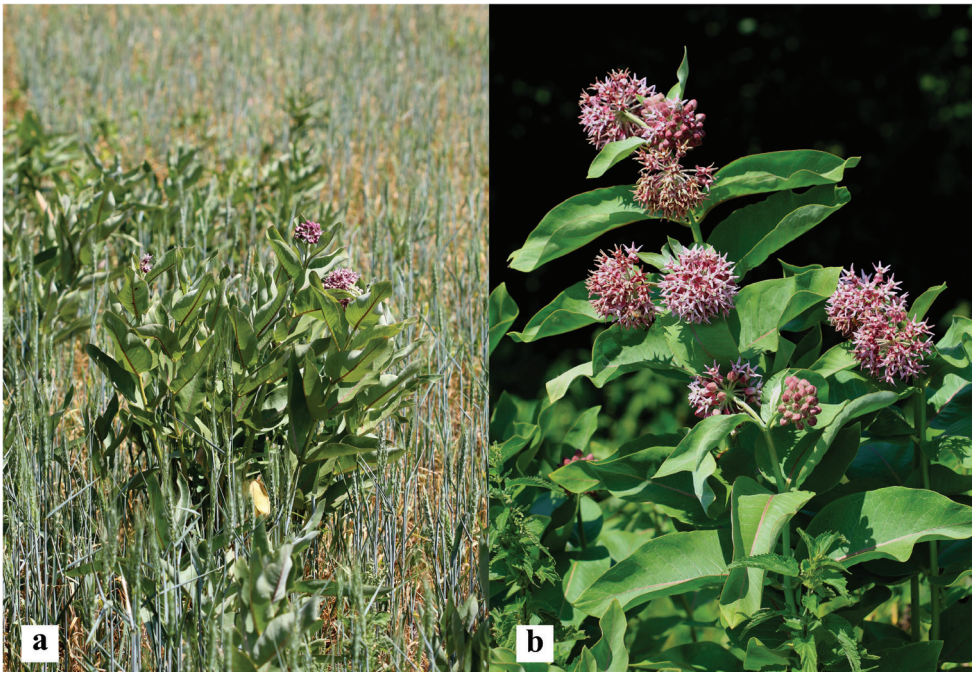

Figure 1. *Asclepias speciosa* in a field of winter wheat (**a**) and at the edge of a woodland (**b**).

Morphological characteristics and identification

Ascepias speciosa can most easily be distinguished from the closely related *A. syriaca* at the flowering stage, based on shape and size of flowers (Fig. 2). The most characteristic features of *A. speciosa* are the size and shape of the corona. Hoods of *A. speciosa* are 10–13 mm long, with a prolonged tongue-like apex, and the horns are longer and evidently curved inwards. Hoods of *A. syriaca* are 3.5–5.0 mm long, with a rounded apex, and the horns are short and only slightly bent inwards (Fig. 2). Another reliable character is the indumentum of the pedicels. The pedicels of *A. speciosa* are densely covered with short white hairs, whereas those of *A. syriaca* are glabrous or have only a few such hairs.

Both species also differ in the number of flowers in the inflorescence. Although the diameter of the inflorescence is almost the same in both species (Table 1), those of *A. speciosa* are laxer and contain almost half the number of flowers as those of *A. syriaca* (mean 36.2 ± 7.2 and 61.2 ± 19.5 flowers, respectively).

Several characteristics of the leaves are reliable for distinguishing *A. speciosa* and *A. syriaca*. The leaf blade of the middle cauline leaves of *A. speciosa* is broadly ovate or elliptical, widest at its slightly cordate base, whereas the leaf blade of *A. syriaca* is ovate or elliptical, with a rounded or slightly cuneate base, and is widest near its middle (Fig. 3). Furthermore, the leaves of *A. speciosa* are significantly longer and

Table 1. Comparison of some morphological characteristics of *Asclepias speciosa* and *Asclepias syriaca*. Mean values are presented with standard deviation and range (minimum and maximum) in parentheses. Different letters denote significant differences of *t*-test ($P < 0.001$) between the same characters.

Character	*Asclepias speciosa* Mean ± SD (range)	*Asclepias syriaca* Mean ± SD (range)
Stem height (cm)	117.6 ± 11.9 (86–134) [a]	95.7 ± 5.4 (80–105) [b]
Number of leaf pairs	10.3 ± 0.7 (9–12) [a]	11.5 ± 0.6 (11–13) [b]
Length of petiole (cm)	0.9 ± 0.2 (0.5–1.2) [a]	0.7 ± 0.2 (0.4–1.1) [b]
Length of leaf blade (cm)	17.1 ± 2.3 (10.0–21.1) [a]	14.6 ± 1.6 (11.2–18.3) [b]
Width of leaf blade (cm)	10.1 ± 1.0 (8.1–12.6) [a]	8.3 ± 0.9 (6.8–10.4) [b]
Number of inflorescences	3.4 ± 0.8 (2–5) [a]	3.4 ± 0.7 (2–5) [a]
Diameter of inflorescence (cm)	7.4 ± 0.3 (6.9–7.9) [a]	7.1 ± 0.9 (5.2–8.5) [a]
Number of flowers in inflorescence	36.2 ± 7.2 (22–57) [a]	61.2 ± 19.5 (30–108) [b]

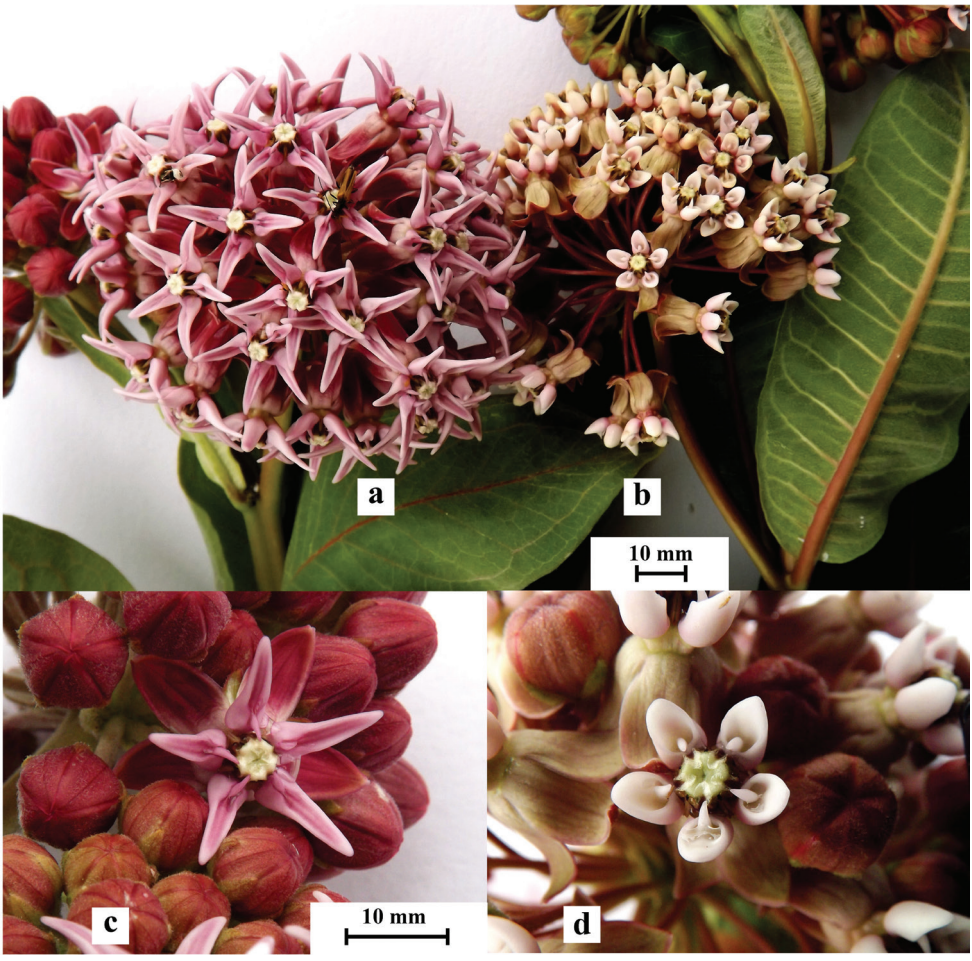

Figure 2. Inflorescences and individual flowers of *Asclepias speciosa* (**a, c**) and *Asclepias syriaca* (**b, d**).

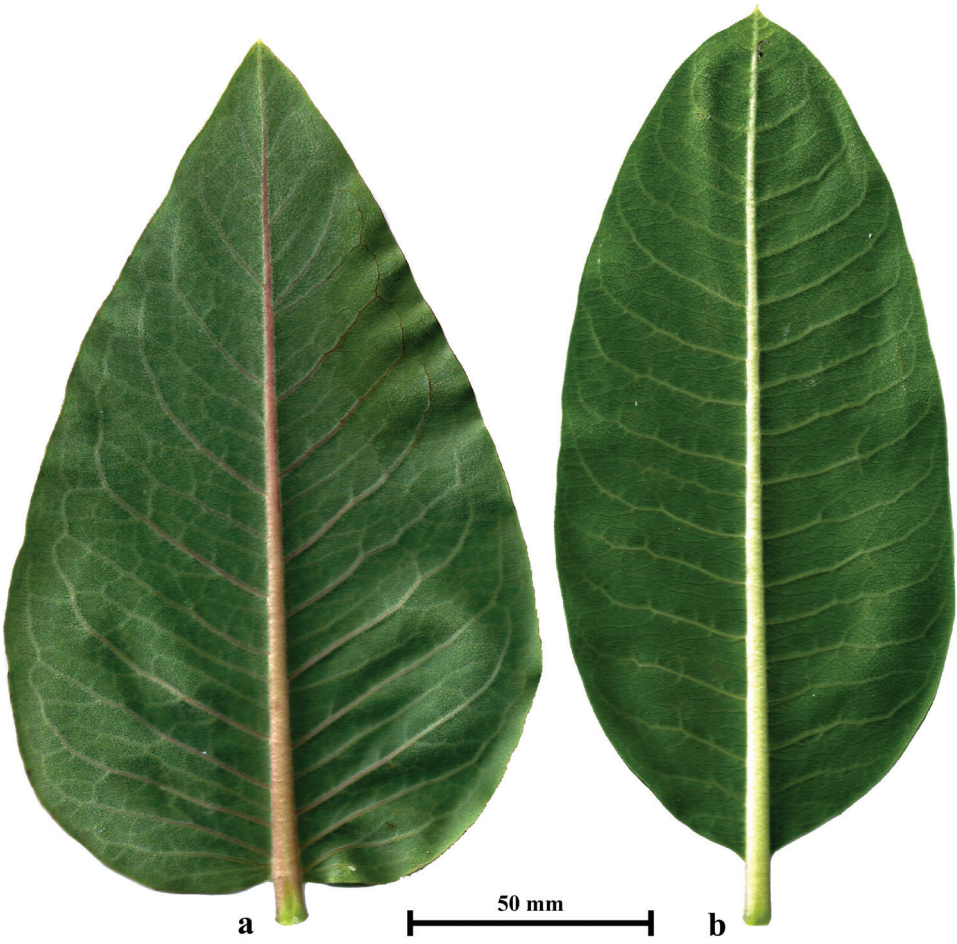

Figure 3. Middle cauline leaves of *Asclepias speciosa* (**a**) and *Asclepias syriaca* (**b**).

wider than those of *A. syriaca*, at least in the studied populations (Table 1). A quite reliable character for distinguishing these two species is leaf venation. Lateral veins in the leaf blades of middle cauline leaves of *A. speciosa* are mainly alternate and ramify from the main vein at a narrow angle, whereas those of *A. syriaca* are usually arranged oppositely and ramify at a wider angle (Fig. 3). Leaf shape and size, as well as leaf venation, can be reliable features for distinguishing the species before or after anthesis, when features of flowers cannot be employed. It should be noted that the leaves of sterile shoots (which were always present in dense stands and at the edge of colonies of both species) significantly differ in shape and size from the leaves of fertile shoots. Usually, the leaves of sterile shoots are much narrower, with more acutely pointed apices.

Although stem height, number of leaf pairs, and length of petiole were statistically different between *A. speciosa* and *A. syriaca* in the studied populations, these features are not reliable for the identification of these species.

Confusion of *A. speciosa* with *A. curassavica*, which is characterized by linear lanceolate or lanceolate leaves and an orange or red corolla and yellow or orange corona, is hardly possible. Confusion is more likely between *A. speciosa* and *A. incarnata*. However, the leaves of *A. incarnata* are narrow lanceolate or lanceolate and the stem is evidently branched. Although the colour of the corona in both species is variable and can be similar, the hoods of *A. incarnata* have a rounded apex and the horns are longer than the hood. Furthermore, *A. incarnata* is a clump-forming plant, whereas *A. speciosa* has long rhizomes and usually forms colonies.

Asclepias purpurascens L. has not been recorded as having escaped from cultivation in Europe; however, it is occasionally planted in gardens and collections. This species is quite similar to *A. speciosa*, particularly in its vegetative characters. However, the leaf base of *A. purpurascens* is abruptly cuneate, whereas that of *Asclepias speciosa* is shallowly cordate or almost rounded, and the petiole is clearly distinct from the leaf blade. *Asclepias purpurascens* usually has one terminal and 1–2 additional inflorescences in the upper leaf axils, whereas *A. speciosa* and *A. syriaca*, being more robust plants, have inflorescences in several lower axils as well. Flower characters are the most reliable for distinguishing *A. speciosa*, *A. syriaca*, and *A. purpurascens*. The hoods of *A. purpurascens* are of a similar shape to those of *A. syriaca*, though longer (5–7 mm vs. 3.5–5.0 mm). The hoods of *A. speciosa* are much longer (10–13 mm) than in both other species and differ in shape, having prolonged acute apices rather than short rounded apices.

Key for the identification of alien *Asclepias* species in Europe

1 Leaves of reproductive shoots linear lanceolate, narrow lanceolate or lanceolate **2**

– Leaves of reproductive shoots elliptic, ovate, or broadly ovate **3**

2 Stems up to 1 m tall, cymes 10–20-flowered; flower corolla red, orange or yellow, corona yellow or orange ..... ***Asclepias curassavica* L.**

– Stems 1.0–1.5 m tall, usually evidently branched; cymes 20–40-flowered, flower corolla bright purple, pink carmine, occasionally white, corona carmine or pink ..... ***Asclepias incarnata* L.**

3 Leaves of reproductive shoots broadest in basal part, with shallowly cordate or almost rounded base; flower pedicels densely white-tomentose; corolla deep purple or pink, corona pink or pinkish, hoods 10–13 mm long, with a prolonged tongue-like apex ..... ***Asclepias speciosa* Torr.**

– Leaves of reproductive shoots broadest at middle of leaf blade, with rounded base; flower pedicels glabrous or sparsely hairy, corolla green-tinged purple or pink, corona lobes pink, pinkish or purple, hoods 3.5–5.0 mm long, with rounded apex ..... ***Asclepias syriaca* L.**

Discussion

Analysis of all available information revealed that the first escape of *A. speciosa* in Lithuania was recorded in 1962 in the district of Alytus. Considering information provided on herbarium labels, this species has been recorded in two separate locations in what is now the Žuvintas Biosphere Reserve and in its vicinity, on the outskirts of the village of Liepakojai. Therefore, the currently studied colony of *A. speciosa* has existed for at least 26 years and this species can be considered as naturalized in Lithuania. Although the time of its introduction into Lithuania is unknown, we suppose that *A. speciosa* might have been introduced at the end of the 19th century or the beginning of the 20th century as an ornamental plant at the nearby Riečiai Manor Park (Mašalaitis 2015). It was later cultivated by local people in their gardens as an ornamental or to attract bees, and then likely escaped from cultivation.

Fruit set and sexual reproduction of *A. speciosa* were not recorded in this study. Therefore, it is possible that this population consists of vegetative descendants of one plant and represents a single clone. It is known that most species of the genus *Asclepias* are primarily or completely self-incompatible (Wyatt and Broyles 1994), and viable seeds are produced in the case of flower pollination from pollen of a genetically distinct individual. Self-compatible individuals are rare even in natural populations of some *Asclepias* species (Bookman 1984; Finer and Morgan 2003). Thus, absence of sexual reproduction significantly reduces the possibility of *A. speciosa* spreading and occupying new habitats. However, in North America, hybrids of *A. speciosa* and *A. syriaca* occur over a broad range in sympatric populations (Woodson 1954; Adams et al. 1987; Wyatt and Broyles 1994). Therefore, in situations where both species occur together in Europe, hybrids can possibly be produced, and these could start to spread.

In its native habitat of Washington State (USA), individual reproductive shoots of *Asclepias speciosa* produce 2–7 (mean 5) inflorescences (Finer and Morgan 2003). In the population studied in Lithuania, individual shoots produced 2–5 (mean 3.4) inflorescences. Although the number of inflorescences was lower in our studied population, the number of flowers in individual inflorescences was higher than in the native range. The number of flowers in an inflorescence in the studied population ranged from 22 to 57 (mean 36.2), whereas in Washington State the number of flowers ranges from 15 to 25 (Finer and Morgan 2003). Such differences might be influenced by climatic and ecological conditions of habitats, and may possibly represent a compensatory mechanism for lower numbers of inflorescences on each shoot. Another factor might be that the population in Lithuania is situated significantly to the north (54°28.51'N) compared to those studied by Finer and Morgan (2003) in Washington State, USA (47°25.43'N).

In its native area in North America, *A. speciosa* grows in a broad range of moisture conditions. Usually it is found in moderately wet but well-drained soil, though quite frequently it is found in riparian sites and sub-irrigated or occasionally flooded habitats. Occasionally, populations of this species can also be found in very dry sites (Stevens 2000; Young-Mathews and Eldredge 2012). Therefore, the mire habitat in which the first Lithuanian population of *A. speciosa* was found fits quite well with the range

of moisture conditions found in the native area of the species. *Asclepias speciosa* also prefers neutral or slightly acid soils (pH 5.0–7.0 range; Stevens 2000). In its native area it usually grows in open or nearly open, well-illuminated habitats, such as pastures, meadows, wetlands with sedges and rushes, forest clearings, untilled fields, roadsides, and river and ditch banks (Young-Mathews and Eldredge 2012).

The northern limit of the native distribution of *A. speciosa* in the southern part of Western Canada (British Columbia, Alberta, Saskatchewan and Manitoba) is at approximately 50°N (Woodson 1954; Agrawal et al. 2009). Therefore, the naturalized population in Lithuania is situated almost 5° north of these native areas. Considering the broad native distribution of *A. speciosa* from southern Manitoba west to British Columbia and south to Minnesota to northwestern Texas and California (Woodson 1954; Wilbur 1976; Endress and Bruyns 2000; Agrawal et al. 2009), one can presume that this species can naturalize in the southern part of the Boreal, Continental, Atlantic, Pannonian and Steppic regions and some areas of the Mediterranean biogeographic regions of Europe (Condé et al. 2008). Potential areas of naturalization and invasion probably coincide with those of *A. syriaca* (Botta-Dukát 2008; Medvecká et al. 2012; Kelemen et al. 2016; Pergl et al. 2016). Based on the diversity of habitats occupied by *A. speciosa* in Lithuania, it can likely invade a broad range of grassland habitats, some types of wetland, many anthropogenic habitats, and become a weed of arable lands, particularly in the Pannonian and Steppic biogeographical regions of Europe. The effect of this species on habitats, their biodiversity and economic impact can be considered comparable to that of *A. syriaca*. A major obstacle to the spreading of this species is the apparent absence of sexual reproduction in the studied populations in Europe. However, further observations on the fruit setting and possible sexual reproduction of the plant in Europe are required.

Conclusions

Currently, *A. speciosa* is a very rare alien species and Lithuania is the first documented country of occurrence in Europe. However, the possibility that this species already occurs in other regions of Europe cannot be excluded. It is possible that this species has been overlooked due to resemblance with the quite variable and similar *A. syriaca*, particularly when plants are examined at the vegetative stage. Therefore, botanists and ecologists should pay particular attention to species of the genus *Asclepias* in nature, as well as critically review herbarium specimens. It seems unlikely that *A. speciosa* has only been introduced into Lithuania.

Acknowledgements

We wish to thank Mr Theodor CH Cole (Freie Universität Berlin, Germany) for linguistic improvement of the manuscript.

References

Adams RP, Spencer Tomb A, Price SC (1987) Investigation of hybridization between *Asclepias speciosa* and *A. syriaca* using alkanes, fatty acids, and triterpenoids. Biochemical Systematics and Ecology 15(4): 395–399. https://doi.org/10.1016/0305-1978(87)90052-4

Agrawal AA, Fishbein M, Jetter R, Salminen J-P, Goldstein JB, Freitag AE, Sparks JP (2009) Phylogenetic ecology of leaf surface traits in the milkweeds (*Asclepias* spp.): Chemistry, ecophysiology, and insect behavior. The New Phytologist 183(3): 848–867. https://doi.org/10.1111/j.1469-8137.2009.02897.x

Arianoutsou M, Bazos I, Delipetrou P, Kokkoris Y (2010) The alien flora of Greece: Taxonomy, life traits and habitat preferences. Biological Invasions 12(10): 3525–3549. https://doi.org/10.1007/s10530-010-9749-0

Bookman SS (1984) Evidence for selective fruit production in *Asclepias.* Evolution; International Journal of Organic Evolution 38(1): 72–86. https://doi.org/10.1111/j.1558-5646.1984.tb00261.x

Botta-Dukát Z (2008) Invasion of alien species to Hungarian (semi-)natural habitats. Acta Botanica Hungarica 50(Suppl. 1): 219–227. https://doi.org/10.1556/ABot.50.2008.Suppl.11

Chuba D, Goyder D, Chase MW, Fishbein M (2017) Phylogenetics of the African *Asclepias* complex (Apocynaceae) based on three plastid DNA regions. Systematic Botany 42(1): 148–159. https://doi.org/10.1600/036364417X694539

Condé S, Richard D, Liamine N, Leclère A-S (2008) Europe's biodiversity – biogeographical regions and seas. Biogeographical regions in Europe. European Environment Agency. https://www.eea.europa.eu/publications/report_2002_0524_154909 [accessed 16.12.2018]

DAISIE (2009) Handbook of alien species in Europe. Springer, Dordrecht, 1–399.

Endress ME, Bruyns PV (2000) A revised classification of the Apocynaceae s.l. Botanical Review 66(1): 1–56. https://doi.org/10.1007/BF02857781

Essl F, Rabitsch W (2002) Neobiota in Österreich. Umweltbundesamt, Wien, 1–432. https://homepage.univie.ac.at/wolfgang.rabitsch/DP089.pdf

Finer MS, Morgan MT (2003) Effects of natural rates of geitonogamy on fruit set in *Asclepias speciosa* (Apocynaceae): Evidence favoring the plant's dilemma. American Journal of Botany 90(12): 1746–1750. https://doi.org/10.3732/ajb.90.12.1746

Fishbein M, Chuba D, Ellison C, Mason-Gamer RJ, Lynch SP (2011) Phylogenetic relationships of *Asclepias* (Apocynaceae) inferred from non-coding chloroplast DNA sequences. Systematic Botany 36(4): 1008–1023. https://doi.org/10.1600/036364411X605010

Galinis V (1964) Kai kurių retesnių Lietuvos TSR augalų naujos radimvietės. Lietuvos TSR Aukstuju Mokyklu Mokslo Darbai: Biologija 4: 97–99.

Gederaas L, Loennechen Moen T, Skjelseth S, Larsen LK (Eds) (2012) Alien species in Norway – with the Norwegian Black List 2012. The Norwegian Biodiversity Information Centre, Trondheim, 1–212.

Goyder DJ, Nicholas A (2001) A revision of *Gomphocarpus* R. Br. (Apocynaceae: Asclepiadeae). Kew Bulletin 56(4): 769–836. https://doi.org/10.2307/4119297

Goyder DJ (2009) A synopsis of *Asclepias* (Apocynaceae: Asclepiadoideae) in Tropical Africa. Kew Bulletin 64(3): 369–399. https://doi.org/10.1007/s12225-009-9133-3

Greuter W, Raus T (2000) Med-Checklist Notulae, 19. Willdenowia 30(2): 229–244. https://doi.org/10.3372/wi.30.30202

Gudžinskas Z (1998) Conspectus of alien plant species of Lithuania. 7. Apiaceae, Apocynaceae, Asclepiadaceae, Caprifoliaceae, Dipsacaceae, Oleaceae, Sambucaceae, Viburnaceae, and Valerianaceae. Botanica Lithuanica 4(3): 249–265.

Gudžinskas Z, Žalneravičius E, Petrulaitis L (2018) Assessment of the potential of introduction, establishment and further spread of invasive alien plant species of European Union concern in Lithuania. Botanica 24(1): 37–48. https://doi.org/10.2478/botlit-2018-0004

Haeger JF, Jordano D, Meléndez ML (2011) Status and conservation of *Asclepiadaceae* and *Danaus* in southern Spain. Journal of Insect Conservation 15(1–2): 361–365. https://doi.org/10.1007/s10841-010-9354-7

Hammer Ø, Harper DAT, Ryan PD (2001) PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 1–9.

Kelemen A, Valkó O, Kröel-Dulay G, Deák B, Török P, Tóth K, Miglécz T, Tóthmérész B (2016) The invasion of common milkweed (*Asclepias syriaca*) in sandy old-fields – is it a threat to the native flora? Applied Vegetation Science 19(2): 218–224. https://doi.org/10.1111/avsc.12225

Knees SG (2000) *Asclepias* Linnaeus. In: Cullen J, Alexander JCM, Brickell CD, Edmondson JR, Green PS, Heywood VH, Jørgensen P-M, Jury SL, Knees SG, Maxwell HS, Miller DM, Robson NKB, Walters SM and Yeo PF (Eds) The European Garden Flora. A Manual for the Identification of Plants Cultivated in Europe, Both Out-of-Doors and Under Glass. 6(4): 51–53. Cambridge University Press, Cambridge.

Konstantinović B, Meseldžija M, Mandić N (2008) Distribution of *Asclepias syriaca* L. on the territory of Vojvodina and possibilities of its control. Herbologia 9(2): 39–46.

Mašalaitis B (2015) Sūduvos krašto dvarai. Piko Valanda, Marijampolė, 1–336.

Medvecká J, Kliment J, Májeková J, Halada Ľ, Zaliberová M, Gojdičová E, Feráková V, Jarolímek I (2012) Inventory of the alien flora of Slovakia. Preslia 84: 257–309. http://www.preslia.cz/P122Medvecka.pdf

NOBANIS (2018) NOBANIS Database. http://www.nobanis.org [accessed 25.11.2018]

Pergl J, Sádlo J, Petrusek A, Laštůvka Z, Musil J, Perglová I, Šanda R, Šefrová H, Šíma J, Vohralík V, Pyšek P (2016) Black, Grey and Watch Lists of alien species in the Czech Republic based on environmental impacts and management strategy. NeoBiota 28: 1–37. https://doi.org/10.3897/neobiota.28.4824

Ping-Tao L, Gilbert G, Stevens WD (1995) Asclepiadaceae. In: Wu ZY, Raven PH, Hong DY (Eds) Flora of China 16. Gentianaceae through Boraginaceae. Science Press, Beijing, Missouri Botanical Garden Press, St. Louis, 189–270.

Pyšek P, Danihelka J, Sádlo J, Chrtek JJr, Chytrý M, Jarošík V, Kaplan Z, Krahulec F, Moravcová L, Pergl J, Štajerová K, Tichý L (2012) Catalogue of alien plants of the Czech Republic (2nd edition): checklist update, taxonomic diversity and invasion patterns. Preslia 84: 155–255.

Pyšek P, Pergl J, Essl F, Lenzner B, Dawson W, Kreft H, Weigelt P, Winter M, Kartesz J, Nishino M, Antonova LA, Barcelona JF, Cabezas FJ, Cárdenas D, Cárdenas-Toro J, Castaño

N, Chacón E, Chatelain C, Dullinger S, Ebel AL, Figueiredo E, Fuentes N, Genovesi P, Groom QJ, Henderson LI, Kupriyanov A, Masciadri S, Maurel N, Meerman J, Morozova O, Moser D, Nickrent D, Nowak PM, Pagad S, Patzelt A, Pelser PB, Schulze M, Seebens H, Shu W, Thomas J, Velayos M, Weber E, Wieringa JJ, Baptiste MP, van Kleunen M (2017) Naturalized alien flora of the world: Species diversity, taxonomic and phylogenetic patterns, geographic distribution and global hotspots of plant invasion. Preslia 89(3): 203–274. https://doi.org/10.23855/preslia.2017.203

Randall RP (2007) The introduced flora of Australia and its weed status. Department of Agriculture and Food, Western Australia, 1–524.

Stevens M (2000) Plant Guide for showy milkweed (*Asclepias speciosa*). USDA-Natural Resources Conservation Service, National Plant Data Center. https://plants.usda.gov/plantguide/pdf/pg_assp.pdf [accessed 10.12.2018]

Verloove F (2006) Catalogue of neophytes in Belgium (1800–2005). Scripta Botanica Belgica 39: 1–89.

Wilbur HM (1976) Life history evolution in seven milkweeds of the genus *Asclepias*. Journal of Ecology 64(1): 223–240. https://doi.org/10.2307/2258693

Woodson RE (1954) The North American species of *Asclepias* L. Annals of the Missouri Botanical Garden 41(1): 1–211. https://doi.org/10.2307/2394652

Wyatt R, Broyles SB (1994) Ecology and evolution of reproduction in milkweeds. Annual Review of Ecology and Systematics 25(1): 423–441. https://doi.org/10.1146/annurev.es.25.110194.002231

Young-Mathews A, Eldredge E (2012) Plant fact sheet for showy milkweed (*Asclepias speciosa*). USDA-Natural Resources Conservation Service, Corvallis Plant Materials Center, OR and Great Basin Plant Materials Center, Fallon, NV. https://plants.usda.gov/factsheet/pdf/fs_assp.pdf [accessed 12.12.2018]

PhytoKeys 121: 43–51 (2019)
doi: 10.3897/phytokeys.121.30570
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Ophiorrhiza shiqianensis (Rubiaceae), a new species from Guizhou, China

Lin-Dong Duan[1], Yun Lin[2], Zhen Lu[1]

1 *Shaoyang University, Shaoyang 422004, Hunan, China* **2** *Hunan Medication Vestibule School, Changsha 410208, Hunan, China*

Corresponding author: *Yu Lin* (leoliny@foxmail.com)

Academic editor: *Petra De Block* | Received 15 October 2018 | Accepted 26 March 2019 | Published 2 May 2019

Citation: Duan L-D, Lin Y, Lu Z (2019) *Ophiorrhiza shiqianensis* (Rubiaceae), a new species from Guizhou, China. PhytoKeys 121: 43–51. https://doi.org/10.3897/phytokeys.121.30570

Abstract

A new species of the genus *Ophiorrhiza* L. (Rubiaceae), *Ophiorrhiza shiqianensis* L.D.Duan & Yun Lin, is described, illustrated and photographed from Shiqian County, Guizhou Province, South-western China. This species was found growing at the side of streams in evergreen broad-leaved forests in mountains at elevations of 960–1100 m. The new species is morphologically similar to *Ophiorrhiza hunanica* H.S.Lo, but differs from the latter by the glabrous, glabrescent or pilose stems, the 5–10 cm long subterranean stem internodes, the glabrous or pilose petioles, the 3–5 mm long stipules, the purple corolla lobes, the ca. 12 mm long style and included stigmas in long-styled flowers and the 3–4 × 8–10 mm, glabrous or glabrescent capsules.

Keywords

Distyly, morphology, new taxon, taxonomy

Introduction

The Rubiaceae genus *Ophiorrhiza* L. includes more than 300 species worldwide (WCSPF 2017) and is mainly distributed in tropical and subtropical Asia, Australia, New Guinea and the Pacific Islands (Darwin 1976, Chen and Taylor 2011). In China, *Ophiorrhiza* is represented by 70 species (Chen and Taylor 2011, Deng and Huang 2012, Wu et al. 2017a, b, Yang et al. 2018) and most of them are distributed in the region south of the Yangtze River, especially in the provinces of Yunnan and Guangxi (Lo 1999).

During three botanical explorations in Shiqian County, Guizhou Province, Southwest China, specimens of *Ophiorrhiza* were collected on the banks of streams in dense evergreen broad-leaved forests in valleys at elevations of 960–1100 m. After comparison of the newly collected specimens with material available in Chinese herbaria and careful consultation of literature, they were found to be most similar to *Ophiorrhiza hunanica* H.S.Lo, but sufficiently different to qualify as a new species, hitherto not reported from any region in China. We therefore describe it as new, under the name *Ophiorrhiza shiqianensis* L. D. Duan & Yun Lin.

Materials and methods

Three field expeditions were carried out in Shiqian County, Guizhou Province, Southwest China in August 2011 and in March and May 2014 and a total of 30 mature individuals from the type locality (latitude 27°19'01.33"N, longitude 108°00'25.76"–108°00'35.76"E) were collected. All morphological measurements were performed on dried and fresh specimens. For the identification of specimens, relevant literature was used (Chen and Taylor 2011, Chen 2004, Deng and Huang 2012, Duan et al. 2014, Lin et al. 2017, Lo 1990, 1999, Wu et al. 2017a, b, Yang et al. 2018). The specimens were compared with herbarium material (about 5,000 specimens of the genus *Ophiorrhiza*) available at the herbaria CDBI, CSFI, GXMI, GZAC, GZTM, HGAS, HIB, HNNU, IBK, IBSC, IMC, KUN, LBG, NAS, PE, SZ and SYS (acronyms follow Fu 1993, Thiers continuously updated). The morphological characteristics of *Ophiorrhiza shiqianensis* were determined using a stereo-trinocular microscope (Nikon SMZ1000) integrated camera system (Nikon DXM1200F). We used NTS-Elements D3.1 (Nikon Instruments Inc.) to make measurements.

Taxonomy

***Ophiorrhiza shiqianensis* L.D.Duan & Yun Lin, sp. nov.**
urn:lsid:ipni.org:names:77196565-1
Figs 1, 2, 4A–E

Diagnosis. Similar to *Ophiorrhiza hunanica* H. S. Lo based on stems, leaves and capsules; differing from it by the stems which are glabrous, glabrescent or pilose, the 5–10 cm long subterranean stem internodes, the glabrous or pilose petioles, the 3–5 mm long stipules, the purple corolla tube and lobes, the ca. 12 mm long styles and the included stigmas in long-styled flowers, the 3–4 mm × 8–10 mm, glabrous or glabrescent capsules [vs. stems densely villose, subterranean stem internodes 1–2 cm long, petioles villose, stipules 5–15 mm long, corolla tube purple and corolla lobes white, style 15–17 mm long and stigmas exserted in long-styled flowers, capsules 5–6 mm × 10–12 mm, densely villose in *Ophiorrhiza hunanica* (Figs 3, 4F)].

