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Two new species of *Eriocaulon* (Eriocaulaceae) from Cambodia

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Summary. Two new species of *Eriocaulon* (Eriocaulaceae) from Bokor National Park, Kampot province, southwest Cambodia are described and illustrated: *E. bokorense* Soulad. & Praj. and *E. cambodianum* Soulad. & Praj. Information regarding the habitat and an IUCN provisional conservation assessment of each species are provided.

Key Words. Bokor National Park, flora, Indo-China, taxonomy.

Introduction

Eriocaulon L. (Eriocaulaceae) consists of over 450 species and is widely distributed in Africa, Asia and America (Larridon *et al.* 2019). The genus is characterised by its habitat in aquatic and wetland areas, by its short stems and basal rosettes of leaves, and solitary heads of many small unisexual flowers at the apices of the scapes (Stützel 1998; Prajaksood *et al.* 2017; Leach 2017). The species of *Eriocaulon* are widely distributed from lowlands to high mountains in subtropical to tropical areas of the world (Stützel 1998). In Asia, the highest number of species is in India with 109 species (Ansari & Balakrishnan 2009; Darshetkar *et al.* 2017; Darshetkar *et al.* 2019; Francis *et al.* 2020; Anoop & Robi 2021), followed by Thailand with 36 species (19 endemics, Prajaksood & Chantaranothai 2002; Prajaksood *et al.* 2012; Prajaksood *et al.* 2017; Khorngton *et al.* 2020), China with 35 species (13 endemics, Ma *et al.* 2000) and Japan with 34 species (8 endemics, Satake 1940).

The flora of Cambodia is poorly known and has one of the lowest estimated collecting densities in Southeast Asia (Middleton *et al.* 2019). *Eriocaulon* in Cambodia was initially represented by three species (of 27 species in total) in the *Flore générale de l'Indo-Chine* (Lecomte 1912) but only one species in the monograph by Zhang (1999). The most up-to-date checklist of Cambodia by Cho *et al.* (2016) and floristic surveys in Cambodia (Rundel & Middleton 2017; Khorngton *et al.* 2020) raised the number of species to 14, with one variety.

Critical examination of *Eriocaulon* specimens collected in Cambodia, Laos and Vietnam has been under way since 2013, during which time lectotypes have been designated (Souladeth *et al.* 2017) and species new to science published (Khorngton *et al.* 2020; Souladeth *et al.* 2020) in preparation of a revision for the Flora of Cambodia, Laos and Vietnam. In the present study, two new species, *Eriocaulon bokorense* Soulad. & Praj. and *E. cambodianum* Soulad. & Praj. are described from Cambodia. Consequently, the number of *Eriocaulon* species known in Cambodia has increased to 16, with one variety also recognised (Table 1).

Materials and Methods

Field collections were made in Cambodia by the first author from August to September 2017. More than 1100 herbarium collections, including type specimens, have been consulted in the following herbaria: BKF, BM, E, FOF, FU, HHU, HNL, K, KAG, KEP, KKU, KYO, L, LINN, M, NY, P, QBG, RUPP and VNM. The new species were compared with morphologically similar species in published descriptions (Lecomte 1912; Moldenke 1950; Royen 1959; Zhang 1999; Ma *et al.* 2000; Ansari & Balakrishnan 2009; Prajaksood *et al.* 2012; Cho *et al.* 2016; Leach 2017; Prajaksood *et al.* 2017; Leach 2018; Khorngton *et al.* 2020; Souladeth *et al.* 2020; Anoop & Robi 2021). The descriptions are based on dried herbarium specimens using standard terms for taxonomic description. Seed coat morphology follows the terminology of Nair (1987) and Zona *et al.* (2012). The conservation assessments were evaluated using the IUCN Red List Categories and Criteria (IUCN 2020). The area of occupancy (AOO, grid resolution = 2 km), the number of sub-populations (radius 5 km), the number of localities (grid resolution = 10 km) and the extent of occurrence (EOO) were calculated using R version 4.1.0 (RStudio Team 2021) with four packages, namely (1) Computation of Parameters Used in Preliminary Assessment of Conservation Status (ConR), (2) Geographic Data Analysis and Modelling (raster), (3) Classes and Methods for Spatial Data (sp), and (4)

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Table 1. Sixteen species of *Eriocaulon* L. found in Cambodia. New taxa reports are indicated in bold. ✓ = reported, - = not reported.

Taxa	Publication				
	Lecomte (1912)	Zhang (1999)	Cho *et al.* (2016)	Khorngton *et al.* (2020)	This report
E. bokorense *Soulad. & Praj.* **sp. nov.**	-	-	-	-	✓
E. breviscapum Körn.	-	-	✓	-	-
E. brownianum Mart.	-	✓	✓	-	-
E. cinereum R.Br.	-	-	✓	-	-
E. cambodianum *Soulad. & Praj.* **sp. nov.**	-	-	-	-	✓
E. echinulatum Mart.	✓	-	✓	-	-
E. infirmum Steud.	-	-	✓	-	-
E. longibracteatum Khorngton, Soulad. & Praj.	-	-	-	✓	-
E. nautilifome Lecomte	✓	-	✓	-	-
E. odoratum Dalzell	-	-	✓	-	-
E. oryzetorum Mart.	✓	-	✓	-	-
E. setaceum L.	-	-	✓	-	-
E. sexangulare L.	-	-	✓	-	-