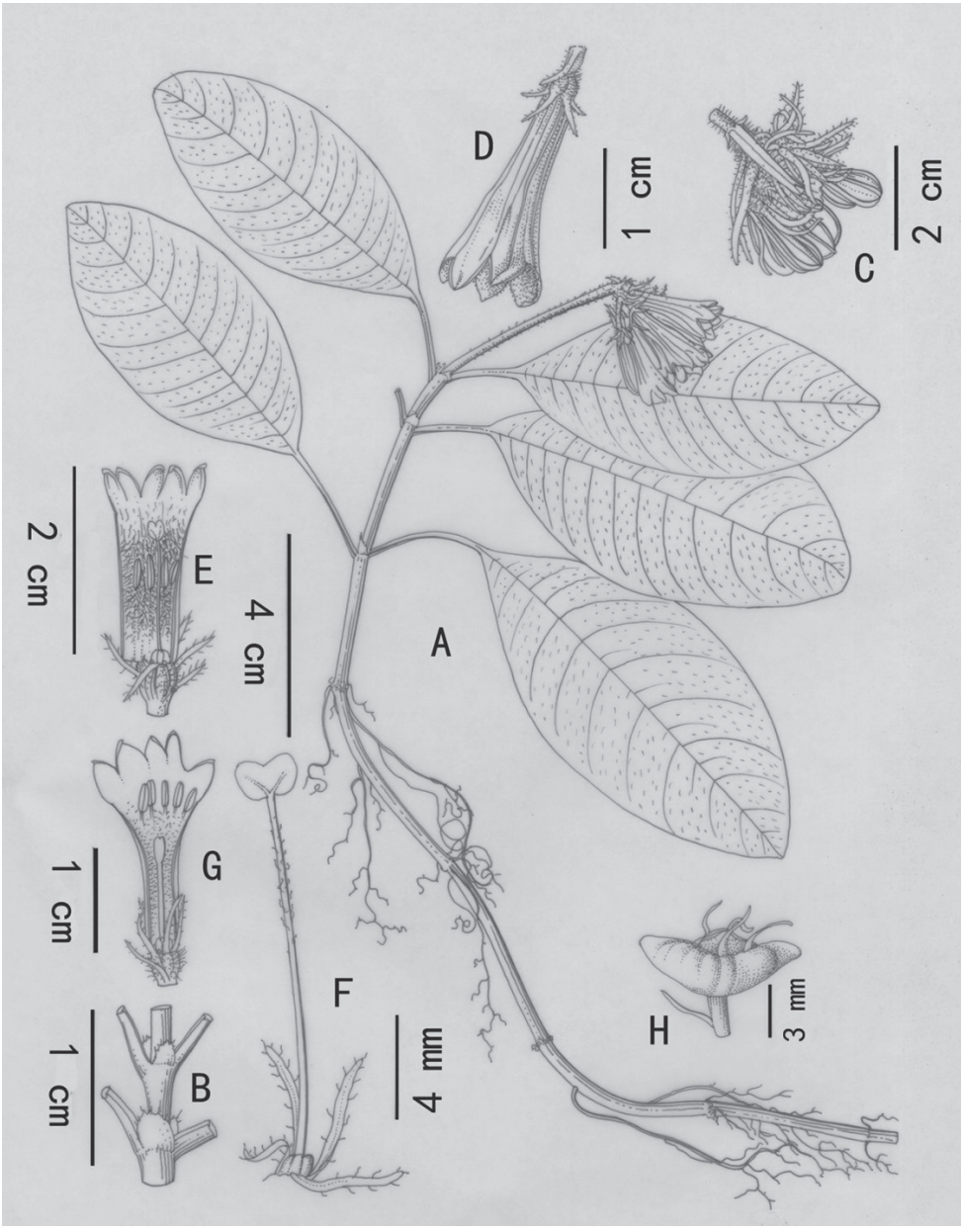

Figure 1. *Ophiorrhiza shiqianensis.* **A** habit of flowering plant **B** section of stem, showing stipules **C** inflorescence **D** flower **E** long-styled flower **F** pistil in a long-styled flower **G** short-styled flower **H** capsule **A–F** from *L.D. Duan, Z. Lu & Q. Lin 5805* **G** from *L.D. Duan, Z. Lu & Q. Lin 5808* **H** from *L.D. Duan, Z. Lu & Q. Lin 5809.*

Type. CHINA. Guizhou: Shiqian County, Pingshan Town, Fudingshan Nature Reserve, at sides of streams in dense evergreen broad-leaved forest in valley at 960 m elevation, 18 March 2014 (fl), *L.D. Duan, Z. Lu & Q. Lin 5805* (holotype: PE!, Herb. Bar. Code No. 02232812; isotypes HUFD! (=Herbarium, Hunan Food and Drug Vocational College, Hunan, China), HUSY! (=Herbarium, Shaoyang University, Hunan, China) IBSC!, K!, KUN!, PE!).

Description. Perennial herbs, 10–30 cm tall, repent at base. Stems erect, fleshy, green, brown to black after drying, glabrous, glabrescent or pilose; subterranean stems glabrous with 5–10 cm long internodes. Leaves: petioles 1.5–4.0 cm long, glabrous or pilose; blades papery after drying, elliptic or obovate-elliptic, 7–17 cm × 3–7.5 cm, adaxially pilose, abaxially pilose on veins, base cuneate, apex obtuse to subacute; secondary veins 9–11 pairs; stipules often persistent, ovate to ovate-lanceolate, 3–5 mm long, ciliate. Inflorescence cymose, terminal, 2- to 10-flowered, densely villose, pendulous; peduncle 2.5–4 cm long when flowering, 8–10 cm long when fruiting, arching, densely villose. Bracts linear-lanceolate, 9–10 mm long, ciliate; bracteoles linear, 4–5 mm long, ciliate. Flowers distylous, pedicels 1–2 mm long, densely covered with hairs. Calyx with hypanthium compressed-turbinate, 2.5–3 mm long, 5-ribbed, densely covered with hairs; lobes 5, lanceolate-linear, 5–6 mm long, ciliate. Corolla tube and lobes purple, funnel-form, outside glabrous, inside pubescent; tube 1.7–1.8 cm long; lobes 5, ovate-triangular, 4–6 mm long, apex rostrate. Stamens 5, inserted near throat and exserted at anthesis in short-styled flowers or inserted below middle of corolla tube and included at anthesis in long-styled flowers; filaments 1.5–2 mm long in short-styled or ca. 1 mm long in long-styled flowers; anthers ca. 2.5 mm long, dorsifixed. Ovary 2-celled, ovules numerous in each cell; style ca. 12 mm long in long-styled or 7–7.5 mm long in short-styled flowers; stigmas 2, linear in short-styled or subcapitate in long-styled flowers, included in both morphs. Capsules purple, mitriform, strongly laterally compressed, 3–4 mm × 8–10 mm, pilose or glabrescent. Seeds numerous.

Phenology. Plants were observed in full bloom on 18 March 2014 and with ripe fruits on 12 May 2014 and neither flowers nor fruits were seen on 12 August 2011. It can be expected that the flowering time of the new species is from March to April and that fruiting time is from April to June.

Habitat. The species grows on the banks of streams in dense broad-leaved forest in valleys at elevations of 960–1100 m.

Distribution. *Ophiorrhiza shiqianensis* is only known from two localities in Shiqian County, northeast Guizhou Province, southwest China, notably: Fudingshan Nature Reserve, Pingshan Town and Nishan Village, Ganxi Town.

Etymology. *Ophiorrhiza shiqianensis* is named after its type locality, Shiqian County, northeast Guizhou Province, southwest China.

Vernacular name. Shi qian she gen cao in Chinese Pinyin.

Preliminary conservation status. *Ophiorrhiza shiqianensis* is only known from four collections in two locations, Fudingshan Nature Reserve (well protected, 152 km^2) and Nishan Village (ca. 50 km^2). It comprises about 200 individuals (criteria D1 ≤ 250) growing in ten populations. This new species can be assessed as Endangered (EN) according to the IUCN Red List Categories and Criteria (IUCN 2001, 2012).

Figure 2. *Ophiorrhiza shiqianensis.* Isotype, showing subterranean stem internodes 5–10 cm long and inflorescences 2- to 10-flowered.

Figure 3. *Ophiorrhiza hunanica.* Neotype (designated by Duan et al. 2014), showing subterranean stem internodes 1–2 cm long and inflorescences 5- to many-flowered.

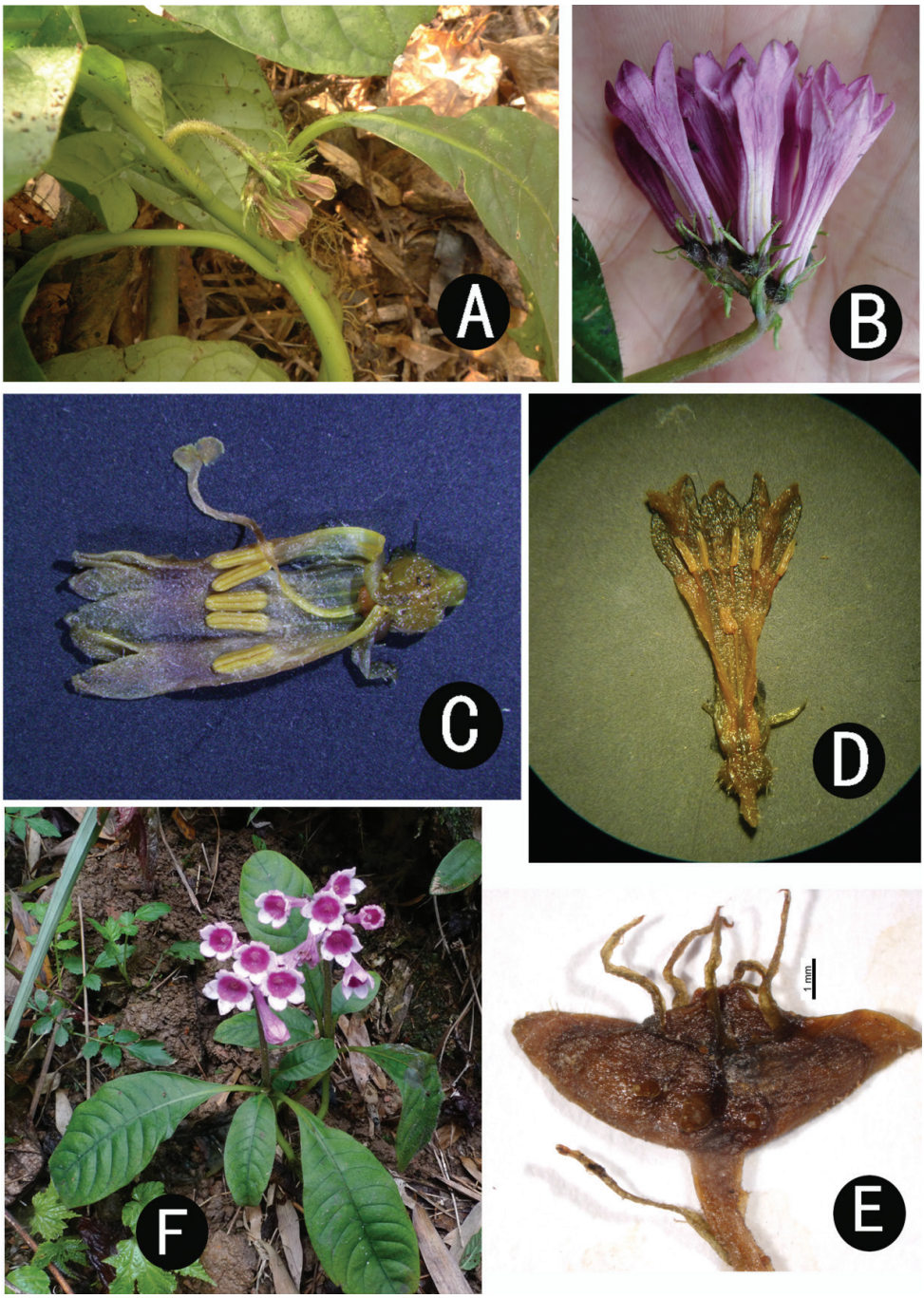

Figure 4. *Ophiorrhiza shiqianensis* (**A–E**) and *O. hunanica* (**F**). **A** Habit of flowering plant **B** Inflorescence **C** long-styled flower **D** short-styled flower **E** capsule **F** habit of flowering plant, showing white corolla lobes.

Table 1. Comparison of morphological characteristics between *Ophiorrhiza shiqianensis* and *O. hunanica.*

Characters	*O. shiqianensis*	*O. hunanica*
Plant	repent at base	procumbent or repent at base
Stem	glabrous, glabrescent or pilose; subterranean stem internodes 5–10 cm long	villose; subterranean stem internodes 1–2 cm long
Leaf	petiole 1.5–4.0 cm long, glabrous or pilose; blade 7–17 cm long; stipules 3–5 mm long	petiole 1–6 cm long, villose; blade 7–23 cm long; stipules 5–15 mm long
Flower	2- to 10-flowered; peduncle 2.5–4 cm long when flowering, 8–10 cm long when fruiting; corolla tube and lobes purple; style c. 12 mm long and stigmas included in long-styled flowers	5- to many-flowered; peduncle 3–8 cm long when flowering, 12–15 cm long when fruiting; corolla tube purple and lobes white; style 15–17 mm long and stigmas exserted in long-styled flowers
Capsule	3–4 mm × 8–10 mm, glabrous or glabrescent	5–6 mm × 10–12 mm, densely villose

However, it is possible that more populations could be found in similar habitats of mountain areas of Zhenyuan, Yuqing and Shibing Counties in northeast Guizhou. With limited fieldwork at present, we would temporarily consider this new species to be **Vulnerable (VU) based on criteria D1 and D2.**

Additional specimens of *Ophiorrhiza shiqianensis* (paratypes). CHINA. Guizhou: Shiqian County, Ganxi Town, Nishan Village, Niujinshan, stream-sides in dense evergreen broad-leaved forest in valley at 1100 m elevation, 12 August 2011 (sterile), *L. D. Duan, Z. Lu & Q. Lin 5356* (HUFD!, HUSY!, PE!); Pingshan Town, Fudingshan Nature Reserve, stream-sides in dense evergreen broad-leaved forest in valley at 960 m elevation, 18 March 2014 (fl), *L. D. Duan, Z. Lu & Q. Lin 5808* (HUFD!, HUSY!, PE!); same locality, 12 May 2014 (fr), *L. D. Duan, Z. Lu & Q. Lin 5809* (HUFD!, HUSY!, IBSC!, K!, KUN!, PE!).

Critical note. The new species most resembles *Ophiorrhiza hunanica*. Detailed morphological differences between the two species are given in Table 1.

Acknowledgements

Thanks are due to the curators of the following herbaria CDBI, CSFI, GXMI, GZAC, GZTM, HGAS, HIB, HNNU, IBK, IBSC, IMC, KUN, LBG, NAS, PE, SZ and SYS for the loan of specimens or for permission to examine specimens. We sincerely thank three reviewers for the English revision and their valuable comments on our manuscript. This work was supported by the project of the Education Department in Hunan Province (grant number 16A194) and supported by the National Specimen Information Infrastructure (grant numbers 2005DKA21400 and 2005DKA21401).

References

Chen T, Taylor CM (2011) *Ophiorrhiza* (Rubiaceae). In: Wu ZY, Raven PH (Eds) Flora of China, Vol. 19. Science Press, Beijing and Missouri Botanical Garden Press, St. Louis, 258–282.

Chen WC (2004) Rubiaceae. In: Fu LK, Hong T (Eds) Higher Plants of China, Vol. 10. Qingdao Publishing House, Qingdao, 506–683.

Darwin SP (1976) The Pacific species of *Ophiorrhiza* L. (Rubiaceae). Lyonia 1(2): 48–101.

Deng YF, Huang YF (2012) *Ophiorrhiza loana*, a new name for *Ophiorrhiza longipes* H. S. Lo (Rubiaceae). Phytotaxa 49(1): 34. https://doi.org/10.11646/phytotaxa.49.1.5

Duan LD, Lin Y, Lin Q (2014) Neotypification of *Ophiorrhiza hunanica* H. S. Lo (Rubiaceae), a species endemic to Hunan, China. Bangladesh Journal of Plant Taxonomy 21(2): 193–195. https://doi.org/10.3329/bjpt.v21i2.21360

Fu LK (1993) Index Herbariorum Sinicorum. China Science and Technology Press, Beijing, 458 pp.

IUCN (2001) IUCN Red List Categories and Criteria, Version 3.1. Prepared by the IUCN Species Survival Commission, IUCN, Gland & Switzerland and Cambridge, United Kingdom.

IUCN (2012) IUCN Red List Categories and Criteria, Version 3.1. Second edition. IUCN, Gland & Switzerland and Cambridge, United Kingdom, 1–32.

Lin Q, Yang ZR, Lin Y, Zhang XB (2017) Rubiaceae. In: Lin Q, Yang ZR, Lin Y, Zhang XB (Eds) Type Specimens in China National Herbarium (PE), Vol. 14. Henan Science and Technology Press, Zhengzhou, 251–283.

Lo HS (1990) Taxonomic revision of the Chinese species of *Ophiorrhiza* (Rubiaceae). Bulletin of Botanical Research 10(2): 1–82.

Lo HS (1999) *Ophiorrhiza* (Rubiaceae). In: Lo HS (Ed.) Flora Reipublicae Popularis Sinicae, Vol. 71(1). Science Press, Beijing, 110–174.

Thiers B (continuously updated) Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanic Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/ [accessed 2 June 2016]

WCSPF (2017) World Checklist of Selected Plant Families: Royal Botanic Gardens, Kew. http://apps.kew.org/wcsp/qsearch.do [accessed 20 Oct. 2017]

Wu L, Hareesh VS, Deng YF (2017a) Excluding *Ophiorrhiza mungos* (Rubiaceae) from Flora of China. Phytotaxa 309(2): 184–188. https://doi.org/10.11646/phytotaxa.309.2.11

Wu L, Hareesh VS, Yu YL (2017b) The taxonomic identity of *Ophiorrhiza rarior* and *O. mycetiifolia* (Rubiaceae). Phytotaxa 299(2): 261–266. https://doi.org/10.11646/phytotaxa.299.2.10

Yang CD, He XZ, Gou GQ (2018) *Ophiorrhiza guizhouensis* (Rubiaceae), a new species from Guizhou Province, southwestern China. PhytoKeys 95: 121–126. https://doi.org/10.3897/phytokeys.95.22506

PhytoKeys 121: 53–72 (2019)
doi: 10.3897/phytokeys.121.30254
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Typification of eight current and seven related names and a new section in the genus *Bromus* (Bromeae, Pooideae, Poaceae)

Félix Llamas[1], Carmen Acedo[1]

1 *Research Group Taxonomy and Biodiversity Conservation TaCoBi, Department of Biodiversity and Environment Management, University of León, E-2407, León, Spain*

Corresponding author: *Félix Llamas* (f.llamas@unileon.es)

Academic editor: *Sandra Knapp* | Received 2 October 2018 | Accepted 21 February 2019 | Published 2 May 2019

Citation: Llamas F, Acedo C (2019) Typification of eight current and seven related names and a new section in the genus *Bromus* (Bromeae, Pooideae, Poaceae). PhytoKeys 121: 53–72. https://doi.org/10.3897/phytokeys.121.30254

Abstract

During our nomenclatural revision of the genus *Bromus* L. (Poaceae) for Flora Iberica, we found that several names were still untypified: nine names in current use or their basionyms and five synonyms. Typifications are still needed since stabilising the names will facilitate their use. We propose lectotypes for *Bromus alopecuros* Poir., *B. contortus* Desf. (and the superfluous *B. alopecuroides* Poir.), *B. benekenii* (Lange) Trimen, *B. intermedius* Guss. subsp. *divaricatus* Bonnier & Layens, *B. molliformis* J.Lloyd ex Billot, *B. lepidus* Holmb., *B. lepidus f. lasiolepis* Holmb., *Bromus* subg. *Stenobromus* (Griseb.) Hack. and *Bromus* sect. *Stenobromus* Griseb. Neotypes for *B. erectus* Huds. and *B. ramosus* Huds. and an epitype for *B. intermedius* subsp. *divaricatus* Bonnier & Layens are proposed. In addition, we identify an isoneotype for *B. erectus* and isolectotypes for *B. lepidus* and *B. lepidus* f. *lasiolepis*. The area inhabited by the typified taxa includes both Africa and Europe. All the selected types are in agreement with the current use of the names and, thus, our selections contribute to stabilising the nomenclature of the genus *Bromus*. A discussion is provided to justify the selections. In addition, we typified two supraspecific names *B.* subg. *Stenobromus* and *B.* sect. *Stenobromus*. Finally, a new section, *B.* sect. *Penicillius* Llamas & Acedo, is described.

Keywords

Africa, *Bromus*, Europe, nomenclature, new name, typification

Introduction

The genus *Bromus* L. (Poaceae) includes about 200 species distributed worldwide, with the greatest diversity and most complex taxonomy in south-eastern Europe and western Asia (Acedo and Llamas 2001). The taxonomy and nomenclature of this genus is difficult and the appropriate ranks of various supraspecific, specific and infraspecific taxa still remain uncertain and contested. In addition, sometimes its sections are raised to genera: *Anisantha* K.Koch, *Boissiera* Hochst. ex Steud., *Bromopsis* (Dumort.) Fourr., *Bromus* L., *Ceratochloa* P.Beauv., *Nevskiella* V.I.Krecz. & Vved. etc. Some authors raise the sections to subgenera (e.g. Stebbins 1981, Acedo and Llamas 1999).

In step with research carried out by various authors in the last decade on the taxonomy and nomenclature of the genus *Bromus* L., we here present a nomenclatural paper concerning the 8 names of well-known and floristically or coenologically important taxa belonging to *Bromus* that remain untypified at present and others related with them.

Besides the basic interest of the typification of the untypified names to stabilise nomenclature, it is valuable for any Flora to include type information and references to the exact places where the designation of types were published. All typifications in our work affect native and naturalised taxa occurring in the Iberian Peninsula, most of them also being present in other European countries and North Africa or have been established as aliens in many territories around the world. In any case, most of these names are applied widely due to their current distribution. We are applying *Bromus* sensu lato circumscription, since there is not sufficient data to split it into different genera.

Materials and methods

This study is based on analysis of relevant literature (every protologue and location indications included) and search for specimens or images of the following herbaria to identify original material: B, BM, BRI, C, G, FI, H, GOET, L, LD, LE, LEB, LINN, K, MPU, P, PH, PI, S, UPS and W (acronyms according to Thiers 2018+). Finally, by studying digital images or specimens, we designate the most suitable type in each case. All our decisions on typifications follow the rules and recommendations of the *International Code of Nomenclature for algae, fungi and plants* (ICN; Turland et al. 2018).

The references are consulted in the Biblioteca Digital del Real Jardín Botánico de Madrid (2018) at http://bibdigital. rjb. csic.es/ing/index.php, BHL (2017), Biodiversity Heritage Library at https://www.biodiversitylibrary.org/, Botanicus Digital Peter H. Raven Library Missouri Botanical Garden at http://www.botanicus.org/ and Gallica https://gallica.bnf.fr. All available images of specimens can be examined via JSTOR Global Plants (2000–2018) https://plants.jstor.org/ and many on the servers of several of cited herbaria.

Currently accepted names are listed in alphabetical order, including their synonyms in each entry. Accepted names are in italic-bold, while junior synonyms are in italic-non-bold. Specimens seen are marked "!", images of specimens seen as "image!".

Results and discussion

Bromus alopecuros Poir., Voy. Barbarie. 2: 100–101 (1789)

Bromus alopecuros Poir., Voy. Barbarie. 2: 100–101 (1789). Type Protologue: "Cette espèce croît dans les prairies aux environs de la Calle ". Type: [Algeria] Numidia (lectotype, designated here: P [P02622864 image!]). (Figure 1)

Bromus contortus Desf., Fl. Atlant. 1: 95, tab. 25 (1798). Type Protologue: "Habitat prope La Calle". Type: [Algeria] La Calle (lectotype, designated here: P [P00320328 image!]). (Figure 2)

Bromus alopecuroides Poir. in Lamarck, Encycl., Suppl. 1: 703 (1810), nom. illeg. superfl. for *Bromus contortus* Desf. Type Protologue: [Algeria] "Barbarie, dans les prés, aux environs de Lacalle".

Remarks. Currently, the species *Bromus alopecuros* Poir. has at least two synonyms: *B. alopecuroides* Poir. and *B. contortus* Desf.

In describing *Bromus alopecuros,* Poiret (1789: 100) stated in the protologue diagnosis "Panicula conferta erecta, spiculis oblongis subsessilibus, aristis inferne spiraliter contortis." followed by a description in French and the locotypic indication indicating this species grows around La Calle [now El Kala, El Tarf province, Algeria].

During our search for original material in the herbaria conserving the plants of Poiret (FI, H, P and UPS), we found only one specimen collected by him. There is a sheet in P (P02622864) from Numidia (Algeria "Numidia" included in the full title of his publication), registered as original material, bearing a single plant annotated as *B. alopecuros* with five labels transcribed below; one of them handwritten by Poiret:

Label 1: [printed]. Herb. Poiret in Herb. Moquin-Tandom.
Label 2: [handwritten by Poiret] "brom. contortus Desf. *Bromus alopecuros* (n) Panicula conferta erecta spiculis oblongis subsessilibus, aristis inferne spiraliter contortis. (nobis) h. Poiret ex Numidia.
Label 3: [printed]: barcode Herbier museum Paris P 02622864
Label 4: [handwritten] *Bromus alopecuros* Poiret, Det. P. Smith 3/72
Label 5: [printed]. Herb. Mus. Paris

As this specimen bears a label handwritten by Poiret with his description of *B. alopecuros* and the word "nobis" [our], indicating the author is describing a new species, it seems sure that it is original material and it is suitable to be described as a lectotype. In addition, there is no other specimen matching with *Bromus alopecuros* Poir. in FI (Chiara Nepi pers. comm. 2018); nor in H (Raino Lampinen pers. comm. 1994; Henry Väre pers. comm. 2018) nor in UPS (Dr. Mats Hjertson pers. comm. 2018).

When Desfontaines (1798: 95), describes *Bromus contortus,* his description closely matches that of Poiret (1789). In his diagnosis, Desfontaines adds that the spikelets are "quindecimfloribus, …pubescentibus". At the end, he has doubts about his plant and

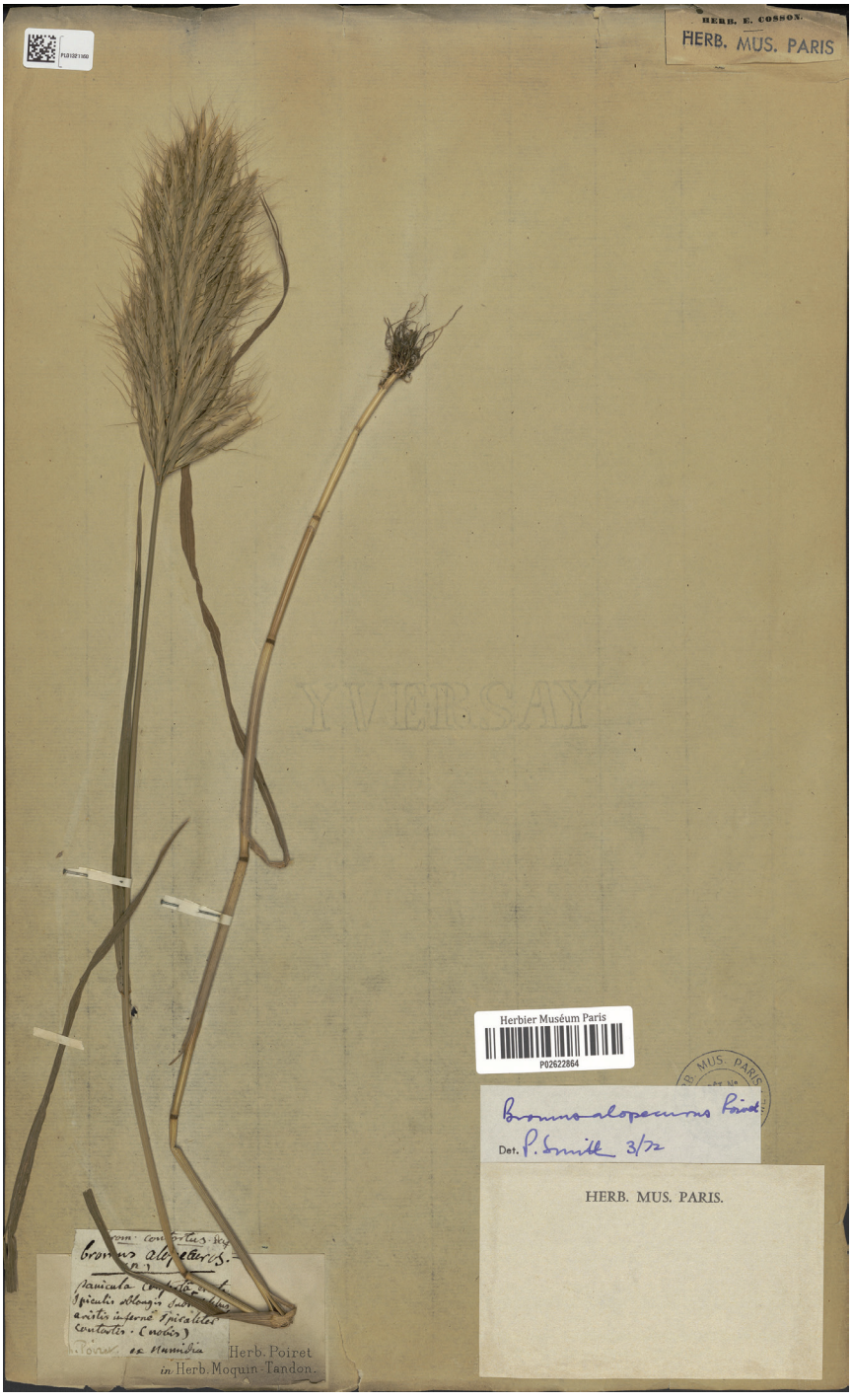

Figure 1. Lectotype of *Bromus alopecuros:* It is a complete specimen preserved at the MNHN Collection Vascular plants Specimen with barcode P02622864. (Available at http://coldb.mnhn.fr/catalognumber/mnhn/p/p02622864).

Figure 2. Lectotype of *Bromus contortus* Desf. is the specimen on the right having subsessile spikelets conserved in the MNHN Collection Vascular plants with barcode P00320328 (image available at: https://science.mnhn.fr/institution/mnhn/collection/p/item/p00320328?listIndex=1&listCount=4).

transcribes a reference to the description of Poiret "An Bromus alopecuros? Poiret. Itin. 2. P. 100)". Subsequently, he includes a more detailed description and asserts "Habitat prope La Calle". The only known original material for *B. contortus* is the illustration quoted in Desfontaines (1798: plate 25) and a single sheet in P (MNHN-P P00320328) bearing two specimens mounted on it with a printed label: *Herbier de la FLORE ATANTIQUE donné au Museum par M. DESFONTAINES* and annotated "*Bromus contortus*" handwritten (unknown by whom). There is another label, handwritten by Desfontaines, containing the exact diagnosis and description as it appears in Flora Atlantica (Desfontaines 1798: 95). Maybe Desfontaines is surprised one specimen is very similar to *B. alopecuros*, but not the other one, justifying his doubt in the description where he states "perhaps *B. alopecuros*?" This sheet bears two plants. The one on the left seems to be *Bromus lanceolatus* Roth and the one on the right is a fragment (contracted and erect panicle with subsessile spikelets) of a specimen matching *B. contortus* Desf., that also exemplifies the typical resemblance to *B. alopecuros* Poir. Therefore, the sheet in question does not represent a specimen as defined in the *Code* (Turland et al. 2018); but each of the two plants on the sheet is a specimen in its own right. Only one specimen is original material for *B. contortus* Desf. It is possible that the illustration in Desfontaines (1798: plate 25) was drawn from the plant designated here as lectotype.

Choosing the specimen on the right of the sheet MNHN-P P00320328 (Figure 2) as lectotype, which taxonomically matches *B. alopecuros* Poir., the name becomes a taxonomic or heterotypic synonym (Turland et al. 2018) of it, as Persoon (1805, 1: 95) asserted. Moreover, it is also possible that the heterogeneous material in this sheet is the origin of some misidentifications of *B. lanceolatus* Roth as *B. contortus* Desf.

Later, Poiret (1810: 703) describes *Bromus alopecuroides* "*Bromus* panicula conferta, erecta; spiculis oblongis, pubescentibus, quindecimfloris, subsessilibus; aristis infernè spiraliter contortis". This description is almost identical to the former of *B. alopecuros*. Its only difference is to include "pubescentibus, quindecimfloris", the same features Desfontaines (1798: 95) uses to describe *B. contortus*. Poiret continues adding the references to *B. alopecuros* Poir. and the synonym *B. contortus* Desf. Therefore, this name does not need a Lectoype as it is a superfluous and illegitimate renaming (Art. 52. 1) of *Bromus contortus* Poir. and has the same type we select here for that name.

Bromus benekenii (Lange) Trimen, J. Bot. 10: 333. (1872)

Schedonorus benekenii Lange, Flora Danica 48: 5, t. 2826. (1871). Type Protologue: "In silvia hinc inde. Specimen depictum fig. 1 in insula Lolland legit cl. E. Rostrup, specimen fig. 2 in silva Jonstrup Vang legit cl. H. Mortensen". Type: [Denmark] Jonstrup Vang. 29TH June 1866, H. Mortensen (lectotype, designated here: C [C10021729 image!]). (Figure 3)

Type. Based on *Schenodorus benekenii* Lange.

Remarks. The current widely used name *Bromus benenkenii* is an implicit combination by Trimen (1872: 333) of the name described as *Schedonorus benekenii* Lange

Figure 3. The original specimen of *Schedonorus benekenii* Lange illustrated in Flora Danica (in table 2826, fig. 2) is the lectotype selected (C10021729). Reproduced with permission of the Natural History Museum of Denmark.

in Flora Danica. In the original publication, Lange (1871: 5) describes a perennial *Bromus* living in forests, with nodding panicle.

An exhaustive search to find the material Lange (1871) cites as models for the illustrations in table 2826 (figs 1, 2), finally had a result. The two syntypes are conserved in C in the Flora Danica subherbarium, that contains specimens drawn in the magnificent work "Flora Danica" (Olof Ryding pers. comm. 2018). Their labels state "insula Lolland legit cl. E. Rostrup" (C10021728)" and "Jonstrup Vang, legit cl. H. Mortensen" (C10021729). Each folder indicates in handwriting that the specimens were drawn for "Flora Danica".

We choose as lectotype the latter sheet since its spikelets conserve most of its florets. The other sheet is in a more advanced phenological state and conserves, in most of its spikelets, only the glumes. The *Rostrup* specimen still conserves its basal part, with leaves, that is missing in the lectotype.

Bromus commutatus Schrad., Fl. Germ.: 353 (1806)

Bromus commutatus Schrad., Fl. Germ.: 353 (1806). Type Protologue: "Inter segetes, ad vias, sepes, alibique". Type: Germany (lectotype designated by Acedo and Llamas 1999: 73): *Bromus commutatus* Fl. Germ. Göttingen GOET 006096!

Remarks. The lectotype has a handwritten label by Schrader "*B. commutatus* / *Fl. Germ.* / *Göttingen*" and a handwritten indication as "typus-material". Currently, there is another label on this sheet by H.Scholz 1998 marking it as Neotypus, which was published in Scholz (1999: 436). Although both publications fulfil the conditions for a formal typification of a lectotype or a neotype, the Acedo and Llamas (1999: 73) publication appeared in February and is probably the first typification (ICN, Art. 10. 5). There are two important facts to consider. First, according to Kerguélen (1975: 100), there is original material in GOET. We consulted that herbarium and found two sheets that Schrader sent to GFW Meyer, which are indeed original material. Both bear handwritten labels by Schrader. The first sheet label says "*B. commutatus* Fl. Germ. Göttingen" and the second sheet label "*B. commutatus* Fl. Germ. var. spic. paulo brevior. Göttingen".

Bromus erectus Huds., Fl. Angl.: 39 (1762)

Bromus erectus Huds., Fl. Angl.: 39 (1762). Type Protologue: "Habitat in cretaceis circa Rochester, Dartford and Gravesend, in Cantio". Type: United Kingdom. England: Kent, near Wye, grassland on chalk. 12 Jun. 1964, S.T. Blake 22178 (neotype, designated here: K [K000618780!]; isoneotype: BRI [BRI 252046 image!]). (Figure 4)

Remarks. As a fire in his house destroyed Hudson's personal herbarium, most specimens were lost and only those borrowed by other botanists are extant. Some specimens which Hudson sent to Linnaeus are preserved in the herbarium of the Linnean Society of Lon-

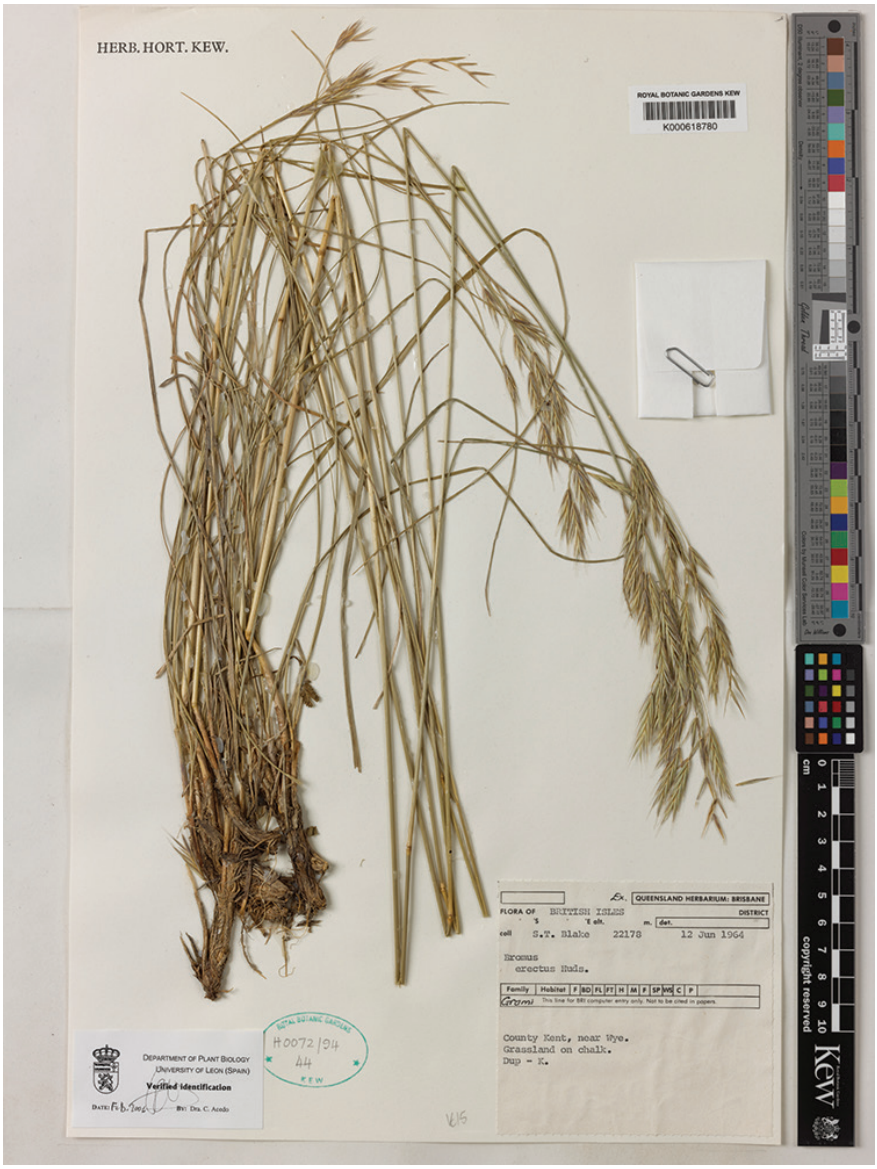

Figure 4. Neotype selected for *Bromus erectus* Huds. Sheet preserved at Herbarium K, barcode K00618780. [Available at http://specimens.kew.org/herbarium/K000618780]. Image used with permission Board of Trustees of the Royal Botanic Gardens, Kew.

don (LINN) but none of them is *Bromus erectus* Huds. There is also one sheet conserved in BM that does not seem to be original material. As Hudson did not give any other reference and, as no original material of *B. erectus* Huds. is available, a neotype must be designated (ICN, Art. 9.13). We searched for material coming from Kent ("Cantium", England) in K and selected one specimen consistent with the protologue as neotype. It was collected in Kent, near Wye. There is a duplicate of it in BRI, which is an isoneotype.

***Bromus hordeaceus* L. subsp. *divaricatus* (Bonnier & Layens) Kerguélen, Soc. Echange Pl. Vasc. Eur. Bassin Médit., Bull. 18: 27. (1981)**

Bromus intermedius Guss. subsp. *divaricatus* Bonnier & Layens, Tabl. Syn. Pl. Vasc. Fl. Fr. 369. (1894), non *B. divaricatus* sensu Rhode ex DC. Type Protologue: [France] "Endroits incultes, sables". Type: [France], (lectotype, designated here: [figure] in Bonnier and Layens, Tabl. Syn. Pl. Vasc. Fl. Fr. 369. (1894); epitype, designated here: [France]: Pornichet, Loire Inférieure [Loire-Atlantique], sea shore, June 25 1856, Lloyd, BM [BM001067302 image! as *Bromus molliformis* Lloyd]). (Figure 5)

Bromus molliformis J.Lloyd ex Billot, Fl. Gall. & Germ. Exsicc. (Haguenau) 1: 297–298. (Feb 1854). Type Protologue: "Loire Inférieure" [Loire-Atlantique]. Type: [France]. Le Roc-Saint-Luc, commune de Pissotte, près de Fontenay-le-Comte (Vendée); June 3, 1853, (lectotype, designated here: P [P02381530 image!]; isolectotypes: P [P03354928, P03354936, P03486702, P03364411]). (Figure 6)

Serrafalcus lloydianus Godr. & Gren. in Grenier and Godron, Fl. France 3: 591 (1855). Type Protologue: "Hab. Sables maritimes; Cannes, Hyères, Montpellier, etc.; littoral de l'Océan depuis Bayonne jusqu'à l'embouchure de la Loire".

Type. Based on *Bromus intermedius* Guss. subsp. *divaricatus* Bonnier & Layens.

Remarks. *Bromus hordeaceus* L. is a very variable species with a complex nomenclatural history at subspecies level. The origin of many problems in the group is the name *B. molliformis* J.Lloyd, Fl. Loire-Inf. (Lloyd 1844: 314–315), which was invalidly published as a provisional name "je proposerais, si c'était une espèce nouvelle, de l'appeler *Br. molliformis*". The name was later validated as *Bromus molliformis* J.Lloyd ex Billot, Fl. Gall. & Germ. Exsicc. (Haguenau) 2: Cent. 14. 1854. Billot supplies a brief description for "cette espèce donnée par M.Lloyd dans sa *Flore de la Loire-Inférieure* sous le nom de *B. divaricatitus* Rohde?" Billot (Feb. 1854: 297–298) neglects to mention several details of Lloyd's description of *B. molliformis* and describes the species as follows:

"Racine fibreuse. Chaume de 2–4 décimètres. Feuilles et graines inférieures mollement poilues. Panicule oblongue, droite, étalée, *resserrée après la floraison;* pédoncules courts, simples. Epillets oblongs, étalés, *velus*; arête égalant la glumelle, d'abord droite, à la fin *tortillée divariquée,* insérée à 1 1/2 millimètre du sommet obtus, échancré".

Billot (1854) publishes the first validating description for *Bromus molliformis*. He includes the reference of the features to differentiate the new species from the closely related *B. hordeaceus* L. and from *B. divaricatus* Rhode. He sold his exsiccata to several herbaria. There is not a register of those herbaria. Currently, some of them are included in P where some original specimens with its species number (1386) are preserved. Additionally, there are several names and combinations at several ranks, both validly and invalidly published and various nomenclatural changes. Nevertheless, *B. molliformis* J.Lloyd ex Billot remained untypified and still lacked a stable nomenclature.

Serrafalcus lloydianus Godr. & Gren. (1855: 591) is a superfluous name for *B. molliformis* J.Lloyd ex Billot. Grenier and Godron (1855) listed several synonyms, including "*B. divaricatus* Lloyd non Rhode" and *B. molliformis* J.Lloyd ex Billot

Figure 5. The epitype of *Bromus hordeaceus* L. subsp *divaricatus* (Bonnier & Layens) Kerguélen is the specimen on the left with barcode BM001067302 (collected and identified by Lloyd as *B. molliformis*; preserved at BM (Permanent URL: http://data.nhm.ac.uk/object/9a6e0684-9e9b-4951-ac7e-ba13ad-34ed31). Reproduced with permission.

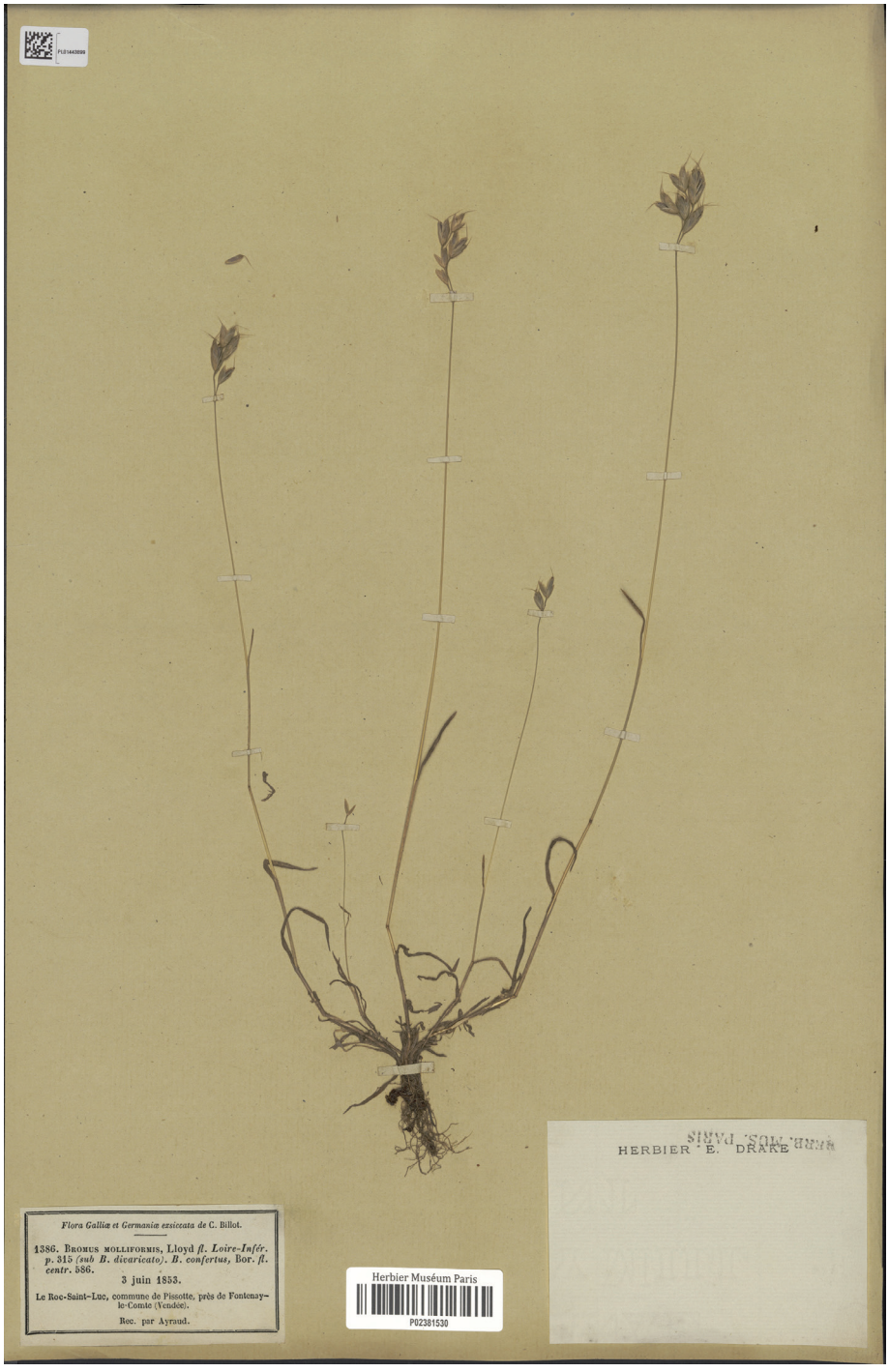

Figure 6. Lectotype for *Bromus molliformis* J.Lloyd ex Billot at P. It is a specimen preserved at the MNHN Collection Vascular plants. Specimen with barcode P02381530. (Available at http://coldb.mnhn.fr/catalognumber/mnhn/p/p02381530) Reproduced with permission.

[sub. *B. molliformis* Lloyd]. They also mention Billot's exsiccate n. 1586; and include his new species in the complex of species having "arête … tordue sur elle-même et divariquée". Therefore, this name does not need a Lectoype as it is a superfluous and illegitimate renaming (Art. 52.1) of *Bromus molliformis* J.Lloyd ex Billot and has the same type we select here for that name.

Bonnier and Layens (1894: 369) describe *Bromus intermedius* Guss. subsp. *divaricatus* Bonnier & Layens, based on *B. divaricatus* [sensu] Lloyd, non Rhode, with the characteristics of Lloyd's plant. Kerguélen (1981: 27) combines it to *Bromus hordeaceus* subsp *divaricatus* (Bonnier & Layens) Kerguélen. Bonnier and Layens type material is unknown (Stafleu and Cowan 1976). Kerguélen (1975: 104) mentions Lloyd's type material is in herbarium NTM, pointing out two localities "Pornic, Saint Brevin" indicated by Lloyd. Nevertheless, no original material is preserved in NTM (Mary Laury Guerin, Com. pers. 2018).

Bromus hordeaceus L. var. *molliformis* (J.Lloyd ex Billot) Halácsy (1904: 396). This is another combination of *B. molliformis* J.Lloyd and Halácsy pointed out its main traits "Panicula magis conferta, ramis brevissime, spiculis densius et longius velutinupilosis, aristis demum extrorso subcurvatis".

Bromus hordeaceus L. subsp. *molliformis* (J.Lloyd) Maire & Weiller (1955: 255). This post-1953 combination, without direct citation to the basionym, nor to a potentially validating Latin description, but only to "*Bromus molliformis* Lloyd, Fl. Loire-Inf. 315 (1844)", is another combination not validly published.

As *Bromus intermedius* subsp. *divaricatus* Bonnier & Layens is an untypified name, we choose, as lectotype, the figure in Bonnier and Layens (1894: 369) that is definitely original material. However, as is common with figures, it is difficult to observe some diagnostic characteristics. Thus, we select, as epitype, a specimen collected by Lloyd, conserved in BM, consistent with the protologue. It is a sheet bearing two collections. We choose the specimen on the left from Pornichet (barcode BM001067302).

Bromus lepidus **Holmb., Bot. Not. 1924: 326 (1924)**

Bromus lepidus Holmb., Bot. Not. 1924: 326 (1924).Type Protologue: "Nach ROUY kommt sie in Frankreich hier und da vor,aber ziemlich selten; Krösche hat sie nur von einem Ståndort in Norddeutschland. In Schweden kommt sie besonders in Schonen vor; ich habe sie mehrmals eingesammelt, wie in der Gegend von Lund und Malmö an mehreren Orten; Svenshög in Wallkärra; Skartofta in Öved; Gudmundtorp. Außerdem sah ich Exemplare aus Blommeröd in Öved (leg. P. Boren 1903), Skelderviken (leg. Sten Selander), Kalmar (leg. N. Blomgren), Borås (leg. C. Sandberg), Fyen, Stenlose (leg. G. Samuelsson). Kommt in Klee- und Grasfeldern, auf Rainen, Wegrändern etc. vor, oft mit *B. mollis* und *B. commutatus* zusammen; bei Malmö auch als Ruderat". Type: SWEDEN. Scania: Malmö, in ruderatis, 18-06-1920, Otto R.Holmberg, (lectotype, designated here: LD [LD1136595 image!]; isolectotype: K [K000913599!]). (Figure 7)

Bromus lepidus Holmb. f. *lasiolepis* Holmb., Bot. Not. 1924: 326 (1924). Type Protologue: not indicated. Type: Sweden. Scania: Vallkörra. Svenenshög. 4-07-1923. Otto R.Holmberg, (lectotype, designated here: LD [LD 1136235 image!]; isolectotype: K [K000913598!]). (Figure 8)

Remarks. This taxon has a long history full of nomenclatural problems. Duval-Jouve (1865: 208), who only lists, without naming them, the variations in spikelet size and hairiness of *Bromus* species, e.g. *Bromus mollis* "microstachys glabre" and *Bromus mollis* "microstachys pubescent". This is the first mention of this taxon. Later Rouy (1913: 236) proposed a named variety under the genus *Serrafalcus* Parl.*: S. mollis* ß *microstachys* Rouy, giving "*Bromus microstachys* Duval-Jouve" (1865: 207) as a synonym and adding a diagnosis. Therefore, there is no doubt this is the same plant cited by Duval-Jouve (l. c.). Afterwards, Krösche (1924: 329) described *B. gracilis* Krösche, which unfortunately is a posterior homonym as Weigel (1772: 15) previously proposed this name for a different plant.

Finally, Holmberg (1924: 326) solves this unfortunate situation and names simultaneously the new taxa *Bromus lepidus* Holmb. and *B. lepidus* f. *lasiolepis* Holmb. The herbaria having Holmberg material are K, LD and S. There are 13 sheets in LD collected before 1924, five in S and three in K. It is reasonably certain that Holmberg studied all those plants before the description of the species and form and that all of them are original material. Therefore, we decided to limit our choices to sheets with the annotations "*B. lepidus* mihi" and "*B. lepidus* f. *lasiolepis* Holmb.", as this annotation indicates that Holmberg is interpreting them as the new taxa he is going to describe.

Bromus ramosus Huds., Fl. Angl.: 40 (1762)

Bromus ramosus Huds., Fl. Angl.: 40 (1762).Type Protologue: "Habitat in sylvis et sepibus frequens". Type: United Kingdom. England: Leighwood, North Somerset. 5 July 1884, White, J.W #s.n., (neotype, designated here: S [S-G-1020!]). (Figure 9)

Remarks. Hudson (1762: 40) proposed the name *Bromus ramosus* for the wood Brome-grass from England. The protologue is a short diagnosis "*BROMUS* panicula ramosa nutante scabra, spiculis linearibus decemfloris arista longioribus, foliis scabris" followed by three polynomials as "synonyms", but without indication of the geographical area in which the new species lives, except an indication to "Anglia". As pointed out before, the fire destroyed Hudson's house as well as his personal herbarium. We were not able to find any sheet that could be "original material". Accordingly, we select a neotype of *Bromus ramosus* Huds. An annotation label indicates that Carmen Fraile verified and chose it as a neotype in 1994, but this designation was never published (ICN, Art. 7. 10). As this sheet agrees with the protologue, we accept her choice and make it effective here.

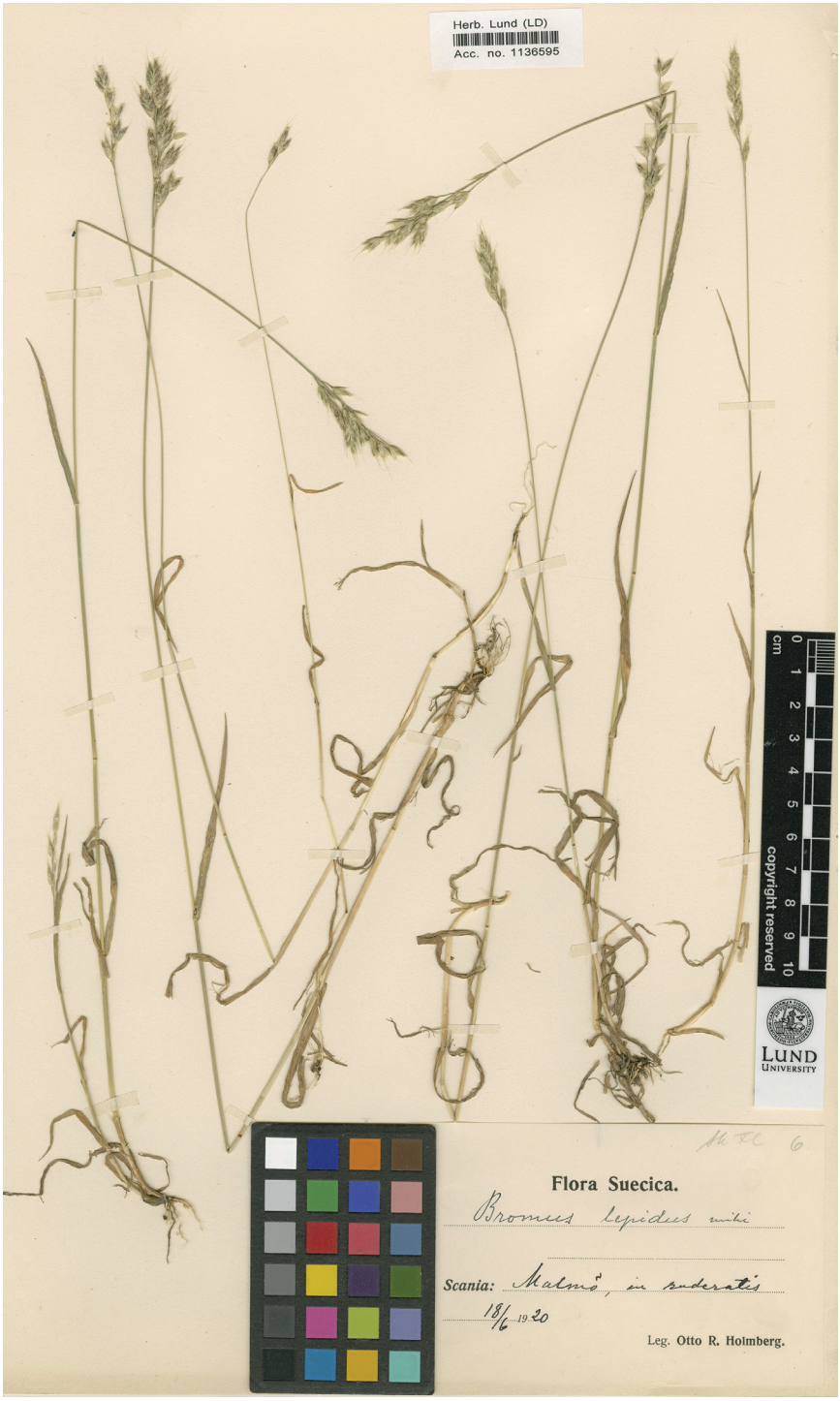

Figure 7. Lectotype of *Bromus lepidus* Holmberg, preserved at the Herbarium of the biological museum of the Lund University (LD1136295), reproduced with permission.

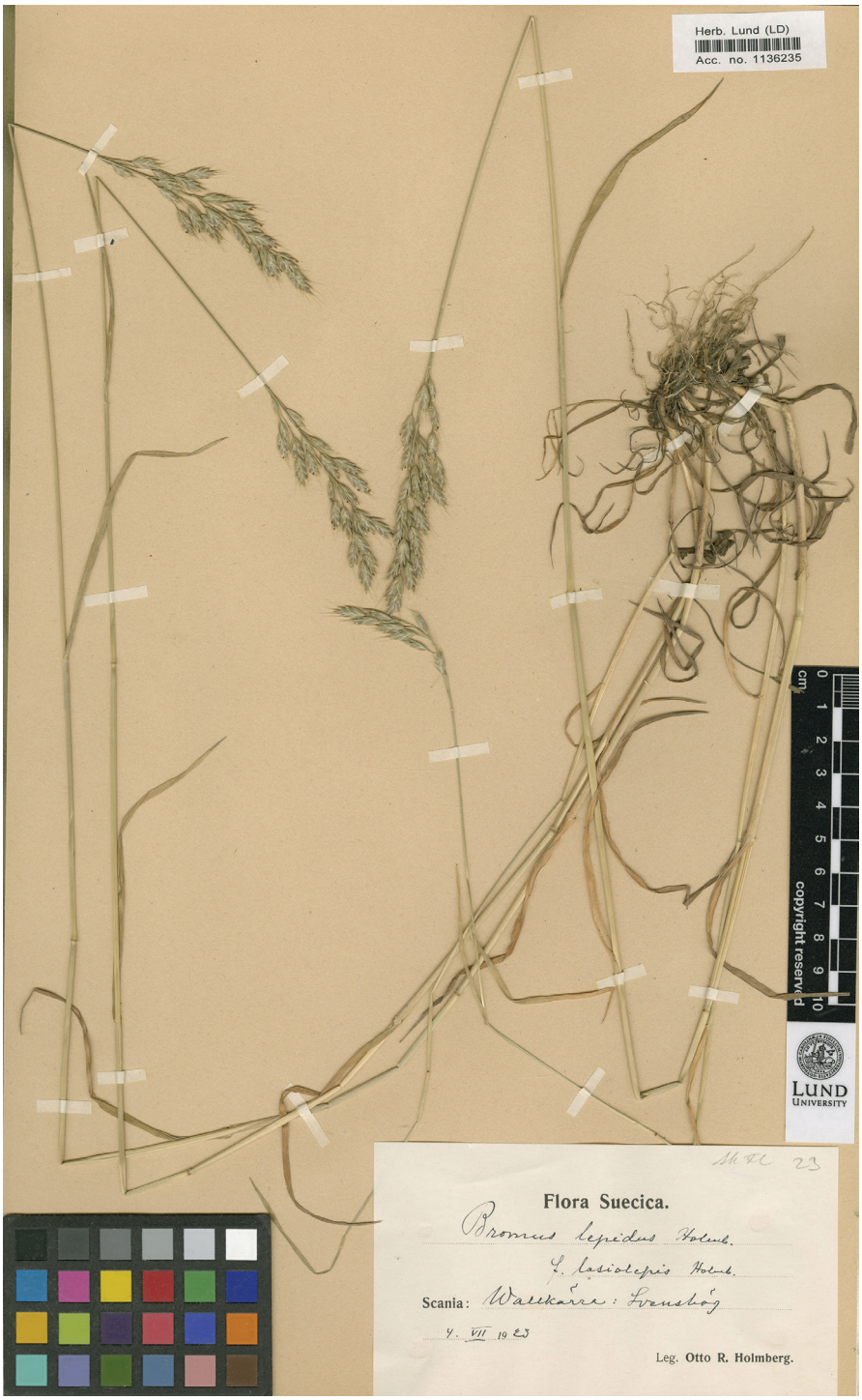

Figure 8. Lectotype of *Bromus lepidus* f. *lasiolepis* Holmberg, preserved at the Herbarium of the Biological Museum of Lund University (LD 1136235). Reproduced with permission.

Figure 9. Neotype selected for *Bromus ramosus* Huds. preserved at the general collection of the Swedish Museum of Natural History (S) (S-G-1020!). Reproduced with permission.

***Bromus* subg. *Stenobromus* (Griseb.) Hack. in Engler & Prantl, Nat. Pflanzenfam. 2(2): 75. 1887**

≡ *Bromus* sect. *Stenobromus* Griseb., Spic. Fl. Rumel. 2: 448 1844 [1846].

Type. (designated here): *Bromus sterilis* L., Sp. Pl.: 77 (1753).

Remarks. Grisebach (1844: 448) described *Bromus* sect. *Stenobromus* including *B. maximus* Desf., *B. madritensis* L., *B. tectorum* L. and *B. sterilis* L. Hackel (1887: 75) described *B.* subg. *Stenobromus* including only two species: *B. tectorum* L. and *B. sterilis* L and gave *Anisantha* K. Koch as a synonym. Afterwards, some other species were included. Until now, *B.* subg. *Stenobromus* has been used in some works (Stebbins 1981, Acedo and Llamas 1999) because there is no correct name available for this taxon at subgenus level. As a consequence, *B.* subg. *Stenobromus* is treated as a new combination at new rank because a potential basionym exists, *B.* sect. *Stenobromus*, applying to the same taxon ICN Art. 41.4.

This subgenus is variable enough to have two sections:

1. *Bromus* sect. *Genea* Dumort., Observ. Gramin. Belg. 116 (1823) [1824]

Type. (designated by Tournay 1961: 294): *Bromus sterilis* L. in Sp. Pl. 77 (1753).

Included species. Dumortier (1824) describes the section including *Bromus sterilis* L., *B. tectorum* L., B. *diandrus* Roth, *B. rigidus* Roth. and *B. rigens* L., a synonym for *B. scoparius* L., now belonging to *B.* sect. *Triniusa* (Steud.) Nevski.

Distribution. Europe, temperate Asia and North Africa.

2. *Bromus* sect. *Penicillus* Llamas & Acedo, sect. nova.
urn:lsid:ipni.org:names:77196853-1

Diagnosis. Panicle dense, compact, with short branches. The erect spikelets seem to be sessile. Awns more or less divaricate at maturity.

Type. *Bromus rubens* L. in Cent. Pl. I: 1 (1755).

Included species. *B. rubens* L., *B. fasciculatus* C.Presl and *B. matritensis* L.

Distribution. Southern Europe, temperate Asia and North Africa. Etymology: Named from the Latin "penicillus", meaning brush, referring to the morphology of the inflorescence, especially in *B. rubens*, the name of which provides the type.

Acknowledgements

Thanks are due to the staff and institutions of the Herbaria consulted for helping us to find materials; in particular Thomas Rouillard (ANG), Olof Rydi (C), Chiara Nepi (FI), Henry U Väre (H), Roxali Bijmoe (L), Ulf Arup (LD), Juan Viruel (K) for their personal assistance with some pictures, Jean-Claude Jolinon, Elodie Lerat and Veronique Durand-

Andro (P), Arne Anderberg (S) and Mats Hjertson (UPS). Mrs. Amelia Llamas and Ms. Elizabeth Bailey for proofreading the paper and English language editing. We are also very grateful to Sandra Knapp (Deputy Editor) and Kanchi N. Gandhi and the reviewers Robert Soreng, Eduardo Ruiz Sánchez and Werner Greuter for their critical comments and helpful suggestions to improve our manuscript. This work was supported by the Spanish "Ministerio de Economía y Competitividad MICINN" under Flora Iberica IX Grant CGL2011-28613-C03-03, and Flora Iberica X Grant CGL2014-52787-C3-1-P.

References

Acedo C, Llamas F (1999) The genus *Bromus* L. (Poaceae) in the Iberian Peninsula. Phaneogamarum Monographiae. J.Cramer, Berlin.

Acedo C, Llamas F (2001) Variation of micromorphological characters of lemma and palea in the genus *Bromus* (Poaceae). Ann. Bot. Fennici 38: 1–14.

BHL (2017) Biodiversity Heritage Library. https://www.biodiversitylibrary.org/

Biblioteca Digital del Real Jardín Botánico de Madrid CSIC (2018) Biblioteca Digital del Real Jardín Botánico de Madrid. http://bibdigital.rjb.csic.es/ing/index.php [Accesed on 12th January, 2018]

Billot C (1854) Flora Galliae et Germaniae Exsiccata. Archives de la Flore de France et d'Allemagne 1: 287–298. https://babel.hathitrust.org/cgi/pt?id=hvd.32044106329642;view=1up;seq=304

Bonnier G, Layens G (1894) Tableaux synoptiques des plantes vasculaires de la Flore de la France. Paul Dupont, Paris. https://doi.org/10.5962/bhl.title.323

Desfontaines RL (1798) Flora Atlantica (1st ed). C Panckoucke, Paris. https://doi.org/10.5962/bhl.title.323

Dumortier BCJ (1824) Observ. Gramin. Belg. Tournay. [J.Casterman Aîné]

Duval-Jouve MJ (1865) Variations paralelles des types congénères. Bulletin de la Societé Botanique de France 12(4): 196–211. https://doi.org/10.1080/00378941.1865.10825009

Grenier M, Godron M (1855) Flore de France. J.-B Baillière, Paris. https://biodiversitylibrary.org/page/6122574

Grisebach AHR (1844) Spicilegium florae rumelicae et bithynicae: exhibens synopsin plantarum. Vol 2. F Vieweg et filium, Brunsvigae.

Hackel E (1887) Gramineae. In: Engler A, Prantl K (Eds) Die Natürlichen Planzenfmilien. 2(2): 1–130. Wihelm Engelmann, Leipzig. http://bibdigital.rjb.csic.es/spa/Libro.php?Libro=1636&Pagina=1

Halácsy E (1904) Conspectus Florae Graecae III. Guilelmi Engelmann, Lipsiae. http://bibdigital.rjb.csic.es/spa/Libro.php?Libro=2294&Pagina=1

Holmberg OR (1924) Bromi molles, eine nomenklatorische und systematische Untersuchung. Botaniska Notiser 1924: 313–328.

Hudson G (1762) Flora Anglica. Impensis auctoris, London.

JSTOR Global Plants (2000–2018) JSTOR Global Plants. https://plants.jstor.org/

Kerguélen M (1975) Les Gramineae (Poaceae) de la Flore Francaise. Essai de mise au point taxonomique et nomenclaturale. Lejeunia 75: 1–343.

Kerguélen M (1981) N 8913 [17] *Bromus molliformis.* Société pour l'Echange des Plantes Vasculaires de l'Europe et du Bassin Méditerranéen 18: 27.

Krösche E (1924) Neue Arten und Formen aus Nordwest-Deutschland. Repertorium Specierum Novarum Regni Vegetabilis 19: 329–332. https://doi.org/10.1002/fedr.4870192904

Lange J (1871) [Flora danica] Icones plantarum sponte nascentium in regnis Daniae et Norvegiae, in ducatibus Slesvici et Holsaticae, et in comitatibus Oldenburgi et Delmenhorstiae; ad illustrandum opus de iisdem plantis, regio jussu exarandum, Florae danicae nomine inscriptum 48: 5, t. 2826. 1871. Kjoebenhan. http://bibdigital.rjb.csic.es/spa/Libro.php?Libro=4682&Pagina=196

Lloyd J (1844) Flore de la Loire-Inférieure. Prosper Sevire, Nantes. https://gallica.bnf.fr/ark:/12148/bpt6k984852/f4.image

Maire R, Weiller M (1955) Flore de l'Afrique du Nord. Vol. III. Paul Lechevalier, Paris.

Persoon CH (1805) Synopsis plantarum, seu enchiridium botanicum, complectens enumerationem systematicam specierum hucusque cognitarum. Pars prima. Carol. Frid. Cramerum, Parisii Lutetiorum. http://bibdigital.rjb.csic.es/spa/FichaLibro.php?Libro=383

Poiret JLM (1789) Voyage en Barbarie: ou lettres écrites de l'ancienne Numidie pendant les années 1785 & 1786, sur la religion, les coutumes & les moeurs des Maures & des Arabes-Bédouins: avec un essai sur l'histoire naturelle de ce pays. JBF de la Rochelle, Paris.https://doi.org/10.5962/bhl.title.13598

Poiret JLM (1810) Encyclopédie Méthodique. Botanique. Supplement, Tome I. H Agasse, Paris. https://doi.org/10.5962/bhl.title.826

Rouy GCH (1913) Flore de France XIV. M.M. Deslis frères, Paris. http://bibdigital.rjb.csic.es/spa/Libro.php?Libro=876&Pagina=1

Scholz H (1999) Eine neue Unterart des *Bromus secalinus* (Gramineae) -ein Sekundäres Unkraut. Feddes Repertorium 110(5–6): 425–438.

Stafleu FA, Cowan RS (1976) Taxonomic literature (2nd ed.) Utrecht: Bohn, Scheltema & Holkema, v.1: A–G. http://www.sil.si.edu/DigitalCollections/tl-2/browse.cfm?vol=1#page/11

Stebbins GL (1981) Chromosomes and evolution in the genus *Bromus* (Gramineae). Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie 102(1–4): 411–425.

Thiers B (2018+) Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. The New York Botanical Garden. http://sweetgum.nybg.org/ih/

Tournay R (1961) La nomenclature des sections du genre *Bromus* L. (Gramineae). Bulletin du Jardin botanique de l'État a Bruxelles 31(2): 289–299. https://doi.org/10.2307/3667334

Trimen H (1872) Notes on some Scandinavian plants. Journal of Botany, British and Foreign 10: 329–334. https://biodiversitylibrary.org/page/34721515

Turland NJ, Wiersema JH, Barrie FR, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Kusber W-H, Li D-Z, Marhold K, May TW, McNeill J, Monro AM, Prado J, Price MJ, Smith GF (2018) International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical Congress Shenzhen, China, July 2017. Regnum Vegetabile 159. Koeltz Botanical Books, Glashütten. https://doi.org/10.12705/Code.2018

Weigel CE (1772) Observationes Botanicae. Ant. Ferd. Röse. Gryphiae. https://doi.org/10.5962/bhl.title.123718

PhytoKeys 121: 73–80 (2019)
doi: 10.3897/phytokeys.121.34271
http://phytokeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

Mitrephora monocarpa (Annonaceae): a new species from Surat Thani Province, Peninsular Thailand

Richard M.K. Saunders[1], Piya Chalermglin[2]

1 *School of Biological Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China* **2** *Agricultural Technology Department, Thailand Institute of Scientific & Technological Research, 35 Technopolis, Liap Khlong Ha Road, Khlong Luang District, Pathum Thani Province 12120, Thailand*

Corresponding author: *Richard M.K. Saunders* (saunders@hku.hk)

Academic editor: *T.L.P. Couvreur* | Received 4 March 2019 | Accepted 8 April 2019 | Published 7 May 2019

Citation: Saunders RMK, Chalermglin P (2019) *Mitrephora monocarpa* (Annonaceae): a new species from Surat Thani Province, Peninsular Thailand. PhytoKeys 121: 73–80. https://doi.org/10.3897/phytokeys.121.34271

Abstract

A new species, *Mitrephora monocarpa* R.M.K.Saunders & Chalermglin, **sp. nov.** (Annonaceae), is described from Surat Thani Province in Peninsular Thailand. It resembles two other species, *M. alba* Ridl. and *M. keithii* Ridl., with which it is broadly sympatric, but can be distinguished by its solitary flowers (not borne in thyrsoid inflorescences as in most other *Mitrephora* species), single carpel per flower (and hence single monocarp per fruit) and the lack of a monocarp stipe. A key to the nine *Mitrephora* species in Thailand is provided.

Keywords

Annonaceae, *Mitrephora monocarpa*, Thailand, new species

Introduction

Mitrephora (Blume) Hook.f. & Thomson (Annonaceae subfam. Malmeoideae tribe Miliuseae; Chatrou et al. 2012; Guo et al. 2017) is a genus of small to medium-sized trees widespread in lowland tropical forests in Southeast Asia. In the most recent taxonomic monograph of the genus, Weerasooriya and Saunders (2010) recognised 47 species (with an additional species subsequently recorded from Borneo: Okada 2014). The genus is likely to be monophyletic (Weerasooriya and Saunders 2010; Guo et al. 2017)

and is characterised by extra-axillary (rarely terminal) cymose inflorescences composed of generally small, trimerous flowers with a whorl of sepals and two whorls of petals. The outer petals are larger than the inner and are free and spreading, whereas the inner petals are clawed-rhombic and apically connivent over the reproductive organs, forming a small mitriform dome (a 'type III' chamber, sensu Saunders 2010); basal apertures between the inner petal claws enable entry to the floral chamber by pollinators (unknown for most species but reported to be small nitidulid beetles in *M. heyneana* (Hook.f. & Thomson) Thwaites: Weerasooriya and Saunders 2010). The flowers are invariably hermaphroditic, with numerous stamens with an apical connective that is expanded to cover the top of the thecae and a variable number of unfused carpels. These carpels develop into free monocarps after fertilisation.

There are currently eight *Mitrephora* species recorded from Thailand (Weerasooriya and Saunders 2010), viz. *M. alba* Ridl., *M. keithii* Ridl., *M. sirikitiae* Weeras., Chalermglin & R.M.K.Saunders, *M. teysmannii* Scheff., *M. tomentosa* Hook.f. & Thomson, *M. vulpina* C.E.C.Fisch., *M. wangii* Hu and *M. winitii* Craib. Here we report a new species, *M. monocarpa* R.M.K.Saunders & Chalermglin, collected from Surat Thani Province in Peninsular Thailand. Of the eight previously described Thai species, only four (*M. alba*, *M. keithii*, *M. teysmannii* and *M. vulpina*) grow in Peninsular Thailand, although another species, *M. macclurei* Weeras. & R.M.K.Saunders, occurs in Kedah, Peninsular Malaysia (Weerasooriya and Saunders 2005, 2010).

New species description

Mitrephora monocarpa **R.M.K.Saunders & Chalermglin, sp. nov.**
urn:lsid:ipni.org:names:60478755-2
http://species-id.net/wiki/Mitrephora_monocarpa
Figs 1–3

Diagnosis. A new species similar to *M. alba* and *M. keithii*, but distinguished by its solitary flowers that are not borne in an inflorescence, its single carpel per flower and single sessile monocarp per fruit.

Type. Thailand: In Para Rubber plantation (*Hevea brasiliensis* (Kunth.) Mull. Arg.), Khlong Sok Village, Phanom District, Surat Thani Province, 15 December 2015, *P. Chalermglin 581215* (holotype: BKF [dry and spirit collection]; isotypes: BK, QBG, PSU, K, SING [dry]).

Description. Treelets or small trees, to ca. 5 m, main trunk slender. Young branches glabrous to sparsely pubescent, with short, appressed golden-brown hairs. Leaf laminas 9–13 cm long, 3.5–5 cm wide, length:width ratio 2.5–3.3, ovate to elliptic, papyraceous, glabrous and ± matt adaxially, glabrous abaxially; base obtuse to slightly cuneate; apex acute to slightly acuminate; primary vein glabrous ad- and

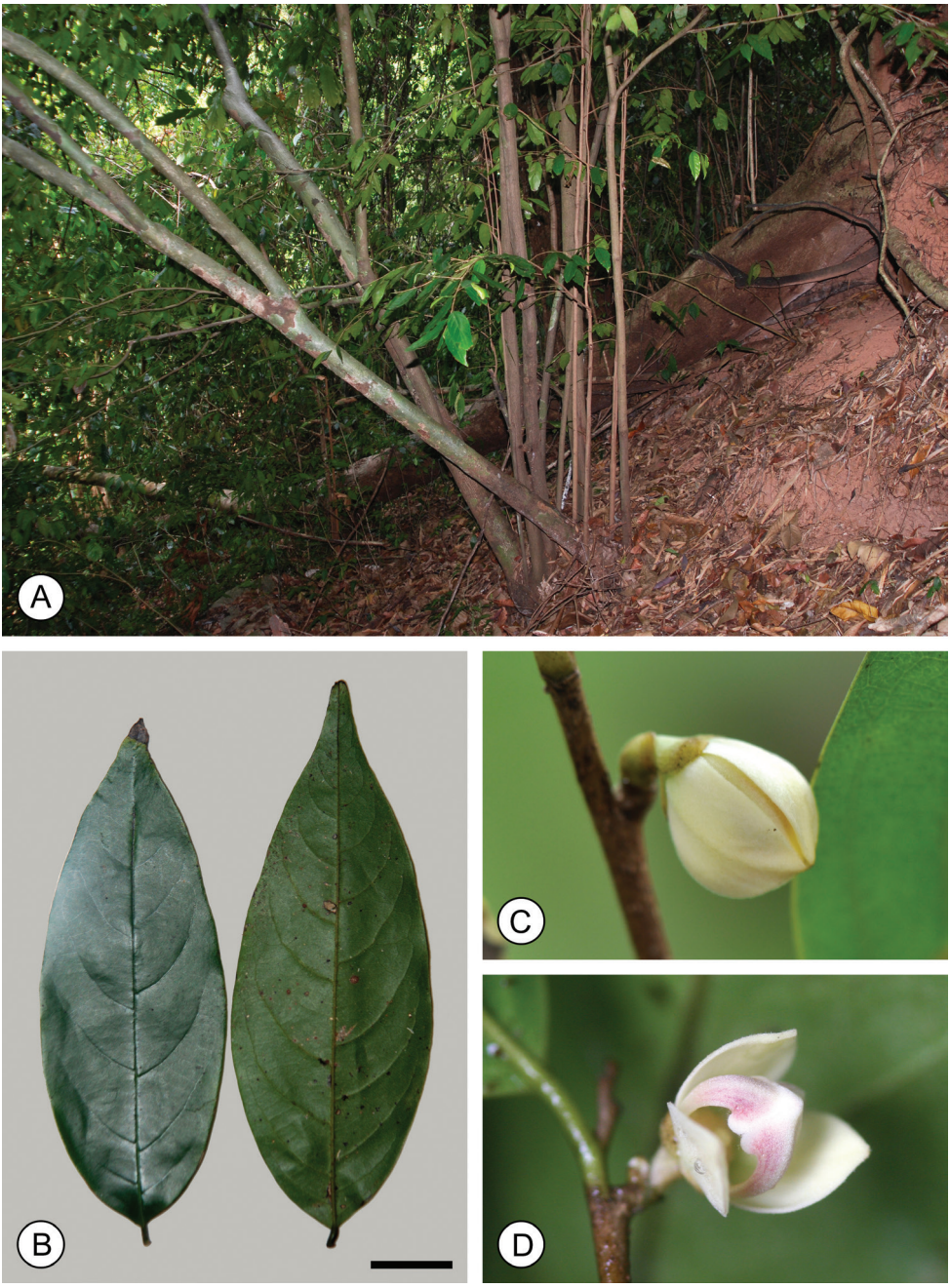

Figure 1. *Mitrephora monocarpa* sp. nov. (*P. Chalermglin 581215*). **A** Habit **B** leaves (left: adaxial; right: abaxial) **C** flower bud **D** young flower, shortly after separation of outer petals. Scale bar: 2 cm. Photos: P. Chalermglin.

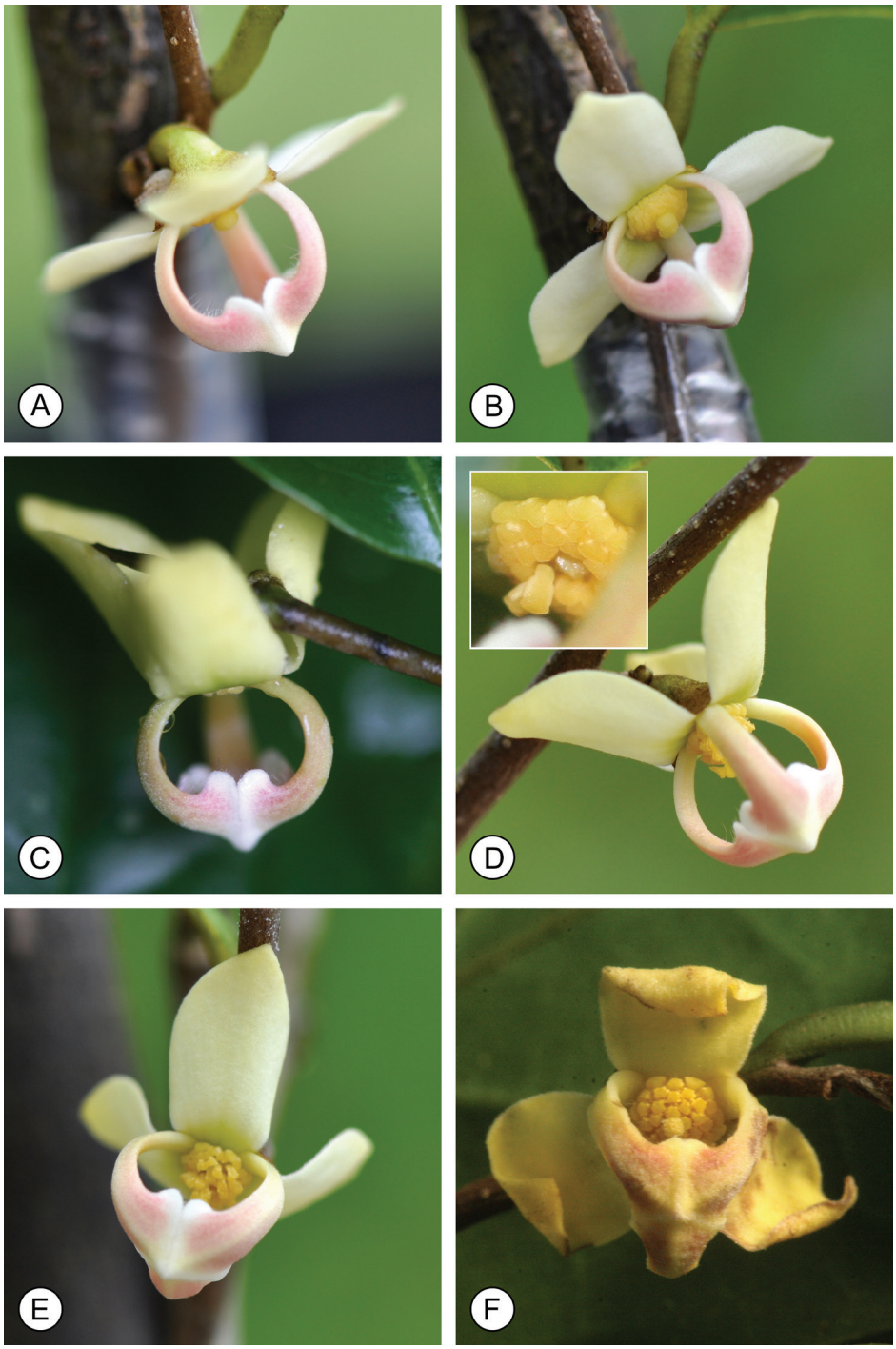

Figure 2. *Mitrephora monocarpa* sp. nov. (*P. Chalermglin 581215*). **A, B** Pistillate-phase flowers **C–E** staminate-phase flowers (insert in **D** shows abscised stamens suspended by tracheary elements in the xylem) **F** late-stage flower, with petals turning yellow. Photos: P. Chalermglin.

abaxially; secondary veins 6–8 pairs per leaf, ± inconspicuous, glabrous ad- and abaxially; domatia absent; petioles 3.5–5 mm long, 1.1–1.4 mm in diameter, glabrous. Inflorescence reduced to a single flower. Flower pedicel ca. 4.5 mm long, ca. 1.5 mm in diameter, pubescent. Sepals ca. 2.5 mm long, ca. 2 mm wide, broadly ovate, pubescent abaxially. Outer petals 11.5–12.5 mm long, 7–8 mm wide, cream-coloured (turning yellowish in late-stage flowers), ovate, apex acute, margin not undulating with age, pubescent abaxially, sparsely pubescent adaxially. Inner petals ca. 9.5 mm long, ca. 3 mm wide apically, ca. 2 mm wide at claw, pale pink with whitish margins and near point of apical connivance (turning yellowish in late-stage flowers), clawed-triangular, hairs non-glandular. Stamens 0.9–1 mm long, 0.7–0.8 mm wide. Carpels solitary per flower, ca. 1.4 mm long; ovary ca. 0.9 mm long, ca. 0.5 mm wide, densely pubescent; stigma ca. 0.5 mm long, ca. 0.9 mm wide; ovules ca. 9 per carpel, in two columns. Monocarp solitary per fruit, ca. 52 mm long, ca. 32 mm in diameter, ellipsoid, smooth, without longitudinal ridge; stipe absent. Fruit pedicel ca. 6 mm long, ca. 4 mm in diameter. Seeds ca. 9 per monocarp, size unknown (fruiting specimen not preserved).

Phenology. Flowering was observed in June, July and December. As with all hermaphroditic-flowered Annonaceae species (Pang and Saunders 2014), *M. monocarpa* is protogynous. The flowers undergo visible change associated with the switch between the pistillate and staminate function: the outer petals are held at right-angles to the floral axis in pistillate-phase flowers (Fig. 2A, B), but become reflexed during the staminate phase (Fig. 2C–E). The stamens partially abscise as the thecae dehisce and ultimately remain suspended from the floral torus by their tracheary elements (inset in Fig. 2D; cf. Endress 1985). As the flower ages, the petals of both whorls begin to turn yellow and wilt (Fig. 2F) before abscising. Fruiting was observed in December.

Distribution and habitat. *Mitrephora monocarpa* is only known from the type collection cited above, from a tropical rain forest over limestone, ca. 250 m elevation.

Etymology. The specific epithet reflects the fact that the flower has only a single carpel and, hence, the fruit consists of a solitary monocarp.

Local name: Phrom Phanom.

Discussion. The phylogenetic affinities of *M. monocarpa* are currently unknown, although morphologically it resembles two species, *M. alba* and *M. keithii*, with which it is broadly sympatric in Peninsular Thailand: all three species have a sparsely hairy indument on the twigs and leaves and comparatively small flowers. *Mitrephora monocarpa* is clearly distinguished from these species, however, as the flowers have only one carpel: *M. alba*, in contrast, has ca. 16 carpels per flower and *M. keithii* has 12–14 (Weerasooriya and Saunders 2010). Carpel number is variable in other species in the genus, although the smallest number previously recorded was four (in the Indochinese species *M. calcarea* Diels ex Weeras. & R.M.K.Saunders, the Bornean species *M. kostermansii* Weeras. & R.M.K.Saunders, the Philippine species *M. lanotan* (Blanco) Merr. and the Sumatran species *M. rufescens* Ridl.; Weerasooriya and Saunders 2010).

The fruits of *M. monocarpa* are easily distinguished from those of *M. alba* and *M. keithii* as they consist of only one monocarp (Fig. 3A, B); this monocarp is further-

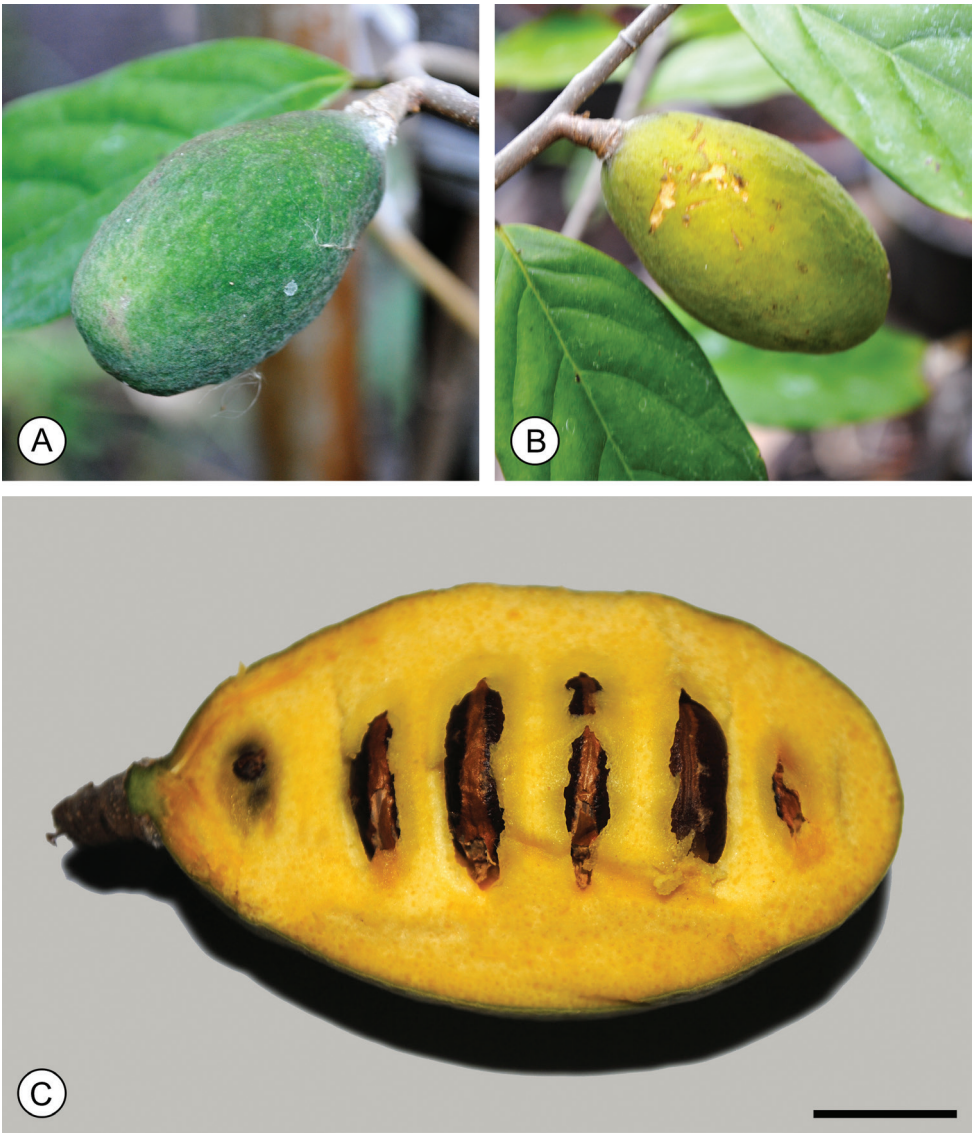

Figure 3. *Mitrephora monocarpa* sp. nov. (*P. Chalermglin 581215*). **A** Immature fruit, composed of a single monocarp **B** partially mature fruit, with the exocarp turning yellow **C** dissected fruit, showing multiple seeds. Scale bar: 1 cm. Photos: P. Chalermglin.

more sessile, whereas those in *M. alba* and *M. keithii* are stipitate, with stipes that are 6–15 mm and 3–3.5 mm long, respectively.

Mitrephora monocarpa also resembles the Bornean species *M. uniflora* Weeras. & R.M.K.Saunders in possessing solitary flowers (Weerasooriya and Saunders 2010), presumably as a result of the evolutionary reduction of the thyrsoid inflorescence, evident in other *Mitrephora* species.

Key to *Mitrephora* species in Thailand

1a Outer petals 37.5–53.5 × 22–53 mm; inner petals 28–43 × 22–41 mm; monocarps with 13–21 seeds. **2**

2a Leaf laminas glossy adaxially, with 8–11 pairs of secondary veins; flower pedicels 18–27 mm long; sepals 13.5–15.5 × 14–19.5 mm; outer petals 44–53.5 × 41–53 mm; inner petals 37–43 × 36.5–41 mm. ***Mitrephora sirikitiae* Weeras., Chalermglin & R.M.K.Saunders**

2b Leaf laminas matt adaxially, with 11–13 pairs of secondary veins; flower pedicels 10–15.5 mm long; sepals 7.5–10.5 × 7.5–11 mm; outer petals 37.5–40 × 22–29.5 mm; inner petals 28–32 × 22–24.5 mm. ***Mitrephora winitii* Craib**

1b Outer petals 9.5–34.5 × 6.5–19 mm; inner petals 6–19 × 3–12.5 mm; monocarps with 4–10 seeds. **3**

3a Young branches sparsely pubescent. **4**

4a Flowers and fruits with a solitary carpel; monocarp sessile. ***Mitrephora monocarpa* R.M.K.Saunders & Chalermglin, sp. nov.**

4b Flowers and fruits with 12–16 carpels; monocarps stipitate. **5**

5a Flower pedicels 10–16 mm long; sepals 1.5–2.5 mm long; outer petals white, 10.5–15.5 mm wide; inner petals white with pink/purple margins, 9–14.5 × 5.5–11 mm; monocarps warty, with longitudinal ridge; stipes 6–15 mm long. ***Mitrephora alba* Ridl.**

5b Flower pedicels 4.5–9 mm long; sepals 3–4 mm long; outer petals yellow, 6.5–9.5 mm wide; inner petals yellow with pink margins, 7.5–9.5 × 4.5–6 mm; monocarps smooth, without longitudinal ridge; stipes 3–3.5 mm long. ***Mitrephora keithii* Ridl.**

3b Young branches densely pubescent. **6**

6a Inflorescence rachides with internodes that elongate, bearing > 3 flowers; 36–40 carpels per flower; monocarps not glaucous. ***Mitrephora vulpina* C.E.C.Fisch.**

6b Inflorescence rachides with internodes that do not elongate, bearing < 3 flowers; 8–17 carpels per flower; monocarps glaucous. **7**

7a Leaf laminas densely pubescent abaxially; sepals 5–9 × 5–9 mm; fruit pedicels densely pubescent; monocarps globose. ***Mitrephora tomentosa* Hook.f. & Thomson**

7b Leaf laminas subglabrous to sparsely pubescent abaxially; sepals 1.5–4 × 2–5.5 mm; fruit pedicels sparsely pubescent; monocarps obovoid or oblong. **8**

8a Leaf laminas matt adaxially, sometimes with domatia at axils of secondary veins abaxially; inner petals cream, 6–12.5 mm long, densely pubescent abaxially; 10–14 carpels per flower; fruit pedicels 15–39 mm long, sparsely pubescent; monocarps without longitudinal ridge, densely pubescent. ***Mitrephora teysmannii* Scheff.**

8b Leaf laminas glossy adaxially, without domatia; inner petals purplish, 11–19 mm long, sparsely pubescent abaxially; 8–10 carpels per flower; fruit pedicels 10–16 mm long, densely pubescent; monocarps with longitudinal ridge, sparsely pubescent. ***Mitrephora wangii* Hu**

Acknowledgements

We are very grateful to Roy Erkens for reviewing the manuscript and Laura Wong for general technical assistance.

References

Chatrou LW, Pirie MD, Erkens RHJ, Couvreur TLP, Neubig KM, Abbott JR, Mols JB, Maas JW, Saunders RMK, Chase MW (2012) A new subfamilial and tribal classification of the pantropical flowering plant family Annonaceae informed by molecular phylogenetics. Botanical Journal of the Linnean Society 169(1): 5–40. https://doi.org/10.1111/j.1095-8339.2012.01235.x

Endress PK (1985) Stamenabszission und Pollenprasentation bei Annonaceae. Flora 176(1–2): 95–98. https://doi.org/10.1016/S0367-2530(17)30105-6

Guo X, Tang CC, Thomas DC, Couvreur TLP, Saunders RMK (2017) A mega-phylogeny of the Annonaceae: Taxonomic placement of five enigmatic genera and recognition of a new tribe, Phoenicantheae. Scientific Reports 7(1): 7323. https://doi.org/10.1038/s41598-017-07252-2

Okada H (2014) Three new species of Annonaceae from West Kalimantan, Indonesian Borneo. Acta Phytotaxonomica et Geobotanica 65: 17–24.

Pang CC, Saunders RMK (2014) The evolution of alternative mechanisms that promote outcrossing in Annonaceae, a self-compatible family of early-divergent angiosperms. Botanical Journal of the Linnean Society 174(1): 93–109. https://doi.org/10.1111/boj.12118

Saunders RMK (2010) Floral evolution in the Annonaceae: Hypotheses of homeotic mutations and functional convergence. Biological Reviews of the Cambridge Philosophical Society 85: 571–591. https://doi.org/10.1111/j.1469-185X.2009.00116.x

Weerasooriya AD, Saunders RMK (2005) The genus *Mitrephora* (Annonaceae) in Cambodia, Laos, and Vietnam. Systematic Botany 30(2): 248–262. https://doi.org/10.1600/0363644054223602

Weerasooriya AD, Saunders RMK (2010) Monograph of *Mitrephora* (Annonaceae). Systematic Botany Monographs 90: 1–167. [+ pl. 1–4]

PhytoKeys 121: 81–131 (2019)
doi: 10.3897/phytokeys.121.29924
http://phytokeys.pensoft.net

CHECKLIST

A peer-reviewed open-access journal
PhytoKeys
Launched to accelerate biodiversity research

A checklist of rheophytes of Cameroon

Felix Kuetegue[1], Bonaventure Sonké[1,2], Gabriel K. Ameka[3]

1 *Plant Systematic and Ecology Laboratory, Higher Teachers´ Training College, University of Yaoundé I, P.O. Box 047, Yaoundé, Cameroon* **2** *International Joint Laboratory DYCOFAC, IRD-UYI-IRGM, BP1857, Yaoundé, Cameroon* **3** *Department of Plant and Environmental Biology, University of Ghana, P. O. Box LG 55, Legon, Accra, Ghana*

Corresponding author: *Gabriel K. Ameka* (gameka@ug.edu.gh)

Academic editor: *Sandra Knapp* | Received 20 September 2018 | Accepted 21 February 2019 | Published 9 May 2019

Citation: Kuetegue F, Sonké B, Ameka GK (2019) A checklist of rheophytes of Cameroon. PhytoKeys 121: 81–131. https://doi.org/10.3897/phytokeys.121.29924

Abstract

Rivers in Cameroon were surveyed to collect and document rheophytic plants. Rheophytes are the dominant aquatic macrophytes in tropical river systems, where they are adapted to extreme environments of rushing water (e.g., river rapids, waterfalls and flash floods). Rheophytic plants are useful indicators of river health. However, their habitats are threatened by human activities such as agriculture, plantation development, alluvial mining and dam construction, particularly in tropical countries. In this survey we documented 66 rheophytic species in 29 genera and 16 families. Two ferns, 8 monocotyledons and 56 dicotyledons were listed. Apart from the Podostemaceae family in which all species are rheophytic, the other 15 families have few species which are rheophytic. Five of these families have up to four species and the remaining 10 have only one member as a rheophytic species. The conservation status of each species is assessed and discussed. This work urges botanists, conservationists, and policy makers to do more to protect the habitats of rheophytes and put in place strategies and action plans for the conservation of this important biological group.

Keywords

Cameroon, conservation, distribution, inventory, Rheophyte diversity

Introduction

Rheophyte, a term coined by van Steenis in 1932 (van Steenis 1978), is used to describe an aquatic plant which is in nature restricted to swift-running rivers and streams and grows up to flood level, but not beyond the reach of regularly occurring flash floods

(van Steenis 1978, 1981). Rheophytes occur worldwide but are found particularly in evergreen rain forests, where they are the dominant aquatic macrophytes in tropical river systems (van Steenis 1978, Quiroz et al. 1997, Ameka 2000, Hoyos-Gomez and Bernal 2018). Members of this biological group of plants are not necessarily taxonomically related, but they show a common adaptation to a restricted ecological habitat or environmental factors (van Steenis 1981, Ameka 2000, Ameka et al. 2002, Hoyos-Gomez and Bernal 2018). Rheophytes are adapted to extreme environments of rushing water by having lanceolate leaves, slender and flexible but tough stems, and strong usually fibrous, root systems (Hoyos-Gomez and Bernal 2018). These plants are generally perennial herbs or shrubs, sometimes small to medium trees, while few grow into tall trees. Two categories of rheophytes are recognized: (i) obligate and, (ii) facultative rheophytes (e.g., Ameka et al. (2002)). Obligate rheophytes are confined to waterfalls, streams and river-beds and banks, and below the flood level. Facultative types are found not only in river-beds but also occur in wet places where they are not subjected to fast-flowing water. In this work, rheophytic plants or rheophytes refer to obligate rheophytes.

Twenty-one rheophytic species, excluding the Podostemaceae, were recognized in tropical Africa, in a worldwide census of rheophytes by van Steenis (1981). Earlier in an assessment of rheophytic plants in South Africa, van Steenis (1978) recognized 7 species, again excluding the Podostemaceae. According to Ameka et al. (2002), in a survey of rivers, for rheophytes, in southern Ghana, from 1994 to 2000, 15 species including four Podostemaceae were recorded. Surprisingly, woody rheophytes were not encountered in the survey by Ameka et al. (2002) although van Steenis (1981) had earlier indicated that half of all rheophytes worldwide are woody. In their work on rheophytes of southern Ghana, Ameka et al. (2002) also reviewed rheophytes of Africa but relied only on records from the literature. Their review revealed that ca. 114 species including 73 Podostemaceae species were documented as rheophytes in Africa. Regarding distribution by country, Cameroon was reported to have 53 rheophytes including 33 Podostemaceae; South Africa 7 rheophytes and 3 Podostemaceae; and Nigeria 19 rheophytes including 4 Podostemaceae (Ameka et al. 2002). The known number of rheophytic plants recorded for Africa (including Cameroon, Ghana, Nigeria and South Africa) probably underestimates the actual number and reflects the degree of paucity of information, and lack of systematic collection effort of Podostemaceae and other rheophytic plants in African countries.

A survey to document and study the rheophytes of Cameroon is important for a number of reasons: (i) rheophytes are poorly known in tropical Africa, including Cameroon, compared to South East Asia and South America, according to van Steenis (1981), (ii) they are the dominant aquatic macrophytes in rivers; and are useful biological indicators of river health, and (iii) the diversity of rheophytes is threatened and some species are in danger of disappearing by the increased land-use practices adjoining the rivers, particularly for agriculture, plantation development, and illegal logging; and in the river courses for alluvial mining (e.g., gold and diamond), and also damming of rivers for hydropower in tropical countries. The

construction of dams causes destruction of the habitats of rheophytes, particularly the Podostemaceae.

The survey to enumerate and document the rheophytes of Cameroon was conducted from 2010 to 2014; and the rheophytic species encountered are reported here. It is hoped that this work will stimulate further research on rheophytes across the rest of tropical Africa. We draw attention to the urgent need to stop the destruction of habitats of rheophytes and rather map out strategies and action plans for the conservation of this important biological group.

Materials and methods

The study site

A survey of rheophytes was carried out in Cameroon, situated between 2°–13°N and 9°–16°E (Fig. 1). Cameroon is generally divided into three main climatic zones: Equatorial climate zone, (2°–6°N), characterized by an annual average precipitation of 2000 mm, and an average temperature of about 25 °C; the Sudanese climate zone, (6°–10°N), characterized by 5–6 months of dry season with an average temperature of about 22 °C, and 1000 mm of precipitation; and the Sudano-Sahalian climate zone, (10°N–13°N), characterized by 7 months of dry season and 400–900 mm of precipitation (Olivry 1986, Munang et al. 2008). From north to south Cameroon, the vegetation ranges from steppe zone, savannah zone, and to forest zone.

The central and western parts of Cameroon are dominated by high mountains and plateaus (Segalen 1967, Suchel 1972, Ndoh et al. 2016). The high western range has peaks which vary in elevation e.g., Mt Etinde (1474 m), Mt Mwoanenguaba (2396 m), Mt Kupe (2050 m), Mt Bamboutos (2740 m) with the highest elevation at Mt Cameroon (4095 m) (Letouzey 1985, Cheek et al. 2004, Sainge 2017). The Adamawa or Central High plateau reaches up to 1500 m (Suchel 1972). Both the western range and the Central High plateau are the result of volcanic and tectonic activities giving rise to faults, volcanic cones and volcanic lakes. These two sectors constitute the main watersheds of Cameroon's drainage systems. The southern section of the country is dominated by a plateau (500 to 900 m) which gently slopes to the east (Congo basin) but falls by steps to the Atlantic coast (Suchel 1972). While the far north is dominated by the lake Chad Basin (Suchel 1972, Olivry 1986), its southern fringe is the River Benue basin, both of which present a monotonous relief. The narrow coastal zone is marked by unstable swamps, especially from the Wouri-Moungo basins to the Ndian-Akpa-Yafe basins (Suchel 1972, Olivry 1986).

Survey

In documenting the rheophytes of Cameroon, several rivers (Fig. 1) were visited during the dry season (November-February and July–August in the southern part of the

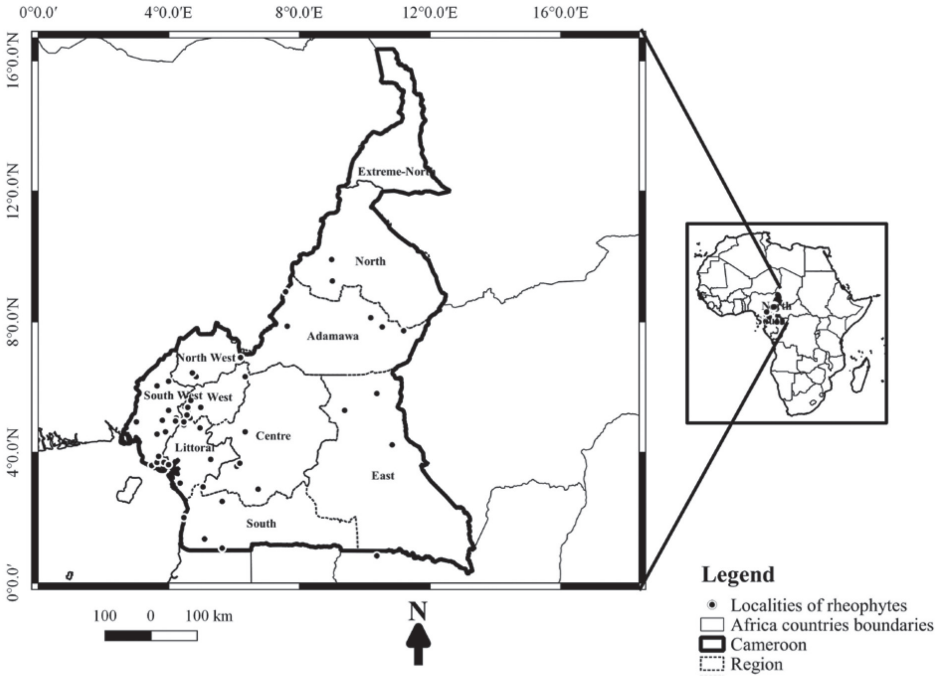

Figure 1. Map of Cameroon showing collecting localities of rheophytes.

country; and October–April in the northern part of the country). In the dry period, water levels recede in rivers and the majority of plants are in their reproductive phase. Sections of the rivers with rocky substrate were intensively sampled. The rheophytic status of some species were in doubt, particularly those on river banks and edge of rivers, such species and their localities were visited also during the wet season (March –June and July–October in the southern part of the country; May–September in the northern part of the country), when the water flow and level were high. This enabled us to determine whether a particular species is able to withstand spate, and is therefore rheophytic. Notes were taken on the habitat conditions, and characteristic rheophytic features of the species encountered, particularly the leaf shape and form, stem characteristics, and rooting system. Voucher specimens of each taxon collected were deposited in the Cameroon National Herbarium in Yaoundé (YA), [YA, acronym, Thiers (2017)]. Voucher specimens were not collected for every rheophyte species (particularly the Podostemaceae) encountered in the field. This is because such species were common and voucher specimens already exist for them. In cases where voucher specimens were not collected, notes were taken to indicate presence of the rheophytic species at the locality.

Voucher specimens in YA were also consulted for rheophytes already collected from Cameroon. The Flora of West Tropical Africa (Keay 1954, 1958, Hepper

1963, 1968, 1972) and other published works on rheophytes (e.g., van Steenis 1978, van Steenis 1981, Ameka et al. 1996, Ameka, et al. 2002), and from the study area (e.g., Hooper (1972), Duncan (1986), Cusset (1987), Cable and Cheek (1998), De Block (1998), Pollard and Paton (2001), Cheek et al. (2004), Brooks et al. (2011), Ghogue (2011), Onana and Cheek (2011), Cheek et al. (2017a), and Cheek et al. (in press)), were also referred to, and used to confirm the identification of rheophyte species collected, and in the compilation of a rheophytic checklist for Cameroon. In addition, the following websites were also consulted: http://www.worldchecklistofplants.org; http://www.ipni.org; http://www.plantlist.org; http://www.iucnredlist.org.

Distribution maps of rheophytes of Cameroon were done using georeferenced specimen data derived from specimen labels or available literature, and our own field surveys. The conservation status of each species was assessed by calculating the extent of occurrence (EOO) and the area of occupancy (AOO) in Cameroon using GeoCAT (Geospatial Conservation Assessment tool; Bachman et al. 2011) and applying The IUCN Red List Categories and Criteria, version 10.1 (IUCN 2013, IUCN Standards and Petitions Subcommittee 2017). The AOO was calculated based on a user defined grid cell of 2 km. The number of 'locations' (as defined by IUCN 2017) was calculated with regard to each particular threat, such that a single 'location' may encompass more than one adjacent subpopulation. The term subpopulation is used according to IUCN (2017). The Red Data Book of the Flowering Plants of Cameroon: IUCN Global Assessments (Onana and Cheek 2011), Ghogue (2011), and the online IUCN Red List (http://www.iucnredlist.org) were consulted while determining the conservation status of the species in this study. Our conservation assessments are yet to be submitted to IUCN and as such these assessments should be treated as "preliminary conservation assessments".

Results

The list of rheophytes identified during the study is presented as a checklist organized by families, and each entry consists of the following:

(i) Species name, authority and place of publication
(ii) Synonym(s) where applicable
(iii) Type, followed by Basionym where applicable
(iv) Description
(v) Specimens examined
(vi) Habitat
(vii) Distribution
(viii) Conservation status in Cameroon

Checklist of rheophytes from Cameroon

The checklist of rheophytes of Cameroon contains 16 families and 66 species. The rheophytic species listed may be placed in two categories: in the first category are families in which few species are rheophytic and in the second category are families in which all species are rheophytic. The former category has 15 families, 17 genera, and 23 species, while the latter category contains only the Podostemaceae family with 12 genera and 43 species.

Families in which few species are rheophytic

Pteridophytes (ferns)

Lomariopsidaceae

***Bolbitis fluviatilis* (Hook.) Ching, Index Filic. Suppl. Tert. 48 (1934)**

Acrostichum fluviatile Hook., Sp. Fil. 5: 274 (1864)
Acrostichum phanerodictyon Baker, Bol. Soc. Brot. 4: 156, t. 2 (1886)
Leptochilus fluviatilis (Hook.) C.Chr., Index Filic. 10, 385 (1905)

Type. Equatorial Guinea, Fernando Po (Bioko), *G. Mann 442* (K, K000435773).

Description. Herbaceous, rhizome creeping, with opaque, castaneous scales; fixed to rocks by roots; sterile fronds lanceolate, up to 85 cm long; fertile fronds up to 90 cm long with sporangia on lower surface.

Specimens examined. 15 km southeast of Zingui, 14 Mar 1968, *R. Letouzey 9031* (YA); near Ababendoman, 65 km southeast of Ebolowa, 00 Jan 1970, *R. Letouzey 9958* (YA); Muanenguba Mts. northeast of Nkongsamba, 4°58'N, 9°53'E, 11 Dec 1971, *A. J. M. Leeuwenberg 8848* (YA).

Habitat. Rocky riverbeds and streams, and rocky borders of streams and rivers; in evergreen rainforest.

Distribution. Cameroon (Fig. 2), Democratic Republic of Congo, Gabon, Ghana, and Liberia.

Conservation status in Cameroon. *Bolbitis fluviatilis* is not listed on http://www.iucnredlist.org nor in Onana and Cheek (2011). The species is currently known from five localities. The extent of occurrence (EOO) is more than 20,000 km^2, and the area of occupancy (AOO) is about 20 km^2. Some collecting localities of the species are within the Cameroon Development Corporation (CDC) palm tree plantations, and other localities are proposed for plantation development. Based on this threat, extent and/or quality of the habitat of the species *B. fluviatilis* is here assessed as Endangered. IUCN Red List Category: **Endangered ENB2ab (ii, iii).**

***Bolbitis heudelotii* (Bory ex Fée) Alston, J. Bot. 72 (Suppl. 2): 3 (1934)**

Gymnopteris heudelotii Bory ex Fée, Mém. Foug., 2. Hist. Acrostich. 84: 45, t. 45 (1845)
Leptochilus heudelotii (Bory ex Fée) C.Chr., Index Filic. 11, 385 (1905)

Type. Guinea Conakry, Fouta Djallon, in herb Bory, *Heudelot 803* (holotype: P).

Description. Herbaceous, rhizome thick with dark brown scales and creeping on rocks; numerous roots; sterile fronds 30–80 cm long, linear to elliptical; fertile fronds 25–100 cm, long, linear, abaxial surface with sporangia.

Specimens examined. Pangar River, at Tapare (Dang Assoura), 5°22'N, 13°31'E, 11 Feb 1961, *R. Letouzey 3452* (YA); Maan, 24 km southeast of Nyabesan, 00 Feb 1963, *J. & A. Raynal 10264* (YA); East of Kribi on Kienke River, 2°56'N, 9°55'E, 05 Apr 1969, *J. J. Bos 4282* (YA); Limbe at Limbe River, 4°2'N, 9°12'E, 13 Jan 2011, *F. Kuetegue 412, 414* (YA).

Habitat. Riverbeds of perennial streams; edge of waterfalls; seasonally flooded in swift-flowing rivers or streams, able to withstand spate; in rainforest.

Distribution. Widespread in tropical Africa. Angola, Benin, Cameroon (Fig. 3), Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of Congo, Ghana, Guinea, Malawi, Mali, Mozambique, Nigeria, Sierra Leone, Tanzania, Togo, Zambia, and Zimbabwe.

Conservation status in Cameroon. *Bolbitis heudelotii* is not listed on http://www.iucnredlist.org nor in Onana and Cheek (2011). The extent of occurrence of this species is about 102,900 km^2 with an area of occupancy of about 32 km^2. The species is currently known from 8 localities. The main pressures on the habitats are logging; dam construction (i.e. Lom-Pangar Hydro-electric dam, between Lom and Pangar) and expansion of cocoa farms. Based on these threats, extent and/or quality of habitat *B. heudelotii* is here assessed as Vulnerable. IUCN Red List Category: **Vulnerable VUB2ab (ii, iii).**

Acanthaceae

***Lepidagathis alopecuroides* R.Br. ex Griseb., Fl. Brit. W. I. 453 (1862)**

Adenosma chenopodiifolia (Poir.) Spreng., Syst. Veg. ed. 16, 2: 829 (1825)
Aetheilema alopecuroidea (Vahl) Spreng., Syst. Veg. 2: 826 (1825)
Ruellia alopecuroidea Vahl, Eclog. Amer. 2: 49 (1798)
Ruellia chenopodiifolia Poir., Encycl. 6(1): 339 (1804)
Teliostachya alopecuroidea Nees, Prodr. 11: 263 (1847)

Type. Sierra Leone, by Scaries River, 1891, *G. F. Scott Elliot 4533* (K, K000529239).

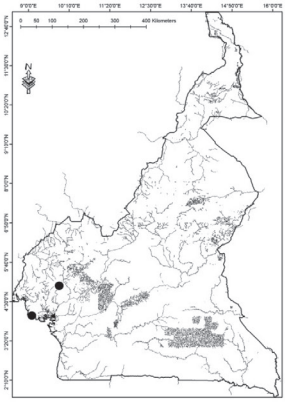

Fig. 2. •*Bolbitis fluviatilis* (Hook.) Ching

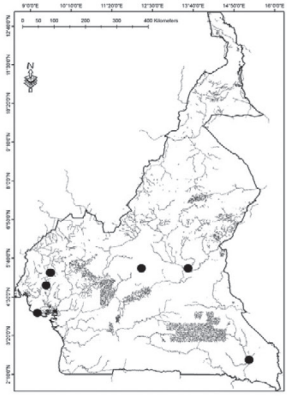

Fig. 3. •*Bolbitis heudelotii* (Bory ex Fée) Alston

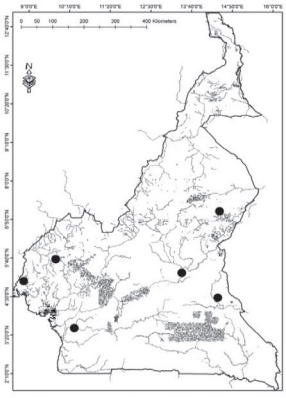

Fig. 4. •*Lepidagathis alopecuroides* (Vahl) R.Br. ex Griseb.

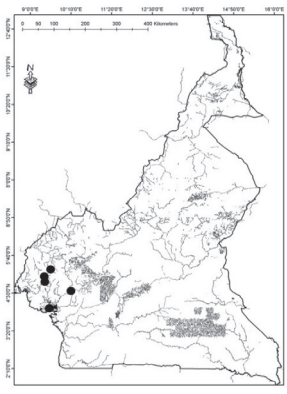

Fig. 5. •*Achyranthes talbotii* Hutch & Daziel

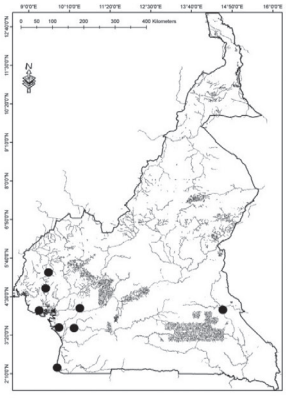

Fig. 6. •*Crinum natans* Baker

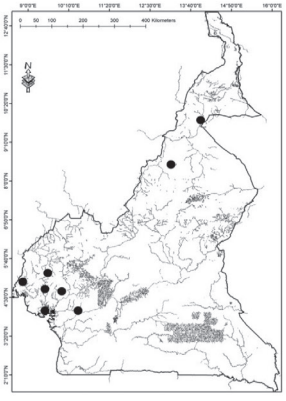

Fig. 7. •*Kanahia laniflora* (Forssk.) R.Br.

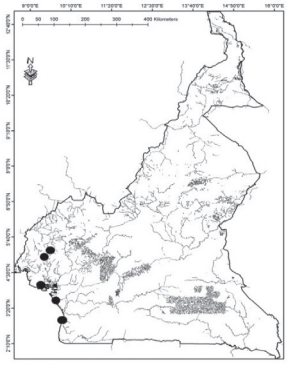

Fig. 8. •*Anubias barteri* Schott

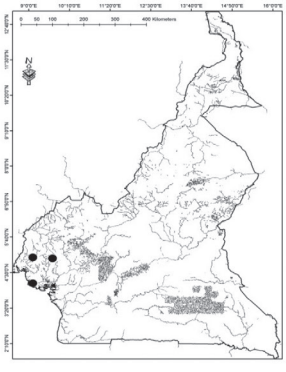

Fig. 9. •*Cyperus rheophyticus* Lye

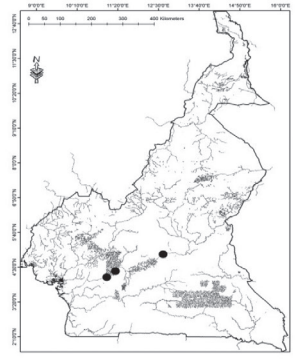

Fig. 10. •*Cyperus tonkinensis* C.B.Clarke var. *baikiei* (C.B.Clarke ex Kük.) S.S.Hooper.

Figures 2–10. 2 *Bolbitis fluviatilis* (Hook.) Ching **3** *Bolbitis heudelotii* (Bory ex Fée) Alston **4** *Lepidagathis alopecuroides* R.Br. ex Griseb. **5** *Achyranthes talbotii* Hutch & Daziel **6** *Crinum natans* Baker **7** *Kanahia laniflora* (Forssk.) R.Br. **8** *Anubias barteri* Schott **9** *Cyperus rheophyticus* Lye **10** *Cyperus tonkinensis* C.B.Clarke var. *baikiei* (C.B.Clarke ex Kuk) S.S.Hooper.

Description. Herb, slender, flexible, decumbent and branching stems, with lanceolate leaves 5.0–6.5 × 0.4–0.6 cm; strong fibrous root system; pink or purplish flowers.

Specimens examined. 40 km northwest of Moloundou on Dja River, 18 Mar 1973, *R. Letouzey 12132* (YA); Ndian 50 m on bank of Mana River, 4°58'N, 8°51'E, 09 Dec 1983, *D. W. Thomas 2659* (YA); Mundemba on Mana River, 11 Jan 1998, *M. Cheek 8850* (YA).

Habitat. Rocky and sandy riverbeds or on the banks of rivers and streams; in rainforest.

Distribution. Benin, Cameroon (Fig. 4), Côte d'Ivoire, Gabon, Ghana, Guinea and Nigeria.

Conservation status in Cameroon. *Lepidagathis alopecuroides* is not listed on http://www.iucnredlist.org nor in Onana and Cheek (2011). The extent of occurrence of this species is estimated at 124,600 km^2 and has an area of occupancy of about 20 km^2. The taxon is currently known from five localities. Construction of dams are in progress at two sites for this species: a hydroelectric dam at Natchigal on the Sanaga River; and another on the Dja River, and if fully operational the habitat of *L. alopecuroides* may be destroyed. Based on these threats, and the fact that the species is only known from five localities, *L. alopecuroides* is here assessed as Endangered. IUCN Red List Category: **Endangered ENB2ab (ii, iii).**

Amaranthaceae

Achyranthes talbotii Hutch. & Dalziel, Fl. W. Trop. Afr. 1: 127 (1927)

Type. Nigeria, *Keay, R. W. J. FHIFHI 28284* (holotype: K, K000243718).

Description. Perennial herb with soft woody stem to 45 cm tall; strong fibrous root system; lanceolate leaves 2–4 × 1–1.5 cm.

Specimens examined. Near Ndokman II, approximately 8 km east of Yingui or 35 km east of Yabassi, 4°34'N, 10°10'E, 00 Jan 1972, *R. Letouzey 10938* (YA); bank of Nkam River, near Sake, 3 km southwest of Nkondjok, 4°77'N, 10°17'E, 07 Jan 1972, *R. Letouzey 11163* (YA); Mumgo River, Kumba-Loum road, 2°49'N, 9°33'E, 00 Jan 1981, *Breyne 5062* (YA); Kombon at the bank of Kombon River, 4°59'N, 9°26'E, 23 Mar 2011, *F. Kuetegue 316* (YA).

Habitat. Sandy and rocky riverbeds or up to flood level on the bank, in rainforest.

Distribution. Cameroon (Fig. 5) and Nigeria.

Conservation status in Cameroon. *Achyranthes talbotii* was assessed by Cheek (2014) globally as Near Threatened (NT) at http://www.iucnredlist.org. The species was, however, assessed by Onana and Cheek (2011) for Cameroon as Vulnerable, since at that time it was known from only 10 sites. The taxon is currently known from about 25 localities. The extent of occurrence is estimated to be above 20,000 km^2 and the area of occupancy is about 100 km^2. At some localities, road construction and arable farming are in progress but on a limited scale. Although the habitat of the species is

under pressure, it does not appear to qualify as threatened under the IUCN red list criteria (IUCN 2013, 2017). While the expectation is that human pressure will increase the loss of habitat, and reduce the area of occupancy and extent of occurrence, it is not anticipated these threats will be significant. *A. talbotii* is here reassessed as of Least Concern. IUCN Red List Category: **Least Concern (LC).**

Amaryllidaceae

***Crinum natans* Baker., Fl. Trop. Afr. 7 (3): 396 (1898)**

Crinum natans Baker subsp. *inundatum* Kwembeya & Nordal; Phylogeny Speciation Biogeogr. Crinum Chlorophytum 3:16 (2008)

Type. Equatorial Guinea, Fernando Po (Bioko), *G. Mann 1416* (lectotype: K; isotype: P).

Description. Herb with small bulb, very strong root system; leaves crinkled, submerged and floating, 140 × 2.2 cm; flowers large, borne above the water.

Specimens examined. 15 km north of Edea, near the bridge, 22 Jan 1969, *J. J. Bos 1969* (YA); Balondo, 25 km southwest of Nkongsamba, 4°43'N, 9°51'E, 00 Mar 1976, *R. Letouzey 14441* (YA); Soo village, near bridge on Soo River, 3°20'N, 11°30'E, 06 Apr 1977, *Inger Nordal 906* (YA); Diongo (Kumba – Nguti road) on bank of Mengue River, 4°45'N, 9°29'E, 21 Mar 2011, *F. Kuetegue 507* (YA).

Habitat. Bed of swift-flowing perennial streams and rivers, submerged permanently, strong fibrous root system, in sand, silt or gravel riverbeds; in evergreen rainforest.

Distribution. Cameroon (Fig. 6), Côte d'Ivoire, Gabon, Ghana, Guinea, Liberia, Nigeria, and Sierra Leone.

Conservation status in Cameroon. *Crinum natans* was not listed on http://www.iucnredlist.org nor assessed by Onana and Cheek (2011). The taxon is currently known from 10 localities. The extent of occurrence of *C. natans* is about 92,850 km^2 and the area of occupancy is about 40 km^2. Human activities at the localities include timber exploitation; and planned mining operations, hydroelectric dams and plantation development. Based on these threats, and the continuous decline of the vegetation cover in the area, extent and/or quality of its habitat, the species is here assessed as Vulnerable. IUCN Red List Category: **Vulnerable VUB2ab (ii, iii).**

Asclepiadaceae

***Kanahia laniflora* (Forssk.) R.Br., Voy. Abyss. App.: Ixiv (1814)**

Asclepias coarctata S.More, J. Bot. 46: 297 (1908)
Asclepias fluviatilis A.Chev., Bull. Soc. Bot. France 61(8): 271 (1917)

Asclepias laniflora Forssk., Fl. Aegypt.-Arab. 51 (1775)
Asclepias rivalis S.More, J. Bot. 52: 337 (1914)
Gomphocarpus glaberrimus Oliv., Trans. Linn. Soc. London 29(3): 110 (1875)
Kanahia consimilis N.E.Br., Fl. Trop. Afr. 4(1.2): 298 (1902)
Kanahia glaberrima (Oliv.) N.E.Br., Fl. Trop. Afr. 4(1.2): 297 (1902)

Type. Cameroon, *G. L. Bates 322* (lectotype: K, K000234855).

Description. Erect woody shrub, up to 2 m high; leaves linear-lanceolate 4–15 × 0.5–1.0 cm, glabrous; inflorescence axillary, one per node between leaf bases; flowers creamy white.

Specimens examined. Dibombe River, 4°41'N, 9°48'E, 16 Mar 1965, *A. J. M. Leeuwenberg 9708* (YA); bank of UVE River, 20 km northwest of Kumba, 20 Mar 1976, *R. Letouzey 38378* (YA); Mundemba, on Ndian (Mana) River, 4°58'N, 8°51'E, 09 Dec 1983, *D. W. Thomas* 2656 (YA); Ntale, bank and bed of Mbier River, 10 Dec 2010, *F. Kuetegue 272, 273* (YA).

Habitat. Rocky or sandy riverbeds and by seasonal rivers, in wet evergreen and semi-deciduous rainforests to deserts.

Distribution. Benin, Cameroon (Fig. 7), Côte d'Ivoire, Nigeria, Somalia, South Africa, and Sudan.

Conservation status in Cameroon. *Kanahia laniflora* was not assessed by Onana and Cheek (2011). It is listed on http://www.redlist.org as Least Concern (LC) by Lansdown (2013). This is because the species, globally, is believed to be widespread and abundant throughout much of its known distribution area. The species is distributed from Saudi Arabia and Yemen, through Ethiopia and Somalia to Cote d'Ivoire and South Africa. The extent of occurrence of *K. laniflora* in Cameroon is about 78,700 km^2; and area of occupancy of the species is about 32 km^2. The taxon is currently known from 8 localities in the country. The localities where the species is found are proposed for timber exploitation and plantation development. Based on these threats and the progressive destruction of the vegetation in the localities, extent and/or quality of the habitats, the species is here assessed, as Vulnerable. IUCN Red List Category: **Vulnerable VUB2ab (ii, iii).**

Araceae

Anubias barteri Schott, Prodr. Syst. Aroid. 159 (1860)

Type. Equatorial Guinea, Fernando Po (Bioko), *Barter 2045* (K).

Description. Hardy herb with thick creeping rhizome, prostrate; strongly rooted; green, lush, narrow shaped leaves 7–30 × 3–15 cm.

Specimens examined. Fenda, 60 km southeast of Kribi, 22 Jan 1962, *R. Letouzey 4120* (YA); Nyon River, 49 km southwest of Eseka, 12 Mar 1965, *A. J. M. Leeuwenberg 5136* (YA); road from Ebone to Yabassi at mile 10, 27 Dec 1967, *P. Bamps 1636*

(YA), Nguti-Kombon, bank of Kombon River, 5°13'N, 9°33'E, 13 Dec 2010, *F. Kuetegue 239* (YA).

Habitat. Rocky beds of swift-flowing streams and rivers, or wet shrubby and bushy bank of rivers and streams; in rainforest.

Distribution. Cameroon (Fig. 8), Congo, Côte d'Ivoire, Gabon, Guinea, Liberia, and Nigeria.

Conservation status in Cameroon. *Anubias barteri* is listed on http://www.iucnredlist.org as Least Concern (LC) in central Africa in 2007 by Ghogue (2010a). The species was not assessed by Onana and Cheek (2011). The taxon is currently known from 16 localities. The extent of occurrence of *A. barteri* is about 7,600 km^2 and has an area of occupancy of about 64 km^2. The habitat is mainly threatened by urban development, road constructions and hydroelectric dams already built or at project stage. Despite the threats, and the fact that the habitats are under pressure, the species does not appear to qualify as threatened under the IUCN red list criterion (IUCN 2017). Though human pressure is expected to increase the loss of habitat and reduce area of occupancy and extent of occurrence (EOO), it is not expected that this will be significant. It is possible that the EOO was underestimated because only specimens with geographical coordinates were used to estimate the EOO. Based on these observations, *A. barteri* is assessed here as Near Threatened. IUCN Red List Category: **Near Threatened (NT).**

Cyperaceae

Cyperus rheophyticus Lye, Nordic J. Bot. 24 (3): 273 (2006)

Type. Cameroon, South West Division, Kupe-Muanenguba Division, Muambong, bank of Chide River, 3°58'N, 9°41'E, 02 Aug 1998, *J.-M. Onana 585*, (holotype: K; isotype: YA).

Description. Perennial herb, 30–50 cm high; deeply rooted; inflorescence terminal, with involucre bracts.

Specimens examined. Kodmin, beside a stream, 4°59'N, 9°42'E, 21 Nov 1998, *M. Etuge 406* (YA).

Habitat. Forest streams and rivers, submerged during wet season.

Distribution. Cameroon (Fig. 9).

Conservation status in Cameroon. *Cyperus rheophyticus* is listed on http://www.iucnredlist.org as Vulnerable in 2017 (Cheek et al. 2017b). The taxon is currently known from five localities, and endemic to Cameroon. The extent of occurrence of this species is about 3,000 km^2 and area of occupancy is about 20 km^2. The localities where they occur are proposed for plantation development, timber exploitation and road construction. Not much has changed since the last assessment of Cheek et al. (2017b); here we maintain its status as Vulnerable. IUCN Red List Category: **Vulnerable B1ab (iii) +2ab (iii).**

***Cyperus tonkinensis* C.B.Clarke var. *baikiei* (C.B.Clarke ex Kük) S.S.Hooper, Kew Bull. 26 (3): 577 (1972)**

Cyperus baikiei C.B.Clarke, Consp. Fl. Afr. [T.A. Durand & H. Schinz] 5: 550 (1894)
Cyperus kottensis Chem. Arch. Bot., Caen iv. Mem. No. 7, 23 (1931)

Type. Vietnam, Tonkin, Tu-Phap, 12 Apr 1888, *Balansa 2831* (K).

Description. Herb, about 12 cm high, with hard tubers, connected by dark brown rhizome; stems dark brown and shiny; inflorescence spikelets, glumes brown.

Specimens examined. 62 km southeast of Bafia, on Sanaga River, 4°75'N, 11°22'E, 27 Mar 1963, *J. & A. Raynal 10538* (YA); Sanaga River, bridge near Nkong Njok, 4°10'N, 11°01'E, 12 Mar 1978, *J. Lowe 3483* (YA); Bongossi Research Plot of the National Herbarium of Cameroon, bank of Sanaga River, 4°22'N, 11°16'E, 29 Mar 1987, *L. Ake Asse 1859* (YA); near Nguti, Mbombe on Loa River, 29 May 2011, *F. Kuetegue, 498* (YA).

Habitat. Sandy bars or beds of streams and rivers.

Distribution. Benin, Cameroon (Fig. 10), Central African Republic, Chad, Congo, Ghana, Guinea, Liberia, Mali, Nigeria, Senegal, and Sierra Leone.

Conservation status in Cameroon. *Cyperus tonkinensis* var. *baikiei* is not listed on http://www.iucnredlist.org nor assessed by Onana and Cheek (2011). The taxon is currently known from five localities. The extent of occurrence of this species is about 800 km^2 and the area of occupancy is about 20 km^2. Construction of a hydropower dam on the Sanaga River from which the species was collected is in progress. Based on this threat and the fact that the species is only currently known from five localities, *C. tonkinensis* var. *baikiei* is here assessed as Endangered. IUCN Red List Category: **Endangered ENB1+2ab (ii, iii)**.

***Cyperus cataractarum* K.Schum ex. Engl., Veg. Erde 9(2): 200 (1908)**

Pycreus cataractarum C.B.Clarke, Bot. Jahrb. Syst. 38(2): 132 (1906)

Type. Cameroon, Bipindi, 1899, *G. Zenker 1935* (syntype: BR, K, P, P00573020, WAG).

Description. Tufted, grass-like leaves forming high sods (up to 30 cm thick cushions); roots forming large fibrous tussocks; stems smoothly glossy; leaves linear, green to dark green; spikelets greenish-white; glumes with a green midrib.

Specimens examined. 27 km from Kribi in Kienké River, 2°52'N, 10°7'E, 27 Jan 1970, *J. J. Bos 6168* (YA); Mpoume waterfalls on Nyong River at Makak, 3°28'N, 11°01'E, 01 Jan 1978, *J. Lowe 3420* (YA); near Akonetyè village, Mboro waterfalls, 15 Jan 1978, *A. Koufani 20* (YA).

Habitat. Banks, edges and beds of streams and rivers; in rainforest.

Distribution. Cameroon (Fig. 11), Congo, Gabon and Nigeria.

Conservation status in Cameroon. *Cyperus cataractarum* is not listed on http://www.iucnredlist.org nor assessed by Onana and Cheek (2011). The taxon is currently known from 6 localities. The extent of occurrence of this species is about 13,400 km^2 and the area of occupancy is about 24 km^2. The habitat of *C. cataractarum* is being progressively destroyed by plantation development and timber exploitation. Based on these threats, and extent and/or quality of habitat, the species is currently assessed as Vulnerable. IUCN Red List Category: **Vulnerable VUB1+2ab (ii, iii).**

Lamiaceae

***Plectranthus cataractarum* B.J.Pollard, Kew Bull 56(4): 976 (2001)**

Type. Cameroon: Hunters path to Lake Njonji at side of seasonal watercourse, *M. Cheek 5563* (holotype: K; isotypes: MA, MO, SCA, WAG, YA).

Description. Annual or perennial herb growing to 60 cm tall; stems decumbent to ascending, sub-woody at the base; leaves slightly fleshy, 20–45(-70) × 5–20(-25) mm, 2–2.5 times as long as broad; inflorescence terminal.

Specimens examined. Etinde, Njonji, footpath from Cameroon Development Corporation oil palm plantations to the summit, 24 Nov 1993, *Williams 52* (K, SCA, WAG, YA); Bakossi Mts: Chutes de 'Ile Ndip Medschang, 21 Nov 1998, *Satabie 1109* (K, K000051130).

Habitat. Invariably growing in spray zone of waterfalls, on wet rocks or on river banks, up to flood level, of swift-running water; lowland or submontane evergreen forest, 300–1450 m alt.

Distribution. Cameroon (Fig. 12) and Equatorial Guinea.

Conservation status in Cameroon. *Plectranthus cataractarum* is listed on http://www.iucnredlist.org. The species was assessed as Vulnerable (Pollard and Paton 2003). Eight years later it was reassessed as Endangered (Onana and Cheek 2011). The taxon is currently known from three collecting localities. The extent of occurrence and the area of occupancy are both estimated to be less than 10 km^2. The associated threats, such as forest logging and plantation establishment, mentioned by Pollard and Paton (2003) are still ongoing. Based on these threats, and that the habitats are still under pressure, the species is here re-evaluated as Endangered. IUCN Red List Category: **Endangered ENB1+2ab (ii+iii).**

Melastomataceae

***Calvoa stenophylla* Jacq.-Fél., Bull. Mus. Natl. Hist. Nat., B, Adansonia Sér. 4, 3(2): 143 (1981)**

Type. Cameroon, 10 km Southeast of Zingui, 16 Mar 1968, *R. Letouzey 9083*. (Holotype: P; isotype: YA).

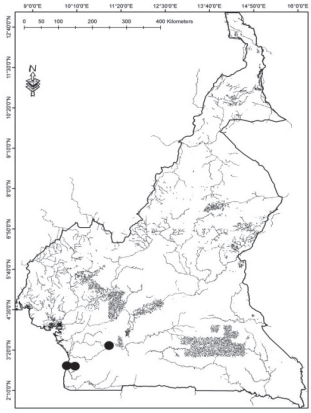

Fig. 11. •*Cyperus cataractarum* K.Schum. ex Engl.

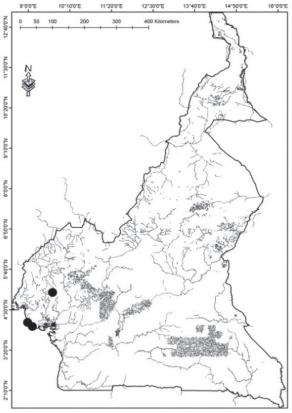

Fig. 12. •*Plectranthus cataractarum* B.J.Pollard

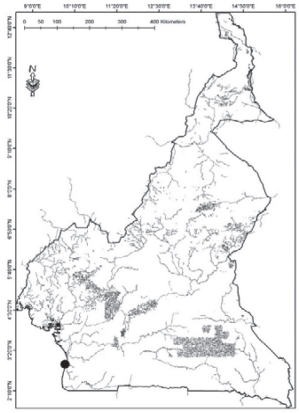

Fig. 13. •*Calvoa stenophylla* Jacq.-Fél.

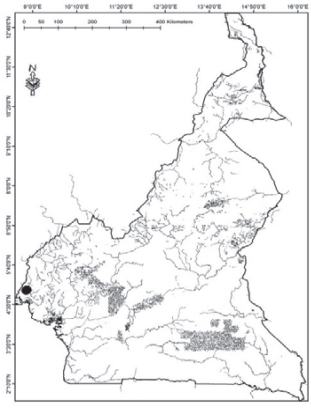

Fig. 14. •*Eugenia dusenii* Engl.

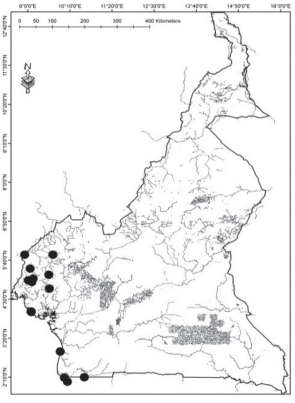

Fig. 15. •*Biophytum talbotii* (Baker f.) Hutch. & Dalziel

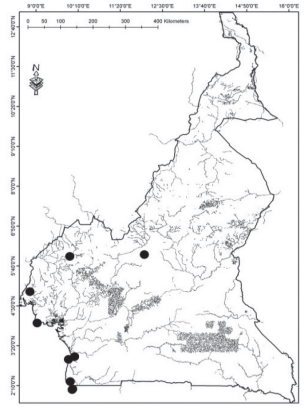

Fig. 16. •*Biophytum zenkeri* Guillaumin

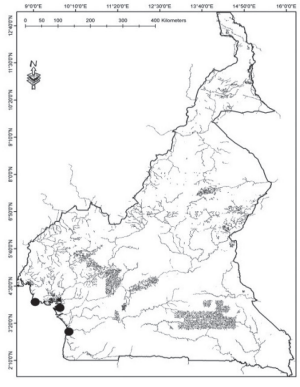

Fig. 17. •*Pandanus satabiei* Huynh

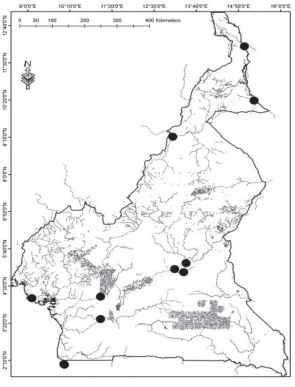

Fig. 18. •*Eragrostis barteri* C.E.Hubb.

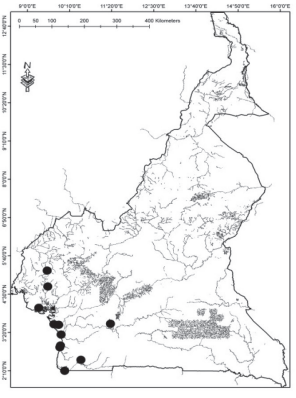

Fig. 19. •*Ixora euosmia* K.Schum

Figures 11–19. 11 *Cyperus cataractarum* K.Schum ex Engl. **12** *Plectranthus cataractarum* B.J.Pollard **13** *Calvoa stenophylla* Jacq.-Fél. **14** *Eugenia dusenii* Engl. **15** *Biophytum talbotii* (Baker f.) Hutch. & Dalziel **16** *Biophytum zenkeri* Guillaumin **17** *Pandanus satabiei* Huynh **18** *Eragrostis barteri* C.E.Hubb. **19** *Ixora euosmia* K.Schum.

Description. Small herb, about 20 cm high; stem flexible; roots spreading and fibrous; leaves narrow-lanceolate 4–6 × 0.2–0.5 cm; flowers terminal, pink.

Specimen examined. Minsomo River, 10 km southeast of Zingui, 2°56'N, 9°54'E, 16 Mar 1968, *R. Letouzey 9083* (YA).

Habitat. Rocks on bed of Minsomo River.

Distribution. Cameroon (Fig. 13) and Equatorial Guinea.

Conservation status in Cameroon. *Calvoa stenophylla* is listed on http://www.iucnredlist.org as Endangered (Cheek 2015). The species was assessed as Critically Endangered (Onana and Cheek 2011), since it was known from only one locality and the associated threats at the time. Cheek (2015) reassessed the species, globally as Endangered, since the number of localities has increased to two, and area of occupancy of 8 km^2. The second locality is in Equatorial Guinea (Cheek 2015). In Cameroon, the species is only known from one locality and the area of occupancy is about 4 km^2. The extent of occurrence (EOO) is estimated at 1 km^2, following the IUCN preferred grid cell size for aquatic organisms (IUCN 2013, 2017). This was used by Cheek et al. (2015) in assessing the conservation status of *Ledermanniella lunda* Cheek (Podostemaceae) from Angola. The main threats are forest logging and agriculture activities. Based on these threats, and the continuous decline of vegetation in the area, extent and /or quality of habitat *C. stenophylla* is here assessed, as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB2ab (ii, iii).**

Myrtaceae

Eugenia dusenii Engl., Notizbl. Königl. Bot. Gart. Berlin 2: 289 (1899)

Myrtus dusenii Kuntze, Deutsche Bot. Monatsschr. 21: 173 (1903)

Type. Cameroon. Mundemba, Mana bridge, 4°58'N, 7°00'E, 11 Jan 1998, *M. Cheek 8845* (holotype: K; isotype: YA).

Description. Small erect shrub, up to 1.5 m; stem very flexible; leaves small and narrow, 2–5 × 0.3–0.5 cm; strongly rooted; white-flowered.

Specimens examined. Ndian waterfalls at Bulu docks, 4°56'N, 8°51'E, 17 Jan 1985, *D. W. Thomas 1985* (YA); Ndian River, west of Mundemba, 5°02'N, 8°53'E, 21 Jan 1986, *J. Nemba & D. W. Thomas 319* (YA); Mundemba, Mana bridge, 4°58'N, 7°00'E, 11 Jan 1998, *M. Cheek 8845* (YA).

Habitat. Beds of swift-running rivers; seasonally inundated river banks; rocks at waterfalls, in evergreen rainforest.

Distribution. Cameroon (Fig. 14), endemic to Cameroon.

Conservation status in Cameroon. *Eugenia dusenii* is not listed on http://www.iucnredlist.org, but it was assessed as Vulnerable VU in Onana and Cheek (2011). The taxon is endemic to Cameroon and currently known from four localities. The area of occupancy is estimated to be about 16 km^2, and the extent of occurrence is estimated

at 4 km^2. Plantation development and illegal logging of timber are ongoing at the localities. Based on these threats, and the continuous decline of vegetation cover in the area, and extent and /or quality of habitat *E. dusenii* is currently reassessed as Endangered. IUCN Red List Category: **Endangered ENB2ab (ii, iii).**

Oxalidaceae

***Biophytum talbotii* (Baker f.) Hutch. & Dalziel, Fl. W. Trop. Afr. 1: 140 (1927)**

Biophytum kamerunense Engl. & R.Kunth ex Engl., Veg. Erde 9(3,1): 717 (1915)
Oxalis talbotii Baker f., Cat. Pl. Oban 16 (1913)

Type. Liberia, 02 Nov 1910, *Bunting, R. H. 103* (holotype: BM).

Description. Perennial herb, woody stem, up to 30 cm high; roots spreading; leaves in shape of umbrella; flowers pink.

Specimens examined. Njabilobé, 54 km southeast of Kribi, 12 Mar 1963, *J. & A. Raynal 10425* (YA); Kienke River, Kribi, 2°56'N, 9°55'E, 20 Jun 1969, *J. J. Boss 4900* (YA); near Numba, 45 km northeast of Mamfe, 5°50'N, 9°42'E, 18 Aug 1975, *R. Letouzey 14331* (YA); Mamfe road, near Numba, 16 Dec 2012, *F. Kuetegue 400* (YA) .

Habitat. Riverbeds and earthbanks of shaded forest streams, periodically inundated rocks in rivers; in rainforest.

Distribution. Cameroon (Fig. 15), Liberia and Nigeria.

Conservation status in Cameroon. *Biophytum talbotii* is not listed on http://www.iucnredlist.org nor assessed by Onana and Cheek (2011). The taxon is currently known from 13 localities. Extent of occurrence of this species is about 38,000 km^2 and the area of occupancy is about 56 km^2. Forest logging is the main threat at these habitats. Based on this threat and the continuous decline of vegetation cover in the area, extent and /or quality of habitat *B. talbotii* is here assessed as Vulnerable. IUCN Red List Category: **Vulnerable VU B2ab (ii, iii).**

***Biophytum zenkeri* Guillaumin, Notul. Syst. (Paris) 1: 26 (1909)**

Type. Cameroon, 01 Jan 1908, *G. Zenker 3428* (BM, BR, G; HBG, K, K000419376, M, P, W).

Description. Perennial herb, up to 30 cm tall, forming dense clumps; leaves in rosette or nearly so; flowers yellow.

Specimens examined. Cross River ferry between Ikom and Manfe, 07 Apr 1955, *J. K. Morton K318* (YA); Korup, rocky river bank of Mana River, 4°55'N, 8°50'E, 08 Jun 1983, *D. W. Thomas 2164* (YA); Ndian Division Mundemba, in Mana River, 5°00'N, 8°50' E, 21 Nov 1986, *Stephen D. Manning 896* (YA).

Habitat. In rock crevices in riverbeds, seasonally flooded; in forest.

Distribution. Angola, Cameroon (Fig. 16), Congo, Gabon and Nigeria.

Conservation status in Cameroon. Like the species before it, *Biophytum zenkeri* is not listed on http://www.iucnredlist.org. The taxon is currently known from 9 localities. The extent of occurrence of this species is about 80,000 km^2 and its area of occupancy is about 36 km^2. Plantation development is in progress at two of the localities and this may affect the survival of the species. Based on this threat, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat *B. zenkeri* is here assessed as Vulnerable. IUCN Red List Category: **Vulnerable VU B2ab (ii, iii).**

Pandanaceae

Pandanus satabiei Huynh, Bull. Mus. Natl. Hist. Nat., B, Adansonia Sér. 4, 6(3): 347 (1984)

Type. Cameroon, near the Ndonga River (30 km W Edea), 20 Dec 1973, *R. Letouzey 12472* (holotype: P; isotype: YA).

Description. Shrub or small tree of about 5 m tall; strongly rooted; leaves narrow 60–80 × 2–4 cm, spine on the borders; fruit green.

Specimens examined. Wouri River, near Bekoko, Douala-Nkongsamba road, 16 Jun 1983, *Satabie 674* (YA); bed of Dilolo River at Bolomeboka, Nkonyé, 4°51'N, 9°28'E, 22 Mar 2011, *F. Kuetegue 462* (YA); Mongo River at Mbakwa Super, Nkonyè, 5°01'N, 9°25'E, 24 Mar 2011, *F. Kuetegue 463* (YA).

Habitat. Banks of rivers subject to flooding.

Distribution. Cameroon (Fig. 17).

Conservation status in Cameroon. *Pandanus satabiei* was not assessed by Onana and Cheek (2011) nor listed on http://www.iucnredlist.org. The taxon is endemic to Cameroon and currently known from five localities. The extent of occurrence of this species is about 2,900 km^2 and the area of occupancy is about 20 km^2. Human settlements are developing around one collecting locality; also arable farming is in progress along the rivers. Based on these threats, and the continuous decline of vegetation cover in the area, extentand /or quality of habitat, *P. satabiei* is here assessed as Endangered. IUCN Red List Category: **Endangered EN B1+2ab (ii, iii).**

Poaceae

Eragrostis barteri C.E.Hubb., Fl. W. Trop. Afr. 2: 514 (1936)

Eragrostis fluviatilis A.Chev., Bull. Mus. Nalt. Hist. Nat. sér 2, 20: 472 (1948)

Type. Nigeria, 1858, *C. Barter 877* (syntype: K, K000366508; isotype: P).

Description. Perennial grass, robust, of about 1 m high; leaves lanceolate; inflorescence in open panicle.

Specimens examined. Nkokmen II, at 8 km east of Yingui, at the bank of Makombe River, 4°32'N, 10°15'E, 09 Jan 1972, *D. van der Zon 10939* (YA). Mpoumé falls on Nyong River, 9 km south of Makak 3°28'N, 11°00'E, 20 Jan 1977, *J. Lowe 3188* (YA); Sanaga River at Nkongnjok, 4°10'N, 11°01'E, 12 Jan 1978, *J. Lowe 3471* (YA); Kikot (Douala-Bafia road), near bridge, bank of Sanaga, 3°51'N, 11°30'E, 16 Dec 2012, *F. Kuetegue 535* (YA).

Habitat. Among rocks, and sandbanks on riverbed or streams.

Distribution. Cameroon (Fig. 18), Congo, Côte d'Ivoire, Ghana, Mali, Nigeria, Senegal and Sierra Leone.

Conservation status in Cameroon. *Eragrostis barteri* was not assessed by Onana and Cheek (2011), nor listed on http://www.iucnredlist.org. The taxon is currently known from 10 localities some of which are on the Sanaga River. The extent of occurrence of the species is about 260,000 km^2 and area of occupancy is about 44 km^2. The proposed dam on Sanaga River will destroy some habitats of the species. Based on this threat, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat, *E. barteri* is currently assessed as Vulnerable. IUCN Red List Category: **Vulnerable VU B2ab (ii, iii).**

Rubiaceae

***Ixora euosmia* K.Schum., Bot. Jahrb. Syst. 33(2): 355 (1903)**

Ixora degemensis Hutch. & Dalziel, Fl. W. Trop. Afr. 2: 86 (1931)

Type. Cameroon. Bipindi, bank of Lokoundje River, 02 Oct 1896, *G. Zenker 1108*, (holotype: K; isotypes: BR, HBG, MO, WAG, Z).

Description. Shrub or small tree up to 5 m tall; leaves narrowly elliptic-oblong 10–19 × 2–4.5 cm; inflorescence terminal.

Specimens examined. Lobe River, 7 km south of Kribi, 2°53'N, 9°54'E, 20 Feb 1969, *J. J. Bos 3940* (YA); Songloulou falls, at 25 km southwest of Ngambé, Massock-Songloulou road, 3°35'N, 9°44'E, 24 Jan 1972, *R. Letouzey 11103* (YA); 5 km southeast of Bipindi, 3°04'N, 10°25'E, 14 Jan 1987, *Stephen D. Manning 1343* (YA); Nguti-Ntalè, Mbièr River, 5°15'N, 9°34'E, 13 Dec 2010, *F. Kuetegue 226* (YA).

Habitat. Inundated sandy or rocky banks of rivers, between rocks in streams or rivers, waterfalls; riverine forest.

Distribution. Cameroon (Fig. 19), Equatorial Guinea and Nigeria.

Conservation status in Cameroon. *Ixora euosmia* was not assessed by Onana and Cheek (2011) nor listed on http://www.iucnredlist.org. The taxon is currently known from 10 localities. The extent of occurrence of this species is about 36,900 km^2 and the area of occupancy is about 44 km^2. There is a dam built (hydro-electric dam at

Songloulou on Sanaga River), and a proposed project, Memve'ele hydro-electric dam at Nyabezan (Ntem waterfall); and mining projects envisaged in Kribi. Based on these threats and the continuous decline of vegetation cover in the area, extent and /or quality of habitat *I. euosmia* is here assessed as Endangered. IUCN Red List Category: **Endangered ENB2ab (ii, iii).**

Ixora inundata Hiern, Fl. Trop. Afr. 3: 166 (1877)

Type. Gabon. Cristal Mountains, 1862, *Mann 1731* (holotype: K; isotype: P).

Description. Shrub up to 1.5 m tall; strongly rooted; stems tough; leaves lanceolate 4–11 × 1–2.5 cm; flowers translucent white.

Specimens examined. Near Nkolemvom, 20 km southeast of d'Ebolowa, 2°54'N, 11°09'E, 03 Mar 1970, *R. Letouzey 9986* (YA); between Bulu and Ekum Bako, SW Region, 4°56'N, 8°52'E, 01 Jun 1984, *D. W. Thomas 3499* (YA); at the bank of Cross River, north of Nsanaragati, 5°52'N, 8°54'E, 16 Dec 1986, *Stephen D. Manning 1217* (YA).

Habitat. Rocky bank of rivers, periodically inundated; between rocks in rivers.

Distribution. Cameroon (Fig. 20) and Gabon.

Conservation status in Cameroon. *Ixora inundata* is not listed on http://www.iucnredlist.org. However, in Onana and Cheek (2011), the species was assessed as Endangered. The taxon is currently known from five localities. The extent of occurrence of the species is about 56,000 km^2, and the area of occupancy is about 20 km^2. The proposed dam on Ntem River is very likely to threaten the survival of *I. inundata*. Based on this threat and the continuous decline of vegetation cover in the area, extent and /or quality of habitat the species is assessed here as Endangered. IUCN Red List Category: **Endangered ENB2ab (ii, iii).**

Virectaria angustifolia (Hiern) Bremek., Verh. Kon. Ned. Akad. Wetensch, Afd. Natuurk., Sect. 2. 48(2): 21 (1952)

Virecta angustifolia Hiern, Fl. Trop. Afr. 3: 48 (1877)
Virecta heteromera K.Schum., Bot. Jahrb. Syst. 23(3): 422 (1896)
Virectaria heteromera (K.Schum.) Bremek., Verh. Kon. Ned. Akad. Wetensch., Afd. Natauurk., Sect. 2, 48(2): 21 (1952).

Type. Gabon, Mounts of Cristal, July 1862, *G. Mann 1686* (holotype: K).

Description. Erect herb, up to 30 cm tall; leaves linear to oblanceolate 5–15 × 1–2 mm; flowers white.

Specimens examined. 50 km southeast of Kribi, 2°42'N, 10°12'E, 14 Mar 1968, *R. Letouzey 9011* (YA); bank of Mana River at Ndian, 4°58'N, 8°51'E, 09 Dec 1983, *D. W. Thomas 50588* (YA); Ndian River northwest of Mundemba, 00 Oct 1986, *Stephen D. Manning 894* (YA); Ntale, bank and bed of Mbier and Essembe River, 23 Dec 2010, *F. Kuetegue 319* (YA).

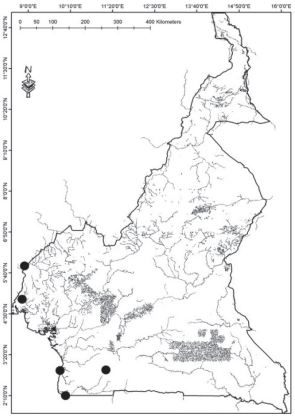

Fig. 20. •*Ixora inundata* Hiern

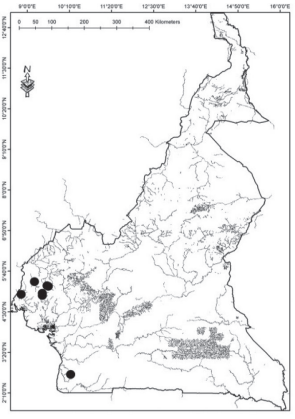

Fig. 21. •*Virectaria angustifolia* (Hiern) Bremek.

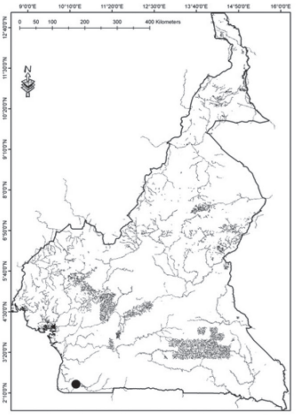

Fig. 22. •*Virectaria salicoides* (C.H.Wright) Bremek.

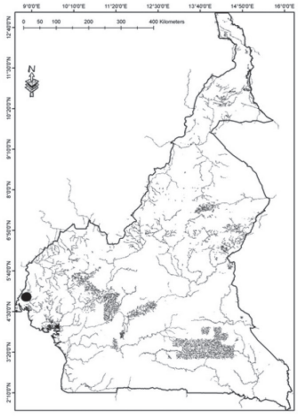

Fig. 23. •*Deinbollia angustifolia* D.W.Thomas

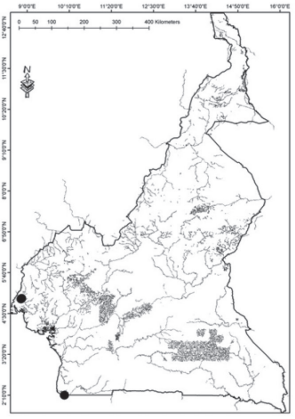

Fig. 24. •*Deinbollia saligna* Keay

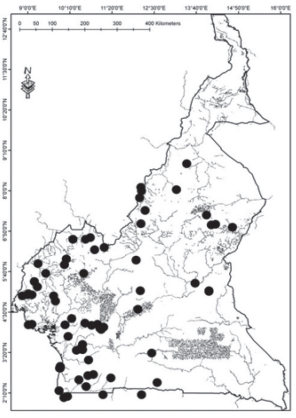

Fig. 25. • *Podostemaceae* distribution

Figures 20–25. 20 *Ixora inundata* Hiern **21** *Virectaria angustifolia* (Hiern) Bremek **22** *Virectaria salicoides* (C.H.Wright) Bremek **23** *Deinbollia angustifolia* D.W.Thomas **24** *Deinbollia saligna* Keay **25** *Podostemaceae* distribution.

Habitat. Rocks of riverbeds and inundated banks, up to flood level of streams and rivers, submerged during rainy season.

Distribution. Cameroon (Fig. 21), Gabon, Ghana and Nigeria.

Conservation status in Cameroon. *Virectaria angustifolia* is not listed on http://www.iucnredlist.org, nor assessed by Onana and Cheek (2011). The taxon is currently known from more than 7 localities. The extent of occurrence of the species is about 66,500 km^2, and its area of occupancy is about 28 km^2. Timber exploitation and plantation development are in progress at the collecting localities. Based on these threats and the continuous decline of vegetation cover in the area, extent and /or quality of habitat *V. angustifolia* is here assessed as Vulnerable. IUCN Red List Category: **Vulnerable VB1+2ab (ii, iii).**

***Virectaria salicoides* (C.H.Wright) Bremek., Verh. Kon. Ned. Akad. Wetensch., Afd. Natuurk., Sect. 2, 48(2): 21 (1952)**

Virecta salicoïdes C.H.Wright, Bull. Misc. Inform. Kew 1898(1430): 302 (1898)

Type. Cameroon, Mfoa, rocky bank of Mbei River, 00 Oct 1827, *G. L. Bates 527* (holotype: K; isotypes: BM, P).

Description. Herb 25 cm high; stems flexible and tough; strongly rooted; leaves narrow 3–9 × 0.5–0.9 cm; inflorescence terminal.

Specimen examined. Nkolebenga, northwest of d'Ebianemeyong, near Nyabesan, 60 km east of Campo, 2°25'N, 10°20'E, 11 Apr 1970. *R. Letouzey 10357* (YA).

Habitat. Rocks at banks and beds of rivers and streams.

Distribution. Cameroon (Fig. 22) and Gabon.

Conservation status in Cameroon. *Virectaria salicoides* is not listed on http://www.iucnredlist.org, nor assessed by Onana and Cheek (2011). The taxon is currently known from two localities (Kribi and Ebianemeyong). The extent of occurrence of the species is estimated at less than 100 km^2, and its area of occupancy is about 4 km^2. The habitat is threatened by dam construction (Memve'ele Hydro-electric dam on Ntem waterfall at Nyabesan). Based on this threat, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat *V. salicoides* is here assessed as Endangered. IUCN Red List Category: **Endangered EN B2ab (ii, iii).**

Sapindaceae

***Deinbollia angustifolia* D.W.Thomas, Ann. Missouri Bot. Gard. 73(1): 219 (1986)**

Type. Cameroon – SouthWest Region, near Mundemba, 4°56'N, 8°52'E, rocky bank of Idu River at Bulu on path to Ekumbako, 10 m, 07 Mar 1984, *D. W. Thomas 3253* (holotype: MO; isotypes: K, P, YA).

Description. Stenophyllous shrub of about 1 m high; roots spreading and deep; stems strong but flexible; leaves narrow 20–25 × 1–1.5 cm, grouped at the summit of the stem.

Specimens examined. Korup Reserve, 4°55'N, 8°50'E, 16 Jul 1983, *D. W. Thomas 2243* (YA); between Bulu and Dibunda, 4°55'N, 8°52'E, 07 Mar 1984, *D. W. Thomas 3253* (YA); between Bulu and Ekumbako, 4°56'N, 8°52'E, 00 Jun 1984, *D. W. Thomas 3497* (YA).

Habitat. Rocky bed of rivers, on banks of streams and rivers.

Distribution. Cameroon (Fig. 23).

Conservation status in Cameroon. *Deinbollia angustifolia* is listed on http://www.iucnredlist.org as Vulnerable by Cheek (2017a). It was earlier assessed in Onana and Cheek (2011) as Vulnerable. The taxon is endemic to Cameroon and currently known from three localities. The extent of occurrence of this species is estimated less than 100

km^2, and the area of occupancy is about 12 km^2. The habitat of *D. angustifolia* is threatened by illegal timber logging. Based on this threat, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat, the assessment of Cheek (2017a) is maintained as Vulnerable. IUCN Red List Category: **Vulnerable VU B2a b (ii, iii).**

Deinbollia saligna Keay, Bull. Jard. Bot. État Bruxelles 26: 193 (1956)

Type. Cameroon, Ndian, Kumba, 03 Mar 1936, *Smith Cam 80/36* (holotype: K, K000093228; isotype: FHI).

Description. Shrub or small tree up to 2.5 m tall; sparingly to much branched; branches thick; stems strong and flexible; leaves clustered terminally; lanceolate 6–10 × 0.5–1 cm; flowers white.

Specimens examined. Canyon of Ntem, 20 km southwest of Nyabessan, 01 Dec 1982, *B. A. Nkongmeneck 410* (YA); Mana River at Korup, 4°55'N, 8°50'E, 00 Dec 1983, *D. W. Thomas 2205* (YA); Ndian, on Ndian (Mana) waterfall, 4°56'N, 8°51'E, 17 Jan 1985, *D. W. Thomas 4268* (YA).

Habitat. Inundated rocky bed and bank of rivers or streams.

Distribution. Cameroon (Fig 24), Ghana and Nigeria.

Conservation status in Cameroon. *Deinbollia saligna* is listed on www.iucnredlist.org. It was assessed globally as Vulnerable (World Conservation Monitoring Centre, 1998). In Onana and Cheek (2011) the species was assessed for the Red data Checklist of Cameroon as Vulnerable. This taxon is currently known from four localities. The extent of occurrence of the species is estimated at less than 100 km^2, and the area of occupancy is about 16 km^2. The localities are threatened by proposals for dam construction and timber extraction. Based on these threats, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat *D. saligna* is here reassessed as Endangered: IUCN Red List Category: **Endangered ENB2ab (ii, iii).**

Family in which all species are rheophytic (Podostemaceae)

The present study and herbarium data have shown that 43 species in 12 genera in the Podostemaceae (riverweed) family have so far been documented from the study area. The results revealed six monotypic genera: *Leiothylax*, *Letestuella*, *Stonesia*, *Tristicha*, *Winklerella*, and *Zehnderia*. The genus *Inversodicraea* has 10 species, *Saxicolella* has four while three genera *Dicraeanthus*, *Djinga*, and *Macropodiella* have two; and the largest genus in our area *Ledermanniella* has 17 species. In an earlier work Ameka et al. (2002) recognized 53 rheophytic species including 33 Podostemaceae for Cameroon. Since then 13 species have been added, 10 of which are in the Podostemaceae family. The Podostemaceae added within the last few years are the result of a deliberate search for the riverweed family in Cameroon. If similar efforts are made to collect the rheophytes in other African countries, many more species would be described

for the continent. Apart from the Podostemaceae, the Hydrostachyaceae is the only other family in which all species are rheophytic in Africa (Ameka et al. 2002). So far the Hydrostachyaceae has not been recorded in the study area. Species of the two families are important since they are indicators of river health and also are the dominant macrophytes in tropical river systems; contributing to primary production and oxygenation of the river water (Quiroz et al. 1997, Ameka 2000). The Podostemaceae, for example, serve as substrate for epiphytic algae e.g., diatoms and cyanobacteria (blue-green algae) and other microscopic organisms (Ameka 2000). They also are habitats for invertebrate larvae (e.g., larvae of Simulium (black) fly, and nymphs of dragonfly and mayfly) that seek shelter and feed (Quiroz et al. 1997, Ameka per. obs.).

Podostemaceae

Description. Podostemaceae are annuals or perennials, that grow attached to rocks, in fast-flowing water, by rhizoids, or expanded holdfast; resembling algae or mosses. They produce flowers and fruits during the dry season when the water level in the rivers or streams drops.

1. *Dicraeanthus africanus* Engl., Bot. Jahrb. Syst. 38(1): 96 (1905)

Dicraeanthus ramosus H.E.Hess, Ber. Geobot. Inst. Eidg. Techn. Hochsch. Rübel Heft 32: 187 (1961).

Type. Cameroon, *Winkler 901* (holotype: B).

Specimens examined. Edea at Sanaga waterfall, *Annet 498* (P); 8 km S Kribi Lobe fall, *J.J. Bos 3590, 3887, 3888* (K, WAG); Ngaoundere, Vina waterfall, *Dulieu 4* (P); Natchigal, 62 km southeast of Bafia, *J. & A. Raynal 10544* (P).

Habitat. River rapids and waterfalls.

Distribution. Cameroon (Fig. 25), Gabon.

Conservation status in Cameroon. *Dicraeanthus africanus* has been assessed for the IUCN Red List, globally, in 2007 as Least Concern (Ghogue 2010b). This species was not assessed by Onana and Cheek (2011). Two localities, waterfalls, are known for this species. The extent of occurrence and the area of occupancy are both estimated at less than 10 km^2. There are currently two major threats to the survival of this species at the Edea and Lobe waterfalls. First is the planned hydropower dam on the Sanaga River. Secondly the waterfalls on Lobe River is a big tourist attraction site. The dam across the river and activities (e.g., trampling) of tourists will adversely impact the habitats of the species and affect its survival. *D. africanus* is currently reassessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (iii).**

2. *Dicraeanthus zehnderi* H.E.Hess, Ber. Geobot. Inst. Eidg. Techn. Hochsch. Stiftung Rŭbel Heft 32: 188 (1961)

Type. Cameroon, Edea, 30 Jan 1951, *Zehnder 259* (syntype: Z, ZT).

Specimens examined. Edea at Sanaga waterfall, *Zehnder 259, 260, 262* (ZT); Sanaga waterfalls, 30 Jan 1951, *Hess 51/270* (ZT).

Habitat. Growing in river rapids and waterfalls of Sanaga.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Dicraeanthus zehnderi* was listed on http://www.iucnredlist.org as Critically Endangered (Ghogue 2010c). It was also assessed by Onana and Cheek (2011) as Critically Endangered since it has not been collected for many decades. The only known collecting locality for *D. zehnderi* is the waterfall on Sanaga River at Edea. The extent of occurrence and the area of occupancy are both estimated at 4 km^2. The hydropower dam on the waterfall will adversely affect the survival of this species and other Podostemaceae species present at this locality. The taxon is here reassessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (iii).**

3. *Djinga cheekii* Ghogue, Huber & Rutish., Nordic J. Bot. 31(4): 458 (2013)

Type. Cameroon, near Manjo, 12 Jan 2011, *J. P. Ghogue 2125* (YA, Z, ZT).

Specimens examined. Littoral Province, Mantem River, near Manjo, on the Douala – Nkongsamba highway, 4°49'N, 9°46'E, 12 Jan 2011, *J.-P. Ghogue 2126* and *2128* (K, YA, Z, ZT); Mbo River, Manjo (Manengole Village), 4°52'N, 9°51'E, 12 Dec 2004, *R. Imaichi, Y. Kita and J.-P. Ghogue CMR35* (TNS, Z, ZT).

Habitat. River rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Djinga cheekii* is not listed on the http://www.iucnredlist.org. The taxon is known only from the type locality, Mantem River near Manjo. The extent of occurrence is estimated as 4 km^2, and area of occupancy is about 4 km^2. The main threat at the locality is agriculture. Based on this threat, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat the taxon is here assessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (iii).**

4. *Djinga felicis* C.Cusset, l. Cameroun 30: 58 (1987)

Type. Cameroon, Adamawa, north of mount Djinga, 29 Oct 1967, *H. Jacques – Felix. 8889* (holotype: P).

Specimen examined. Adamawa stream, north of mount Djinga, 29 Oct 1967, *Jacque-Félix 8889* (holo-P).

Habitat. Mt. Djinga, Adamaoua, near Tignere, river rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. This taxon, *D. felicis*, has not yet been assessed for the IUCN Red List. This species was assessed by Onana and Cheek (2011) as Critically Endangered since known from a single collection at the time. The species is most likely extinct at the type locality, Djinga Mts, Admmoua, north-western Cameroon. There are two other localities for the species, Juafef waterfall, where a hotel has been built, which is visited by many tourists coming into that area of Cameroon; and the other Anyajua waterfall is in an agricultural landscape, all in NW Cameroon (Ghogue et al. 2009). The extent of occurrence and area of occupancy are both estimated at 4 km^2 each. Tourism and agricultural activities will adversely affect the habitat of the species. *D. felicis* is, therefore, reassessed currently as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (iii).**

5. *Inversodicraea achoundongii* J.J.Schenk, R.Herschlag & D.W.Thomas, Syst. Bot. 40(2): 542 (2015)

Type. Cameroon, West of Nyabezan, 01 Dec 1992, *D.W. Thomas & G. Achoundong 9642* (YA).

Specimen examined. Ntem River, west of Nyabessan, 02°24'N, 10°22'E, 01 Dec 1992, *D. W. Thomas & G. Achoundong 9642* (YA).

Habitat. Memve'ele waterfalls, Ntem River, alt. 395 m.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea achoundongii* is yet to be assessed for the IUCN Red List. The taxon is currently known only from the type locality at Memve'ele waterfalls on the Ntem River. The extent of occurrence and area of occupancy are both estimated at 4 km^2 each. The proposed hydropower dam on the Ntem River will certainly impact the survival of the species. Based on this threat, the species is here assessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (iii).**

6. *Inversodicraea bosii* (C.Cusset) Rutish. & Thiv, Plant Syst. Evol. 283: 57 (2009)

Ledermanniella bosii C.Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia 4: 385 (1984)

Type. Cameroon, South of Kribi, 08 Jan 1969, *J.J. Bos 3592* (YA). Basionym: *Ledermanniella bosii* C.Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia 4: 385 (1984).

Specimens examined. South of Kribi on Lobe waterfall, 08 Jan 1969, *J.J. Boss 3592* (K, WAG, P); near Bongola, Ntem waterfall, Dec, *R. Letouzey 15333* (P); South Region, south Kribi, Lobe waterfall, 08 Jan 1969, *J.J. Boss 3597* (WAG).

Habitat. Lobe waterfall, south of Kribi.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea bosii* is listed on http://www.iucnredlist.org. The taxon was assessed as Endangered (Ghogue 2017a). Onana and Cheek (2011) assessed this species earlier as Endangered. The species is known from two localities, Campo waterfalls and Lobe waterfalls at Kribi. The extent of occurrence and area of occupancy are both estimated at 4 km^2 each. Based on the continuing decline in quality of the habitat of the species at Lobe waterfalls due to activities of tourists; and the possible adverse effect of the proposed hydropower dam near Campo waterfalls the assessment of Onana and Cheek (2011) and Ghogue (2017a) cannot be maintained. The species is here reassessed as Critically Endangered. IUCN Red List Category**: Critically Endangered CRBI+ B2ab (iii).**

7. *Inversodicraea cristata* Engl., Veg. Erde 9(3, 1): 274 (1915)

Ledermanniella cristata (Engl.) C.Cusset, Adansonia sér. 2, 14(2): 273 (1974)

Type. Cameroon, near Malaka, Nov, *Ledermann 1173* (lectotype: B).

Specimens examined. Near Malaka, 500 m alt., Nov, *Ledermann 1173, 1189* (U); Mari River waterfall, c. 8 km north of Betare Oya, 05 Feb 1966, *Leeuwenberg 7761* (WAG, YA); in Mvigili, northwest of Moan, 24 km southeast of Nyabezan, Mar, *J. & A. Raynal 10263* (P); Maan (24 km southeast of Nyabezan), rocky bank of Mvigili River, northwest of the village, 06 Mar 1963, *J. & A. Raynal 10263* (P, YA).

Habitat. River rapids.

Distribution. Angola, Cameroon (Fig. 25), Central African Republic, Equatorial Guinea, Gabon.

Conservation status in Cameroon. *Inversodicraea cristata* is listed on http://www.iucnredlist.org. The taxon was assessed globally as Vulnerable (Ghogue 2017b). The species is known from five localities. The extent of occurrence of *I. critata* is about 73,144 km^2 and the area of occupancy is about 24 km^2. The main threats currently known from the localities are mining and agriculture. Based on these threats, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat, *I. cristata* is currently assessed as Vulnerable IUCN Red List Category: **Vulnerable VUB1+2ab (iii).**

8. *Inversodicraea ebo* Cheek, Blumea 62: 125 (2017)

Type. Cameroon, Yabassi, near Locndeng, 07 Dec 2013, *van der Burgt 1716* (YA).

Specimens examined. Cameroon, Littoral Region, Yabassi, near Locndeng, Ebo River, 07 Dec 2013, *van der Burgt 1716* (YA).

Habitat. On rocks in river rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea ebo* is not listed on http://www.iucnredlist.org. The taxon is known only from the type locality. The extent of occurrence and the area of occupancy are both estimated at about 4 km^2 each. The main threats at the locality are forest logging, mining and agriculture. The species is here assessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (iii).**

9. *Inversodicraea eladii* Cheek, Blumea 62: 151 (2017)

Type. Cameroon, Campo Ma`an area, 30 Nov 2001, *M. Elad & P. Tchouto 1485A* (YA).

Specimen examined. Cameroon, South Region, Campo Ma'an area, Lobe, Lobe waterfalls, 30 Nov 2001, *M. Elad & P. Tchouto 1485A* (YA).

Habitat. On rocks in waterfall near the sea, in evergreen forest zone.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea eladii* as for the species before it is not as yet assessed for the IUCN Red List. The taxon is known from one locality. The extent of occurrence and the area of occupancy are both estimated at 4 km^2 each. The main threat at the locality is touristic activity. The species is here assessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (iii).**

10. *Inversodicraea kamerunensis* Engl., Veg. Erde 9(3, 1): 274 (1915)

Ledermanniella kamerunensis (Engl.) C.Cusset, Adansonia sér. 2, 14(2): 274 (1974).

Type. Cameroon, Campo, near Dipikar, Aug, *Ledermann 440a* (YA).

Specimen examined. Campo River waterfalls, near Dipikar, 00 Aug 1908, *Ledermann 440a* (YA).

Habitat. Waterfalls in low altitudes.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea kamerunensis* is listed on http://www.iucnredlist.org as Vulnerable (Ghogue 2017c). It was assessed by Onana and Cheek (2011) as Critically Endangered. The species is endemic to Cameroon and known from only the type locality; the species has not been collected since 1908. The extent of occurrence and the area of occupancy are both estimated at 4 km^2 each. The main threat at this locality is dam construction on Ntem River. *I. kamerunensis* is here reassessed and Critically Endangered status maintained. IUCN Red List Category: **Critically Endangered CRB1+2ab (ii, iii).**

11. *Inversodicraea ledermannii* Engl., Veg. Erde 9(3, 1): 274 (1915)

Ledermanniella ledermannii (Engl.) C.Cusset, Adansonia sér. 2, 14(2): 274 1974)

Type. Cameroon, South Region, near Kribi, Grand Batanga, *Ledermann 225* (YA).

Specimens examined. SW Region, Korup National Park, 5°01'N, 8°50'E, 50 m, 5–15 Dec 1984, *D.W. Thomas 4135A* (K, P); near Kribi, Lobe waterfalls, Grand Batanga, *Ledermann 225* (U); 6 km from Kribi, Lobe waterfalls, *De Wilde 2875* (P, YA).

Habitat. River rapids.

Distribution. Angola, Cameroon (Fig. 25), Côte d'Ivoire, Gabon, Guinea, Sierra Leone.

Conservation status in Cameroon. *Inversodicraea ledermannii* is listed on http://www.iucnredlist.org as Least Concern, globally (Diop 2017). The taxon is known from five localities. The extent of occurrence of *I. ledermannii* is about 29,454 km^2 and the area of occupancy is about 20 km^2. The main threats currently known from the localities are logging, agriculture and touristic activities. Based on these threats, and the continuous decline of vegetation cover in the area, extent and/or quality of habitat, *I. ledermannii* is currently reassessed as Vulnerable. IUCN Red List Category: **Vulnerable VUB2ab (iii).**

12. *Inversodicraea ntemensis* (Y.Kita, Koi, Rutish. & M.Kato) J.J.Schenk, R.Herschlag & D.W.Thomas, Syst. Bot. 40(2): 542. (2015)

Ledermanniella ntemensis Y.Kita, Koi, Rutish. & M.Kato; Acta Phytotax. Geobot. 59: 224 (2008)

Type. Cameroon, *R. Imaichi Kita, Y. & J. P. Ghogue CMR 65* (YA). Basionym: *Ledermanniella ntemensis* Y.Kita, Koi, Rutish. & M.Kato; Acta Phytotax. Geobot. 59: 224 (2008).

Specimens examined. South Region, Canon of Ntem, 30 km southwest of Nyabessan, 01 Dec 1982, *Nkongmeneck 420* (YA); Ntem waterfalls, near Bongola, 40 km southeast of Campo, 10 Dec 1979, *R. Letouzey 15333* (P, YA); Campo a'an area, Memve'ele waterfalls, 2°24'N, 10°21'E, 17 Jan 2002, *P. Tchouto 3373* (K, KRI, SCA, WAG, YA).

Habitat. Rapids of Ntem River.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea ntemensis* is not listed on http://www.iucnredlist.org. It was assessed in Onana and Cheek (2011) as Critically Endangered. The taxon is endemic to Cameroon and to the Ntem River. The extent of occurrence is about 4 km^2, and the area of occupancy is about 4 km^2. The main threat to the survival of the species is dam construction on Ntem River. The species is here reassessed and maintained as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (ii, iii).**

13. *Inversodicraea tchoutoi* Cheek, Blumea 62: 149 (2017)

Type. Cameroon, *P. Tchouto 3378* (YA).

Specimens examined. South Region, Campo Ma'an Area, Boucle du Ntem, near Meyas Ntem, 2°20'N, 10°35'E, 480 m alt., 16 Feb 2001, *P. Tchouto 3170* (K, KRI, SCA, WAG); Memve'ele waterfalls, 2°24'N, 10°21'E, 360 m alt., 17 Jan 2002, *P. Tchouto 3376* (K, KRI, SCA, *R. Letouzey 10299* (P).

Habitat. Waterfalls in evergreen forest.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea tchoutoi* has not yet been assessed for the IUCN Red List. The taxon is known from only the Memve'ele waterfalls. The extent of occurrence is about 2 km^2, and the area of occupancy is also about 2 km^2. The main threat is the construction of a dam on the Ntem River and touristic activities. The species is here assessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (ii, iii).**

14. *Inversodicraea xanderi* Cheek, Blumea 62: 147(2017)

Type. Cameroon, Campo, 04 May 2016, *van der Burgt 1940* (holotype: K; isotypes: P, Z).

Specimens examined. South Region, Campo, Campo-Ma'an National Park, north of the road Campo to Ma'an, 2°20'N, 10°13'E, 230 m alt., 04 Mar 2016, *van der Burgt 1940* (holotype: K; isotype: P, YA, Z).

Habitat. On rocks in streams.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Inversodicraea xanderi* is not listed on http://www.iucnredlist.org. The taxon is currently known only from Campo. The extent of occurrence is estimated at 4 km^2, and the area of occupancy is also about 4 km^2. No major threat is known from the locality where the species occurs, therefore, *I. xanderi* is currently assessed as Near Threatened. IUCN Red List Category: **Near Threatened (NT).**

15. *Ledermanniella aloides* (Engl.) C.Cusset, Adansonia sér. 2, 14(2): 273 (1974)

Inversodicraea aloides Engl., Veg. Erde 9(3, 1): 271 (1915)

Type. Cameroon, Tschape pass, near Tchabal Mbabo, *Ledermann 2785* (lectotype: B; isotype: U).

Specimens examined. Nigeria, Butum River, *Keay FHI 25150*; Utanga, Butum River, *Keay FHI 25153*; Tschape pass, near Tchabal Mbabo, *Ledermann 2785* (U).

Habitat. On rocks in river.

Distribution. Cameroon (Fig. 25) and Nigeria.

Conservation status in Cameroon. *Ledermanniella aloides* has been assessed globally as Vulnerable by Diop (2010a). Onana and Cheek (2011) assessed this taxon for Cameroon as Endangered. The taxon is known from one locality. The extent of occurrence, and the area of occupancy are both estimated at 4 km^2 each. Based on the area

of occupancy, the number of localities and the agricultural development impact in the area, *L. aloides* is here reassessed and maintained as Endangered. IUCN Red List Category: **Endangered EN B2ab (iii).**

16. *Ledermanniella batangensis* (Engl.) C.Cusset, Adansonia sér. 2, 14(2): 273 (1974)

Dicraeia batangensis Engl., Bot. Jahrb. Syst. 43(4): 380 (1909)
Inversodicraeia batangensis Engl., Veg. Erde 9(3, 1): 271 (1915)

Type. Cameroon, Grand Batanga, *Ledermann 221* (holotype: B). Basionym: *Dicraeia batangensis* Engl., Bot. Jahrb. Syst. 43(4): 380 (1909).

Specimen examined. Grand Batanga, Lobe waterfalls, *Ledermann 221* (holotype: B, isotype: U).

Habitat. On rocks in waterfalls.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella batangensis* is listed on http://www.iucnredlist.org globally as Critically Endangered (Ghogue 2010d). Onana and Cheek (2011) also assessed this species as Critically Endangered. The taxon is known from only Lobe waterfalls. The area of occupancy and extent of occurrence are both estimated at 4 km^2. The locality has a booming tourist industry and this has led to a general decline in quality of the habitat of the species. *L. batangensis* is here reassessed and the earlier assessment is maintained as Critically Endangered. IUCN Red List Category: **Critically Endangered B1ab (ii, iii) +2ab (ii, iii).**

17. *Ledermanniella bifurcata* (Engl.) C.Cusset, Adansonia sér. 2, 14(2): 273 (1974)

Inversodicraea bifurcata Engl., Veg. Erde 9(3, 1): 273 (1915)

Type. Cameroon, Kribi, *Mildbraed 5951*(holotype: B).

Specimens examined. Bipindi, *Annet 321* (P); 10 km from Kribi-Lolodorf, Kienke rapids, *J.J. Bos 7071, 7072* (WAG); 33 km northeast of Eta, 60 km southeast of Ngoila, Nki waterfalls, *R. Letouzey 11949* (P); 50 km east of Grand Batanga, Kribi waterfalls, *Mildbraed 5951, 5952, 5952a* (YA).

Habitat. River rapids and waterfalls in evergreen forests.

Distribution. Cameroon (Fig. 25), Gabon, Congo, Equatorial Guinea.

Conservation status in Cameroon. *Ledermanniella bifurcata* has been assessed globally as Vulnerable (Ghogue 2010e). The taxon is known from 6 localities. The extent of occurrence of *L. bifurcata* is about 11,166 km^2 and the area of occupancy is about 24 km^2. The main threats currently known from the localities are forest logging and agriculture. Based on these threats, the number of localities currently known, and

the continuous decline of vegetation cover in the area, extent and /or quality of habitat, *L. bifurcata* is currently reassessed as Vulnerable. IUCN Red List Category: **Vulnerable VUB1+2ab (iii).**

18. *Ledermanniella keayi* (G.Taylor) C.Cusset, Adansonia sér. 2, 14(2): 274 (1974)

Inversodicraea keayi G.Taylor; Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 78 (1953)

Type. Cameroon, Kumbo, *Keay FHI 28457* (holotype: K).

Specimens examined. Cameroon: Banso, Bamenda, *Keay FHI 28457* (YA); near Sagbo, Ndop near Bamenda, 1800 m alt., *C. D. Adams 11073* (LISC); Kumbo, 1650 m alt., *Keay FHI 28457* (K).

Habitat. River rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella keayi* is listed on http://www.iucnredlist.org as Critically Endangered (Diop 2010b). The taxon is known from one locality, restricted to a small area in an agricultural landscape. The extent of occurrence and the area of occupancy are both estimated at 2 km^2 each. The earlier assessment is here maintained as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB2ab (iii).**

19. *Ledermanniella letouzeyi* C.Cusset, Bull. Mus. Natl. Hist. Nat., B, Adansonia Sér. 4, 6(3): 260. (1985)

Type. Cameroon, near Lokando, Mount Rumpi, Ure, 23 Mar 1976, *R. Letouzey 14517* (YA).

Specimen examined. 30 km northwest of Kumba, near Lokando, Mount Rumpi, Ure, on river, Mar, *R. Letouzey 14517* (holotype P, isotype YA).

Habitat. River rapids and waterfalls in tropical forests.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella letouzeyi* is listed on http://www.iucnredlist.org. The taxon was assessed as Endangered by Cheek (2004). Onana and Cheek (2011) maintained the Endangered status of Cheek (2004). The species is known from two localities. The extent of occurrence is estimated at 4 km^2 and the area of occupancy is about 8 km^2. The main threats in the locality are forest exploitation and agriculture. The earlier assessment by Cheek (2004) and Onana and Cheek (2011) is maintained. IUCN Red List Category: **Endangered ENB2ab (iii).**

20. *Ledermanniella linearifolia* Engl., Bot. Jahrb. Syst. 43(4): 378 (1909)

Sphaerothylax linearifolius Engl., Veg. Erde 9(3, 1): 275 (1915)

Type. Cameroon, 28 Aug 1908, *C. Ledermann 440* (YA).

Specimens examined. 7 km south of Kribi, Lobe waterfall, Jan, *J. Bos3591* (K); 7 km south of Kribi, Lobe waterfalls, Aug, *De Wild 2876* (P, WAG, YA); Nkam, near Sahe, 3 km southwest Nkondjok road Bafang-Yabassi, Feb *R. Letouzey 11146* (P).

Habitat. River rapids and waterfall.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella linearifolia* is listed on http://www.iucnredlist.org. It was assessed as Endangered (Ghogue 2010f). Onana and Cheek (2011) reassessed this species and maintained the Endangered status. The taxon is known from 6 localities. The extent of occurrence of *L. linearifolia* is about 42,848,649 km^2 and the area of occupancy is about 16 km^2. The main threats currently known from the localities are agriculture and touristic activities. Based on these threats, the number of localities currently known, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat, *L. linearifolia* is currently reassessed and maintained as Endangered. IUCN Red List Category: **Endangered ENB2ab (iii).**

21. *Ledermanniella monandra* (Engl.) C.Cusset, Adansonia, sér., 2, 14(2): 274 (1974)

Monandriella linearifolia Engl., Bot. Jahrb. Syst. 60(4): 457 (1926)

Type. Cameroon, Mao Bika, near Dodeo, 05 Mar 1909, *C. Ledermann 2872* (YA).

Specimen examined. Mao Bika, near Dodeo, 60 km west of Tignere, 700 m alt., Mar, *Ledermann 2872* (holotype B).

Habitat. River rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella monandra* has not yet been assessed for the IUCN Red List, but it was assessed in Onana and Cheek (2011). The taxon is known from one locality. The extent of occurrence and the area of occupancy are estimated at 4 km^2 each. Due to habitat degradation and the continuous decline of vegetation cover in the area, extent and /or quality of habitat, *L. monandra* is currently reassessed as Critically Endangered. IUCN Red List category: **Critically Endangered CRB2ab (iii).**

22. *Ledermanniella musciformis* (G.Taylor) C.Cusset, Adansonia ser 2 14(2): 274 (1974)

Inversodicraea musciformis G.Taylor; Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 75 (1953)

Type. Cameroon, Mba Kokeka, near Bamenda, Jan, *Keay FHI 28542* (holotype: K). Basionym: *Inversodicraea musciformis* G.Taylor; Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 75 (1953).

Specimens examined. Northwest slopes of Mts. Mba Kokeka, near Bamenda, Jan, *Keay FHI 28542* (K); Tchamba, Nakalba, 21 km southwest of Tchamba 1200 m alt., Jan, *J. & A. Raynal 13166* (P).

Habitat. River rapids and waterfalls.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella musciformis* is listed on http://www.iucnredlist.org as Data Deficient (Diop 2010c). Onana and Cheek (2011) reassessed this species as Endangered. This taxon is endemic to Cameroon and known from at least four localities. The extent of occurrence of *L. musciformis* is about 68,419,636 km^2 and area of occupancy is about 16 km^2. The main threat currently known from the localities is deforestation and agriculture. Based on these threats, the number of localities, and the continuous decline of vegetation cover in the area, extent and/or quality of habitat, *L. musciformis* is currently reassessed and Endangered status maintained. IUCN Red List Category: **Endangered ENB2ab (iii).**

23. *Ledermanniella onanae* Cheek, Kew Bull. 58: 733 (2003)

Type. Cameroon, Bakossi Mts, northwest of Muambong, 04 Feb 1998, *J.-M. Onana 558* (K, YA).

Specimens examined. Cameroon: South West Province, Bakossi Mts., Chide River falls, northwest of Muambong, 04 Feb 1998, *J.-M. Onana 558* (YA, K); South West Province, Bakossi Mts., Ndip River rapids between Nzimbeng and Kodmin, alt. 1150 m. fl. & fr., 14 Feb 1998, *M. Cheek 9196* (K, YA).

Habitat. Perennial waterfalls and river rapids in submontane forest.

Distribution. Cameroon (Fig. 25) and Gabon.

Conservation status in Cameroon. *Ledermanniella onanae* is listed on http://www.iucnredlist.org as globally Endangered (Ghogue 2010g). Onana and Cheek (2011) maintained the Endangered status. The taxon is known from three localities, two of which are on the same river. The extent of occurrence of *L. onanae* is about 23,751 km^2 and the area of occupancy is about 12 km^2. The main threats currently known from the localities are forest logging and agriculture. Based on these threats, and the continuous decline of vegetation cover in the area, extent and /or quality of habitat, *L. onanae* is currently reassessed and the Endangered status maintained. IUCN Red List Category: **Endangered ENB2ab (iii).**

24. *Ledermanniella pollardiana* Cheek & Ameka, Nordic J. Bot. 26: 214 (2008)

Type. Cameroon, North Western Province, Bali, 1 km east, 5°52'N, 10°01'E, 19 Nov 2000, *B. Pollard 536* (K, YA).

Specimens examined. Cameroon, North-western Province, Bali, 1 km east, 5°52'N, 10°01'E, 1280 m alt. fl., 19 Nov 2000, *B. Pollard 536* (K, YA).

Habitat. Perennial waterfall, in full sun, in deforested area.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella pollardiana* is not as yet assessed for the IUCN Red List. Onana and Cheek (2011) assessed this species as Critically Endangered. The taxon is endemic to Cameroon, and known from only the type locality. The extent of occurrence and the area of occupancy are both estimated at 4 km^2 each. Agricultural activities in the general area of the locality; with increased turbidity and siltation from agricultural practices will adversely affect the species. The species is here reassessed and Critically Endangered status maintained. IUCN Red List Category: **Critically Endangered CRB2ab (iii).**

25. *Ledermanniella prasina* J.J.Schenk & D.W.Thomas, Novon 14(2): 227 (2004)

Type. Cameroon, 01 Dec 1990, *D.W. Thomas 11550* (K, WAG, YA).

Specimen examined. Cameroon, 01 Dec 1990, *D.W. Thomas 11550*, [K, WAG, YA].

Habitat. River rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella prasina* was assessed as Vulnerable (Cheek 2017b) for the IUCN Red List. The taxon is known only from the Mana River valley system in Cameroon. The extent of occurrence and the area of occupancy are both estimated at 2 km^2 each. The assessment of Cheek (2017b) is maintained since no major changes have taken place at the locality since that assessment. The species is here reassessed as Vulnerable. IUCN Red List Category: **Vulnerable VUB1+2ab (iii).**

26. *Ledermanniella pusilla* (Warm.) C.Cusset, Adansonia ser. 2, 14(2): 274 (1974)

Dicraeanthus pusillus C.H.Wright, Fl. Trop. Afr. 6(1.1): 127 (1909)
Sphaerothylax pusilla Warm Kongel. Danske Vidensk. Selsk. Skr., Naturvidensk. Math. Afd. VI, 9: 146 (1899)

Type. Cameroun, Bipindi, *G. Zenker 1050* (holotype: B; isotype: G). Basionym: *Sphaerothylax pusilla* Warm., Kongel. Danske Vidensk. Selsk. Skr., Naturvidensk. Math. Afd. VI, 9: 146 (1899).

Specimens examined. 7 km south of Kribi, Lobe waterfall, *J.J. Bos 3598* (WAG); Lokoundje waterfall, Bipindi, *G. Zenker 1050* (G, K, L, M, U, Z).

Habitat. Waterfalls.

Distribution. Cameroon (Fig. 25), Democratic Republic of Cong and Gabon.

Conservation status in Cameroon. *Ledermanniella pusilla* is listed on http://www.iucnredlist.org globally as Endangered (Ghogue 2010h). The taxon is known from two localities. The extent of occurrence is about 9,042 km^2 and the area of occupancy is about 16 km^2. The waterfalls at Lobe are a huge tourist center and the activities have caused a deterioration in the habitat of the species. The species is here reassessed as Endangered. IUCN Red List Category: **Endangered ENB1 + 2ab (iii).**

27. *Ledermanniella sanagaensis* C.Cusset, Bull. Mus. Natl. Hist. Nat. B, Adansonia Sér. 4, 6(3): 256 (1985)

Type. Cameroon, Natchigal, *J. & A. Raynal 10543* (YA).

Specimens examined. Cameroon, *J. & A. Raynal 10543* (YA); Natchigal, Sanaga waterfall, *A. & J. Raynal 10542* (P).

Habitat. River rapids and waterfalls.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella sanagaensis* is listed on http://www.iucnredlist.org as Critically Endangered (Ghogue 2010i). The taxon is endemic to Cameroon, and known only from the Sanaga waterfall at Natchigal. The extent of occurrence and area of occupancy are both estimated at 4 km^2 each. There is a proposal to build a dam at the locality of the species. Based on this threat the earlier assessment of Ghogue (2010i) as Critically Endangered is maintained. IUCN Red List Category: **Critically Endangered B2ab (ii, iii).**

28. *Ledermanniella schlechteri* (Engl.) C.Cusset, Adansonia sér., 2, 14(2): 275 (1974)

Dicraeia schlechteri Engl., Bot. Jahrb. Syst. 43: 381 (1909)
Inversodicraeia tenuissima Hauman, Bull. Jard. Bot. État 17: 180 (1944)

Type. Congo Democratic Republic, 01 Jun 1899, *R. Schlechter12574* (K). Basionym: *Dicraeia schlechteri* Engl., Bot. Jahrb. Syst. 43: 381 (1909).

Specimens examined. Dehane, between Edea and Kribi, Jun, *Annet 459* (P).

Habitat. River rapids and waterfalls.

Distribution. Cameroon (Fig. 25), Congo and Democratic Republic of Congo.

Conservation status in Cameroon. *Ledermanniella schlechteri* is listed on http://www.iucnredlist.org as Vulnerable, globally (Ghogue 2010j). The taxon is known from two localities. The extent of occurrence is less than 100 km^2, and the area of occupancy is about 8 km^2. The proposed dam at Edea waterfall will further deteriorate the quality of the habitat of the species at that locality. Base on this threat and the number of localities where the species is currently found, *L. schlechteri* is here reassessed as Endangered. IUCN Red List Category: **Endangered ENB1+2ab (iii).**

29. *Ledermanniella thalloidea* (Engl.) C.Cusset, Adansonia sér 2, 14(2): 275 (1974)

Inversodicraeia thalloidea Engl., Veg. Erde 9(3, 1): 274 (1915)

Type. Cameroon, Ndoungue near Nkongsamba, *Ledermann 6328a* (lectotype: B; isotypes: BM, U). Basionym: *Inversodicraeia thalloidea* Engl., Veg. Erde 9(3, 1): 274 (1915).

Specimens examined. Tributary of Sanaga, 10 km north of Edea, *Kers 1904* (LISC); Ndoungue near Nkongsamba, 800 m alt., *Ledermann 6328a* (BM, U); Natchigal, Sanaga waterfall, *A. & J. Raynal 10542* (P).

Habitat. River rapids and waterfalls in tropical rain forest.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella thalloidea* is listed on http://www.iucnredlist.org as Endangered (Ghogue 2010k). However, Onana and Cheek (2011) assessed the taxon as Vulnerable. The taxon is endemic to Cameroon and known from two localities. The species' area of occupancy is estimated to be less than 10 km^2, and the extent of occurrence estimated at 18 km^2. There is a decline in the quality of the habitat of the species; there is a dam at the Sanaga waterfalls, and another dam construction is in progress at the Nachtigal waterfalls, the two sites for the species. Due to the impact of the dams on the habitat of the species it is here reassessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB2ab (iii).**

30. *Ledermanniella raynaliorum* C.Cusset, Bull. Mus. Natl. Hist. Nat. B, Adansonia Ser. 4, 6(3): 264 (1985)

Type. Cameroon, 14 Jan 1965, *J. & A. Rayanal 12988* (YA).

Specimen examined. Cameroon, 14 Jan 1965, *J. & A. Rayanal 12988* (YA).

Habitat. River rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella raynaliorum* is not listed on http://www.iucnredlist.org. Onana and Cheek (2011) assessed this species as Endangered. The taxon is known from only one locality. The extent of occurrence and the area of occupancy are estimated at about 4 km^2 each. Forest degradation is the main threat at the locality. The species is here assessed as Near Threatened. IUCN Red List Category: **Near Threatened (NT).**

31. *Ledermanniella variabilis* (G.Taylor) C.Cusset, Adansonia sér 2, 14(2): 275 (1974)

Inversodicraeia variabilis G.Taylor, Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 75 (1953)

Type. Cameroon, Manfe, Munaya, *Keay FHI 28688*, (holotype: K). Basionym: *Inversodicraeia variabilis* G.Taylor, Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 75 (1953).

Specimens examined. Lobe waterfall, 7 km south of Kribi, *J.J. Boss 3594* (WAG); Mamfe, Munaya River, *Keay FHI 28688* (K).

Habitat. River rapids and waterfalls.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Ledermanniella variabilis* is listed on http://www.iucnredlist.org as Endangered (Ghogue 2010l). Onana and Cheek (2011) re-

assessed this species as Endangered. The species is known from two localities and the area of occupancy and extent of occurrence are estimated to be less than 10 km^2 each. The Lobe waterfall locality is a famous tourist attraction so there is a continuous decline in the quality of the habitat at this site. The species is here reassessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (ii, iii).**

32. *Leiothylax quangensis* Warm., Danske Vid. Selsk. Skrift. Ser.. VI, 9: 147 (1899)

Dicraeia quangensis Engl., Bot. Jahrb. Syst. 20(1–2): 134 (1894)
Leiocarpodicraea buesgenii Engl., Engl. Bot. Jahrb. Syst. 60: 465 (1926)
Leiothylax buesgenii Warm. ex Engl., Nat. Pflanzenfam. 18 a ed. 2, 58 (1930)
Leiothylax edeensis Engl. Nat. Pflanzenfam. 18 a ed. 2, 58 (1930)

Type. Democratic Republic of Congo, *Teuscz in von Mechow's Expedition 506* (holotype: M; isotype: G).

Specimens examined. Edea, Sanaga waterfall, *Buesgen 439* (M); Sanaga waterfall, *Buesgen s.n.* (B, U).

Habitat. River rapids and waterfalls in tropical rain forests.

Distribution. Angola, Cameroon (Fig. 25), Democratic Republic of Congo.

Conservation status in Cameroon. *Leiothylax quangensis* has been assessed for the IUCN Red List as Endangered (Ghogue 2010m). The taxon is known from one locality, Edea waterfalls. The area of occupancy and extent of occurrence are both estimated at 2 km^2 each. The hydropower dam at Edea will certainly impact the quality of the habitat of the species. *L. quangensis* is here reassessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (ii, iii).**

33. *Letestuella tisserantii* G.Taylor, Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 57 (1953)

Letestuella chevalieri G.Taylor, Bull. Brit. Mus. (Nat. Hist.), Bot. 1: 59 (1953)
Leiothylax warmingii (Engl.) Warm., Danske Vid. Selsk. Skrift. Ser. VI. ix 150 (1899)

Type. Central African Republic, *Tisserant 1769* (holotype: BM; isotype: P).

Specimens examined. Near Goyoum in Sanaga River, 20 km west of Deng Deng, *F.J. Breteler 981* (WAG); Plateau de l'Adamaoua, Vina waterfall, 15 km from Ngaoundere, *Zehnder 163* (ZT).

Habitat. River rapids and waterfalls in tropical rain forest.

Distribution. Benin, Cameroon (Fig. 25), Central African Republic, Mali, Namibia and Niger.

Conservation status in Cameroon. *Letestuella tisserantii* is listed on http://www.iucnredlist.org as Least Concern (Diop 2010d) since it occurs in many countries. The

taxon is known from two localities in Cameroon. The extent of occurrence is less than 100 km^2, and the area of occupancy is less than 10 km^2. Dams on the Sanaga River and agricultural activities are the main threats to the species. Based on the threats and the number of localities where the species is found, *L. tisserantii* is here assessed as Endangered. IUNC Red List Category**: Endangered ENB2ab (iii).**

34. *Macropodiella heteromorpha* (Baill.) C.Cusset, Adansonia, sér. 2, 17(3): 298 (1978)

Sphaerothylax heteromorpha Baill., Bull. Mens. Soc. Linn. Paris ii 876 (1890)
Macropodiella mildbraedii Engl., Bot. Jahrb. Syst. 60(5): 466 (1926)

Type. Gabon, *Thollon 729* (holotype: P). Basionym: *Sphaerothylax heteromorpha* Baill., Bull. Mens. Soc. Linn. Paris ii 876 (1890).

Specimens examined. Makak Forest Reserve, *P. Bamps 1453* (YA); Nyong River, near Mbalmayo, *Mildbraed 7749, 7750* (B, U).

Habitat. River rapids and waterfalls in tropical rainforests.

Distribution. Cameroon (Fig. 25), Côte d'Ivoire and Gabon.

Conservation status in Cameroon. *Macropodiella heteromorpha* is listed on http://www.iucnredlist.org as Vulnerable (Ghogue 2010n). The taxon is known from four localities, and the area of occupancy is less than 500 km^2 and the extent of occurrence estimated at 75 km^2. At one of the localities (Meve'ele waterfalls) it is proposed to build a hydropower dam. The species is threatened by habitat decline due to future dam construction. According to Ghogue (2010n) two other localities, Nyong River near Mbalmayo and the Mpoume waterfalls on the Nyong River near Makak, have been listed by Cusset (1987) for this species. These two sites have been surveyed by Ghogue but the species has not been seen or collected. *M. heteromorpha* is, therefore, here reassessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB2ab (ii, iii).**

35. *Macropodiella pellucida* (Engl.) C.Cusset, Fl. Cameroun 30: 64 (1987)

Type. Cameroon, Bare, near Nkongsamba, *Ledermann 6142* (lectotype: BM). Basionym: *Inversodicraea pellucida* Engl., Veg. Erde 9(3, 1): 271, 272. (1915).

Specimens examined. Bare, near Nkongsamba, on rocks in a waterfall, *Ledermann 6142* (BM); Ndian River, near Mundemba, Dec, *D.W. Thomas 2552* (MO, P).

Habitat. River rapids and waterfalls in rainforest.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Macropodiella pellucida* is listed on http://www.iucnredlist.org as Endangered (Ghogue 2010o). Onana and Cheek (2011) maintained the Endangered status of Ghogue (2010o). The taxon is endemic to Cameroon

and known from two localities. The extent of occurrence is less than 4 km^2 and the area of occupancy of this species is estimated at less than 20 km^2. There have not been further threats at the habitat of the species since the previous assessment. The species is reassessed as Endangered, maintaining the previous status. IUCN Red List Category: **Endangered ENB2ab (iii).**

36. *Saxicolella flabellata* (G.Taylor) C.Cusset, Fl. Cameroun 30: 94 (1987)

Pohliella flabellata G.Taylor, Bull. Brit. Mus. (Nat. Hist.), Bot. 1: 53 (1953)

Type. Nigeria, Afi River, Dec, *Keay FHI 28240* (K). Basionym: *Pohliella flabellata* G.Taylor, Bull. Brit. Mus. (Nat. Hist.), Bot. 1: 53 (1953).

Specimens examined. Nigeria: Afi River, on Aboabam-Boje path, Dec, *Keay FHI 28240* (K); Cameroon: Ndian, near Mundemba, *D.W. Thomas 2654* (MO, P).

Habitat. Submerged on rocks in fast-flowing river.

Distribution. Cameroon (Fig. 25) and Nigeria.

Conservation status in Cameroon. *Saxicolella flabellata* is list on http://www.iucnredlist.org. The taxon has been assessed as Data Deficient (Ouedraogo 2010a) since species distribution, population status and threats to the species are unknown at the time of the assessment. Onana and Cheek (2011) reassessed the species as Endangered. The species is found in two localities. The extent of occurrence is estimated at 2 km^2 and the area of occupancy is about 8 km^2. The main threats at the localities are described as forest exploitation and agriculture. The species is here reassessed as Endangered. IUCN Red List Category: **Endangered ENB2ab (iii).**

37. *Saxicolella laciniata* (Engl.) C.Cusset, Fl. Cameroun 30: 94 (1987)

Inversodicraea laciniata Engl., Veg. Erde 9(3, 1): 271 (1915)
Pohliella laciniata Engl., Bot. Jahrb. Syst. 60(4): 458 (1926)

Type. Cameroon, near Babong, *Ledermann 1185* (holotype: B). Basionym: *Pohliella laciniata* Engl., Bot. Jahrb. Syst. 60(4): 458 (1926).

Specimens examined. Dinger River near Babong, *Ledermann 1185* (B); Bawan River, on path to Agborkem (ex Ossidinge) at Tabo, 20 km west of Mamfe, *R. Letouzey 13731* (YA).

Habitat. River rapids.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Saxicolella laciniata* is listed on http://www.iucnredlist.org as Vulnerable (Ghogue 2010p). It was assessed in Onana and Cheek (2011) as Endangered. The taxon is known from two localities. The extent of occurrence is estimated at 2 km^2 and the area of occupancy is 8 km^2. The main threats at

the localities are forest exploitation for agriculture purposes. The species is here reassessed and the Endangered status maintained. IUCN Red List Category: **Endangered ENB2ab (iii).**

38. *Saxicolella marginalis* (G.Taylor) C.Cusset ex Cheek, Pl Mount Oku & Ijim Ridge, Cameroon, Conserv. Checklist 153 (2000)

Butumia marginalis G.Taylor, Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 55 (1953).

Type. Nigeria, 25 Dec 1948, *Keay, Savory & Russell, #25152* (BM). Basionym: *Butumia marginalis* G.Taylor, Bull. Brit. Mus. (Nat. Hist.) Bot. 1: 55 (1953).

Specimens examined. Nigeria: Butum River, Utanga, 2 miles north of Bagga, Obudu, 25 Dec 1948, *Keay, Savory & Russell FHI 25152* (YA); Cameroon: Fundong, 22 Nov 1996, *M. Cheek 8740* (YA).

Habitat. On smooth granite rocks in swift-flowing stream or river.

Distribution. Cameroon (Fig. 25) and Nigeria.

Conservation status in Cameroon. *Saxicolella marginalis* is listed on http://www.iucnredlist.org. The taxon has been assessed globally as Critically Endangered (Ouedraogo 2010b). There is only one known collecting locality in the country. According to Ouedraogo (2010b) there is decline in the quality of the habitat due to pollution from laundry operations in the town of Fundong upstream of the site of this species. Based on this threat the assessment of Critically Endangered is maintained. IUCN Red List Category: **Critically Endangered B1ab (iii) +2ab (iii)**.

39. *Saxicolella nana* Engl., Bot. Jahrb. Syst. 60(4): 456 (1926)

Type. Cameroon, near Mbalmayo, *Mildbraed 7749a* (holotype: B; isotype: U).

Specimens examined. Cameroon, near Mbalmayo, Nyong River, 644 m alt, *Mildbraed 7749a* (YA); 11°27'N, 3°22'E, 28 Feb 2007, *M. Kato, R. Imaichi, S. Koi, & N. Katayama CMR-129* (YA).

Habitat. River rapids and waterfalls.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Saxicolella nana* is listed on http://www.iucnredlist.org as Vulnerable (Ghogue 2010q). Onana and Cheek (2011) assessed this species as Critically Endangered, since at that time it had not been collected since the first collection many years ago. The taxon is endemic to Cameroon and is known from only Nyong River near Mbalmayo. The species was, however, collected again by Kato and associates in 2007. The area of occupancy of this species can be estimated to be less than 20 km^2. The extent of occurrence -estimated to be less than 2 km^2. The main threat is agricultural activity. The species is here reassessed as Endangered. IUCN Red List Category: **Endangered ENB2ab (ii, iii).**

40. *Stonesia ghoguei* E.Pfeiter & Rutish., Novon 19(1): 103 (2009)

Type. Cameroon, Adamawa, Ngaoundere, 16 Feb 2005, *J. P. Ghogue 1665* (YA, K, Z).

Specimens examined. Adamawa, Ngaoumdere, Tello Waterfalls, 16 Feb 2005, *J. P. Ghogue 1665* (YA, K, Z).

Habitat. Growing in waterfalls, Tello Waterfalls, Ngaoundéré, Adamawa (Cameroon).

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Stonesia ghoguei* is listed on http://www.iucnredlist.org as Vulnerable (Cheek 2018). Pfeifer et al. (2009) assessed *S. ghoguei* as Vulnerable. The taxon is endemic to Cameroon and known from only one collecting locality, Tello Waterfalls. The extent of occurrence and area of occupancy are estimated at 4 km^2 each. Their assessment is retained for now. IUCN List Category: **Vulnerable VU D1 + 2**.

41. *Tristicha trifaria* (Bory ex Willd.) Spreng., Systema Vegetabilium 1 (1824)

Dufourea boryi A.Rich., Dict. Class. Hist. Nat. 5: 636 (1824)
Dufourea hypnoides St-Hil. Mém. Mus. Hist. Nat. 10: 472 (1823)
Dufourea trifaria Bory ex Willd., Sp. Pl., ed. 4 5(1): 55 (1810)
Dufourea alternifolia Willd., Mag. Neuesten Entdeck. Gesammten Naturk. Ges. Naturf. Freunde Berlin 6: 64 (1812)
Tristicha alternifolia Thouars ex Spreng., Syst. Veg. ed. 16(1): 22 (1824)
Tristicha alternifolia Thouars, ex Roem. & Schult. Syst. Veg. i. 50 (1817)

Type. Mauritius, *Bory de St Vincent s.n.* (holotype: B; isotype: P).

Specimens examined. 8 km south of Kribi, Lobe waterfall, *J.J. Bos 3593* (YA); Vina waterfall, near Ngaoundere, Feb, *Dulieu 5* (ALF); Hossere Koum, 40 km west of Tchollire, Nov, *Fotius 2418* (P); Limbe (Joke River), Mar, *Brenen 9495, 9496* (BR, COL, P, SRGH); 8 km North Betare Oya (Mari River fall), Nov, *Leeuwenberg 7767* (P, WAG); Roua 20 km northeast of Mokolo, Oct, *R. Letouzey 7280* (P); Sahe, 3 km southwest of Nkondjok (Bafang – Yabassi Road), Nkam River, Feb, *R. Letouzey 11145* (P).

Habitat. River rapids and waterfalls.

Distribution. AFRICA; Angola, Benin, Burkina Faso, Cameroon (Fig. 25), Cote d'Ivoire, Democratic Republic of Congo, Ethiopia, Ghana, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritius, Mascarene Islands, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe. CENTRAL AND SOUTH AMERICA; Argentina, Brazil, Columbia, Costa Rica, Cuba, El Salvador, Guatemala, Mexico, Nicaragua, Panama, Paraguay, Uruguay, Venezuela.

Conservation status in Cameroon. *Tristicha trifaria* is not listed on www.iucnredlist.org. The extent of occurrence of *T. trifaria* is about 12,000 km^2 and the area of occupancy is about 28 km^2. The taxon is currently known from about 7 localities. Lobe area, one of the localities where the species is found is a famous touristic site. Also

agricultural activities are on the increase in other localities. Based on these threats, the number of localities and the continuous decline of vegetation cover in the area, extent and /or quality of the habitat, *T. trifaria* is here assessed as Vulnerable. IUCN Red List Category: **Vulnerable VUB1 + 2ab (ii, iii).**

42. *Winklerella dichotoma* Engl., Bot. Jahrb. Syst. 38(1): 97 (1905)

Type. Cameroon, Edea, 30 Jan 1951, *Winkler 900* (holotype: B).

Specimens examined. Edea waterfall, *Winkler 900* (B); Edea waterfall, 30 Jan 1951, *Zehnder 271, 275, 277* (BR, ZT).

Habitat. River rapids and waterfalls.

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Winklerella dichotoma* is list on http://www.iucnredlist.org as Critically Endangered (Ghogue 2010r). The species is endemic to Cameroon and only known from the Edea waterfalls on the Sanaga River. There is a hydropower dam built on the river at the collecting locality of the species. The area of occupancy and extent of occurrence are estimated at 2 km^2 each. The earlier assessment of Ghogue (2010r) as Critically Endangered is maintained. IUCN Red List Category: **Critically Endangered B1ab (iii) +2ab (iii).**

43. *Zehnderia microgyna* C.Cusset, Fl. Cameroon 30: 56 (1987)

Type. Cameroon, Edea, 29 Jan 1951, *Zehnder 264* (holotype: ZT).

Specimen examined. Edea, Sanaga waterfall, 29 Jan 1951, *Zehnder 264, 276, 278* (ZT).

Distribution. Cameroon (Fig. 25).

Conservation status in Cameroon. *Zehnderia microgyna* is listed on http://www.iucnredlist.org. as Critically Endangered (Ghogue 2010s). The taxon is known from only one locality. The extent of occurrence of *Z. microgyna* and the area of occupancy are estimated at about 4 km^2 each. There is a dam built on the Sanaga River, the habitat of the species. Based on that threat, and the fact that the species is known only from one locality and the continuous decline of vegetation cover in the area, and extent and/or quality of habitat, *Z. microgyna* is here assessed as Critically Endangered. IUCN Red List Category: **Critically Endangered CRB1+2ab (ii, iii).**

Discussion

The survey of rheophytic plants from Cameroon revealed 66 species distributed in 16 families, and in three major plant groups: 2 ferns, 8 monocotyledons, and 56 dicotyledons (Table 1). Among the monocotyledons only one grass and two sedges were recorded. Within the dicotyledons three shrub/small tree species, *Deinbolla saligna* Keay

Table 1. Number of rheophyte species and genera per family in Cameroon.

Family	Genus	Species
Ferns		
Lomariopsidaceae	1	2
Dicotyledons		
Acanthaceae	1	1
Amaranthaceae	1	1
Apocynaceae	1	1
Lamiaceae	1	1
Myrtaceae	1	1
Oxalidaceae	1	2
Podostemaceae	12	43
Rubiaceae	2	4
Sapindaceae	1	2
Monocotyledons		
Amaryllidaceae	1	1
Araceae	1	1
Cyperaceae	2	3
Melastomataceae	1	1
Pandanaceae	1	1
Poaceae	1	1

(Sapindaceae), *Ixora euosmia* K.Schaum (Rubiaceae) and *Pandanus satabiei* Huynh (Pandanaceae) were encountered (Table 1). According to van Steenis (1981), however, about half the species of rheophytes worldwide are trees and thus the paucity of trees in the current survey is surprising. Rheophytic woody plants (e.g., *Coffea congensis* Froehn and *Breonadia salicina* (Vahl) Hepper & Wood in the Rubiaceae) are known to occur outside the study area in Africa. Rheophyte diversity, according to some authors e.g., van Steenis (1981) and Hoyos-Gomez and Bernal (2018), is high in South East Asia and South America compared with tropical Africa. A survey of rheophytes of Africa by Ameka et al. (2002) found 53 rheophytes including 33 Podostemaceae species in Cameroon. This means that we have documented 10 more Podostemaceae and three other rheophytic species (from Cyperaceae: *Cyperus rheophyticus*, *C. tonkinensis*, and *C. cataractarum*) for Cameroon within the last 16 years. Further surveys are required across Africa for the full picture of rheophyte diversity and distribution to emerge.

Invariably, the species encountered in the study have characteristic features that adapt them to their peculiar habitats, and enable them to persist in the harsh conditions of swift-flowing water, flush floods, torrents, and waterfalls. The leaves are lanceolate or narrow with a leaf index of at least 3 similar to what van Steenis (1978, 1981) observed while studying the rheophytes of the world. *Crinum natans* and some other hydrophytes usually have ribbon-like leaves. The rheophytes encountered in Cameroon have firm but flexible stems which can withstand the tearing effect of swift-running rivers and streams. Their roots are strong or mat-rooted to hold them to their various substrates including rocks, gravel and boulders.

The habitats of this unique biological group are, however, threatened by human activities. We show that about 36% of rheophytes are Critically Endangered (CR) in

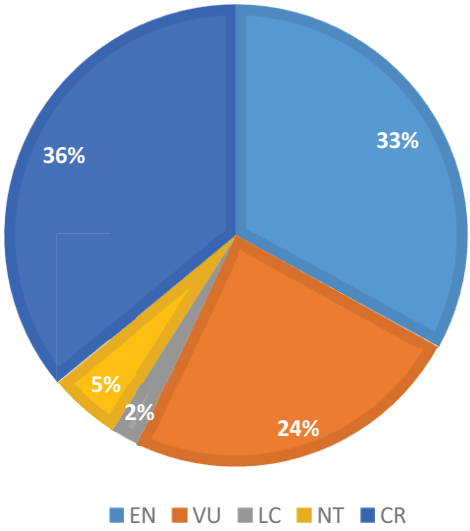

Figure 26. Percent distribution of rheophytes of Cameroon according to IUCN Red List Categories (CR- Critically Endangered; EN- Endangered; LC- Least Concern; NT- Near Threatened; and VU- Vulnerable).

Cameroon and only 2% are considered to be of Least Concern (Fig. 26). Fifty three percent of Podostemaceae in Cameroon are in the CR group. There is the need to do more to protect the habitats of the rheophytes, particularly the Podostemaceae in Cameroon.

The habitats of rheophytes in Cameroon and indeed across Africa are threatened by the land use practices around the rivers, and the damming of the rivers for hydroelectric power (Cheek et al. 2015). One such land use practice, agriculture (arable farming), introduces agro-chemicals and silt to the rivers. This may make the river turbid, thus affecting photosynthetic ability and therefore the productivity of the plants (Ameka 2000). The agro-chemicals may also poison the plants. Timbering loosens the topsoil and during the wet season run-off water carries silt into the rivers; and the effect is the same as for silt from arable farming (Ameka pers. obs.) – turbid water which results in reduced productivity of submerged water plants. Mining is another land use practice affecting the plants and in particular alluvial mining in rivers may contribute silt into the rivers as suggested by Cheek et al. (2015) and Cheek and Lebbie (2018). The amount of silt from alluvial mining could be much higher than from agriculture because that from alluvial mining is generated *in-situ*, in the riverbed and, therefore, the effect may be more severe. Silt not only reduces photosynthesis efficiency but may also reduce or even prevent establishment of seedlings of rheophytes on rocks, particularly the members of Podostemaceae (Cheek et al. 2015). In some instances heavy metals such as mercury are used in the recovery of alluvial gold (Afum and Owusu 2016) and these may poison the plants. Indeed Philbrick and Crow (1983) and Philbrick and Novelo (1995) have provided evidence to show that there is a correlation between increased pollution (chemicals) and loss of Podostemaceae populations in South America.

The recent upsurge in dam construction effort in many African countries raises concern for the survival of rheophytes. In Cameroon, there are a number of dams built across rivers for hydropower, and efforts are continuing to build many more dams across a number of rivers: (http://www.theworldfolio.com/news/hydroelectric-projects/659/eroon); examples of these are:, Memve'élé hydroelectric dam on Ntem River(http://www.edennewspaper.net/memveele-hydroelectric-dam-is-60-complete-energy-minister/); Mekin hydro-electric dam on Dja River, Lom-Pangar hydroelectric dam on Lom River (https://www.internationalrivers.org/sites /default/files/attached-files/lp_factsheet.pdf); Menchum hydroelectric dam on Menchum River, and the Natchigal hydroelectric dam on Sanaga Rive1r at Edea; http://www.hydroworld. com/ articles/2013/11/cameroon-makes-deal-for-330-mw-nachtigal-falls-hydropower-project. html; and https://afrique.edf.com/en/edf-in-africa/news/a-new-phase-for-the-nachtigal-hydroelectric -project).

River rapids, cataracts, and waterfalls, are usually the preferred sites for dam construction for hydro-electric power, and also the habitats for many rheophytes, particularly the Podostemaceae. The rheophytes have become permanently submerged upstream of the dam due to flood water. The plants downstream are subjected to a different threat, that is, the change in flow rate and absence of flash floods below the dam (Cheek et al. 2015). In Ghana, two collecting localities of *Tristicha trifaria* (Podostemaceae) on the Volta River are now under lake water. Before the construction of the Akosombo dam on the Volta River in 1965, *T. trifaria* was collected at Kpando upstream of the dam. A second dam on the Volta River, down-stream of the Akosombo dam, was completed in 1982. *T. triticha* was collected on rocks in the river rapid just north of the Akuse dam (Ameka 2000). These two collecting sites have been lost because of the localities are permanently submerged (Ameka 2000). Thus dams threaten and /or endanger the very existence of rheophytic plants. We wish to draw attention to the threats posed by alluvial mining and dam construction to the survival of rheophytes and call on conservationists to do more to curb the indiscriminate damming of rivers, and alluvial mining across Africa. They must engage with policy makers in government and suggest alternative livelihoods for alluvial mine workers; and alternative green energy sources e.g., biofuels, biogas, and solar, instead of dam construction for hydropower.

Acknowledgements

We would like to thank the many individuals who have helped in diverse ways to enable the completion of this study. The contribution of those who helped in the field work is hereby acknowledged. Special thanks also go to the Director of the National Herbarium of Cameroon (YA) for the use of herbarium facilities. We thank the staff of the Plant Systematic and Ecology Laboratory of the Higher Teacher Training College for their assistance while doing this work. The support of Dr. Atanga Ekobo, former coordinator of WWF-CFP Limbe, for this study is highly appreciated. Dr Martin Cheek, Royal Botanic Gardens, Kew is thanked for his helpful comments on an earlier draft of this paper. Finally, we are also grateful to the anonymous referees.

References

Afum BO, Owusu CK (2016) Heavy metal pollution in the Birim River of Ghana. International Journal of Environmental Monitoring and Analysis 4(3): 65–74. https://doi.org/10.11648/j.ijema.20160403.11

Ameka GK (2000) The Biology, Taxonomy and Ecology of the Podostemaceae in Ghana. PhD Thesis, University of Ghana, Legon.

Ameka GK, Adomako JK, deGraft-Johnson KAA, Cheek M, Swaine MD (1996) Rheophytes of Ghana. In: van der Maesen LJG, et al. (Eds) The Biodiversity of African Plants. Kluwer Academic Publishers, Amsterdam, 780–782. https://doi.org/10.1007/978-94-009-0285-5_99

Ameka GK, Adomako JK, deGraft-Johnson KAA, Cheek M, Swaine MD (2002) Rheophytes of Africa – A review. Journal of Ghana Science Association 4(1): 83–96.

Bachman S, Moat J, Hill AW, de la Torre J, Scott B (2011) Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. In: Smith V, Penev L (Eds) e-Infrastructures for Data Publishing in Biodiversity Science. ZooKeys 150: 117–126. https://doi.org/10.3897/zookeys.150.2109

Brooks EGE, Allen DJ, Darwall WRT (2011) The Status and Distribution of Freshwater Biodiversity in Central Africa. Gland, Switzerland and Cambridge.

Cable S, Cheek M (1998) The Plants of Mount Cameroon, A Conservation Checklist. Royal Botanic Gardens, Kew.

Cheek M (2004) *Ledermanniella letouzeyi*. The IUCN Red List of Threatened Species 2004: e.T45901A11021118. [Downloaded on 19 August 2018]

Cheek M, John PB, Darbyshine I, Onana J M, Wild C (2004) The plants of Kupe Mwanenguba and the Bakossi mountains, Cameroon. A conservation checklist. Royal Botanic Gardens, Kew and National Herbarium of Cameroon.

Cheek M (2014) *Achyranthes talbotii*. The IUCN Red List of Threatened Species 2014: e.T39471A2927093. https://doi.org/10.2305/IUCN.UK.2014-3.RLTS.T39471A2927093.en [Downloaded on 16 March 2018]

Cheek M (2015) *Calvoa stenophylla*. The IUCN Red List of Threatened Species 2015: e.T202776A2752734. [Downloaded on 09 August 2018]

Cheek M, Poveda LL, Darbyshire I (2015) *Ledermanniella lunda* sp. nov. (Podostemaceae) of Lunda Norte, Angola. Kew Bulletin 70(1): 10–15. https://doi.org/10.1007/s12225-015-9559-8

Cheek M (2017a) *Deinbollia angustifolia*. The IUCN Red List of Threatened Species 2017: e.T110084840A110084842. [Downloaded on 09 August 2018]

Cheek M (2017b) *Ledermanniella prasina*. The IUCN Red List of Threatened Species 2017: e.T110079107A110079109. [Downloaded on 20 August 2018]

Cheek M (2018) *Stonesia ghoguei*. The IUCN Red List of Threatened Species 2018: e.T110074293A110074296. [Downloaded on 16 January 2019]

Cheek M, Lebbie A (2018) *Lebbiea* (Podostemaceae-Podostemoideae), a new, nearly extinct genus with foliose tepals, in Sierra Leone. PLoS One 13(10): e0203603. https://doi.org/10.1371/journal.pone.0203603

Cheek M, Feika A, Lebbie A, Goyder D, Tchiengue B, Sene O, Tchouto P, Van der Burgt X (2017a) A synoptic revision of *Inversodicraea* (*Podostemaceae*). Blumea 62(2): 125–156. https://doi.org/10.3767/blumea.2017.62.02.07

Cheek M, Larridon I, Rokni S (2017b) *Cyperus rheophyticus*. The IUCN Red List of Threatened Species 2017: e.T110093122A110093124. [Downloaded on 09 August 2018]

Cheek M, Swaine MD, Ameka GK (in press). Rheophytes of Africa.

Cusset C (1987) Podostemaeae –Tristichaceae. In: MESRES (Ed.) Flore du Cameroun 30: 51–99.

De Block P (1998) The African species of IXORA (Rubiaceae – Pavetteae). Opera Botanica Belgica 9: 1–218.

Diop FN (2010a) *Ledermanniella aloides*. The IUCN Red List of Threatened Species 2010: e.T185425A8409077. [Downloaded on 14 August 2018]

Diop FN (2010b) *Ledermanniella keayi*. The IUCN Red List of Threatened Species 2010: e.T39741A10261684. https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T39741A10261684.en [Downloaded on 14 August 2018]

Diop FN (2010c) *Ledermanniella musciformis*. The IUCN Red List of Threatened Species 2010: e.T185507A8425176. [Downloaded on 20 August 2018]

Diop FN (2010d) *Letestuella tisserantii*. The IUCN Red List of Threatened Species 2010: e.T185497A8422867. [Downloaded on 20 August 2018]

Diop FN (2017) *Inversodicraea ledermannii* (amended version of 2010 assessment). The IUCN Red List of Threatened Species 2017: e.T185295A1204640 96. https://doi.org/10.2305/IUCN.UK.2017-3.RLTS.T185295A120464096.en [Downloaded on 19 August 2018]

Duncan WT (1986) Note on *Deinbollia* species from Cameroon. Annals of the Missouri Botanical Garden 73(1): 219–221. https://doi.org/10.2307/2399152

Ghogue J-P, Ameka GK, Grob V, Huber KA, Pfeifer E, Rutishauser R (2009) Enigmatic morphology of Djinga felicis (Podostemaceae – Podostemoideae), a badly known endemic from northwestern Cameroon. Botanical Journal of the Linnean Society 160: 64–81. https://doi.org/10.1111/j.1095-8339.2009.00961.x

Ghogue J-P (2010a) *Anubias barteri*. The IUCN Red List of Threatened Species 2010: e.T185219A8369177. [Downloaded on 07 August 2018]

Ghogue J-P (2010b) *Dicraeanthus africanus*. The IUCN Red List of Threatened Species 2010: e.T185460A8416093. [Downloaded on 17 August 2018]

Ghogue J-P (2010c) *Dicraeanthus zehnderi*. The IUCN Red List of Threatened Species 2010: e.T185600A8444300. https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T185600A8444300.en [Downloaded on 17 August 2018]

Ghogue J-P (2010d) *Ledermanniella batangensis*. The IUCN Red List of Threatened Species 2010: e.T185525A8428951. [Downloaded on 19 August 2018]

Ghogue J-P (2010e) *Ledermanniella bifurcata*. The IUCN Red List of Threatened Species 2010: e.T185509A8425558. https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T185509A8425558.en [Downloaded on 19 August 2018]

Ghogue J-P (2010f) *Ledermanniella linearifolia*. The IUCN Red List of Threatened Species 2010: e.T185505A8424796. https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T185505A8424796.en [Downloaded on 19 August 2018]

Ghogue J-P (2010g) *Ledermanniella onanae*. The IUCN Red List of Threatened Species 2010: e.T45902A11021276. [Downloaded on 20 August 2018]

Ghogue J-P (2010h) *Ledermanniella pusilla*. The IUCN Red List of Threatened Species 2010: e.T185384A8400620. [Downloaded on 20 August 2018]

Ghogue J-P (2010i) *Ledermanniella sanagaensis*. The IUCN Red List of Threatened Species 2010: e.T185325A8389265. [Downloaded on 20 August 2018]

Ghogue J-P (2010j) *Ledermanniella schlechteri*. The IUCN Red List of Threatened Species 2010: e.T185208A8366931. https://doi.org/10.2305/iucn.uk.2010-3.rlts.t185208a8366931.en [Downloaded on 20 August 2018]

Ghogue J-P (2010k) *Ledermanniella thalloidea*. The IUCN Red List of Threatened Species 2010: e.T45903A11021582. [Downloaded on 20 August 2018]

Ghogue J-P (2010l) *Ledermanniella variabilis*. The IUCN Red List of Threatened Species 2010: e.T185224A8370407. [Downloaded on 20 August 2018]

Ghogue J-P (2010m) *Leiothylax quangensis*. The IUCN Red List of Threatened Species 2010: e.T185346A8392899. [Downloaded on 20 August 2018]

Ghogue J-P (2010n) *Macropodiella heteromorpha*. The IUCN Red List of Threatened Species 2010: e.T185399A8403508. [Downloaded on 20 August 2018]

Ghogue J-P (2010o) *Macropodiella pellucida*. The IUCN Red List of Threatened Species 2010: e.T45904A11021892. [Downloaded on 20 August 2018]

Ghogue J-P (2010p) *Saxicolella laciniata*. The IUCN Red List of Threatened Species 2010: e.T185310A8386482.https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T185310A8386482.en [Downloaded on 20 August 2018]

Ghogue J-P (2010q) *Saxicolella nana*. The IUCN Red List of Threatened Species 2010: e.T185400A8403816. [Downloaded on 20 August 2018]

Ghogue J-P (2010r) *Winklerella dichotoma*. The IUCN Red List of Threatened Species 2010: e.T185552A8434624. [Downloaded on 20 August 2018]

Ghogue J-P (2010s) *Zehnderia microgyna*. The IUCN Red List of Threatened Species 2010: e.T185538A8431595.https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T185538A8431595.en [Downloaded on 20 August 2018]

Ghogue J-P (2011) The status and distribution of freshwater plants of central Africa. In: Brooks EGE, Allen DJP, Darwell WRT (Compilers) The status and distribution of freshwater biodiversity in central Africa. IUCN, Gland, Switzerland & Cambridge.

Ghogue J-P (2017a) *Inversodicraea bosii* (amended version of 2010 assessment). The IUCN Red List of Threatened Species 2017: e.T185299A120458893. [Downloaded on 17 August 2018]

Ghogue J-P (2017b) *Inversodicraea cristata* (amended version of 2010 assessment). The IUCN Red List of Threatened Species 2017: e.T185309A1204598 89. [Downloaded on 17 August 2018]

Ghogue J-P (2017c) *Inversodicraea kamerunensis* (amended version of 2010 assessment). The IUCN Red List of Threatened Species 2017: e.T185482A120463590. https://doi.org/10.2305/IUCN.UK.2017-3.RLTS.T185482A120463590.en [Downloaded on 17 August 2018]

Hepper FN (1963) Flora of West Tropical Africa. 2nd Edition. Volume 2. Crown Agents, London, 544 pp.

Hepper FN (1968) Flora of West Tropical Africa. 2nd Edition. Volume 3, Part 1. Crown Agents, London, 276 pp.

Hepper FN (1972) Flora of West Tropical Africa. 2nd Edition, Volume 3, Part 2. Crown Agents, London, 574 pp.

Hooper SS (1972) New taxa, names and combination in Cyperaceae for the Flora of West Tropical Africa. Kew Bulletin 26(3): 577–583. https://doi.org/10.2307/4120322

Hoyos-Gomez SE, Bernal R (2018) Rheophytes of the Samana Norte River, Colombia: A hydroelectric Project Threatens an Endemic Flora. Tropical Conservation Science 11: 1–13. https://doi.org/10.1177/1940082918756816

IUCN (2013) Guidelines for using the IUCN Red List Categories and Criteria. Version 10.1. http://jr.iucnredlist.org/documents/RedListGuidelines.pdf [Downloaded on 23 December 2015]

IUCN Standards and Petitions Subcomittee (2017) Guidelines for Using the IUCN Red List Categories and Criteria. Version 13. http://www.iucnredlist.org/documents/RedListGuidelines.pdf [Downloaded on 6 August 2017]

Keay RWJ (1954) Flora of West Tropical Africa. 2nd Edition. Volume 1, Part 1. Crown Agents, London, 295 pp.

Keay RWJ (1958) Flora of West Tropical Africa. 2nd Edition. Volume 1, Part 2. Crown Agents, London, 825 pp.

Lansdown RV (2013) *Kanahia laniflora*. The IUCN Red Liat of Threatened Species 2013: e.T13581896A13594766. [Downloaded on 07 August 2018]

Letouzey R (1985) Notice de la carte phytogéographique du Cameroun au 1/500.000è. Inst. Carte Intern. Végétation, Toulouse, et Inst. Rech. Agron., Yaoundé.

Munang T, Mike R, Giani B, Sayed AA, Jeremy C (2008) Effects of climate change on crop production in Cameroon. Climate Research 36: 65–77. https://doi.org/10.3354/cr00733

Ndoh MI, Bitondo D, Balgah RA (2016) Climate variability and change in the Bamenda highlands of North Western Cameroon: Perception,impact and coping mechanisms. British Journal of Applied Science and Technology 12(5): 1–18. https://doi.org/10.9734/BJAST/2016/21818

Olivry JC (1986) Fleuves et rivières du Cameroun. Monographies Hydrologiques, ORSTOM 9: 1–733.

Onana JM, Cheek M (2011) Red data list of the flowering plants of Cameroon: IUCN Global Assessments. Royal Botanic Gardens, Kew, 578 pp.

Ouedraogo L (2010a) *Saxicolella flabellata*. The IUCN Red List of Threatened Species 2010: e.T185205A8366173. [Downloaded on 20 August 2018]

Ouedraogo L (2010b) *Saxicolella marginalis*. The IUCN Red List of Threatened Species 2010: e.T39742A10261941. [Downloaded on 20 August 2018]

Pfeifer E, Grob V, Thiv M, Rutishauser R (2009) *Stonesia ghoguei*, peculiar morphology of a new Cameroonian species (Podostemaceae, Podostemoideae). Novon 19(1): 102–116. https://doi.org/10.3417/2007080

Philbrick CT, Crow GE (1983) Distribution of Podostemum Ceratophyllum Michx. (Podostemaceae). Rhodora 85: 325–341.

Philbrick CT, Novelo RA (1995) New World Podostemaceae: Ecological and evolutionary enigmas. Brittonia 47(2): 210–222. https://doi.org/10.2307/2806959

Pollard BJ, Paton A (2001) A new rheophytic species of *Plectranthus* L'Hér. (Labiatae) from the Gulf of Guinea. Kew Bulletin 56(4): 975–982. https://doi.org/10.2307/4119309

Pollard BJ, Paton A (2003) *Plectranthus cataractarum*. The IUCN Red List of Threatened Species 2003: e.T43886A10829133. [Downloaded on 16 August 2018]

Quiroz FA, Novelo RA, Philbrick CT (1997) Water chemistry and the distribution of Mexican Podostemaceae: A preliminary evaluation. Aquatic Botany 57(1–4): 201–212. https://doi.org/10.1016/S0304-3770(96)01118-7

Sainge NM (2017) Vegetation patterns in tropical forests of the Rumpi Hills and Kimbi Fungom National Park, Cameroon, West Central Africa. PhD Thesis, Cape Peninsula University of Technology, South Africa, 210 pp.

Segalen P (1967) Les sols et la geomorphologie du Cameroun. Service scientifiques centraux de l'ORSTOM, serie pédologie. Bondy, Montpellier 5(2): 1–187.

Suchel JB (1972) La répartition des pluies et les régimes pluviométriques au Cameroun. Contribution à l'étude des climats de l'Afrique Tropicale. Université fédérale du Cameroun, centre d'études de géographie tropicale, centre national de la recherche scientifique.

Thiers B (2017) Index Herbariorum: A global directory of public herbaria and associated staff, New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/ [Downloaded on 06 August 2017]

van Steenis CGGJ (1978) Rheophytes in South Africa. Bothalia 12(3): 543–546. https://doi.org/10.4102/abc.v12i3.1813

van Steenis CGGJ (1981) Rheophytes of the World. Sijthoff & Noordhoff, Aalphen aan den Rijn, The Netherlands. https://doi.org/10.1007/978-94-009-8588-9

World Conservation Monitoring Centre (1998) *Deinbollia saligna*. The IUCN Red List of Threatened Species 1998: e.T34668A9882213. [Downloaded on 16 August 2018]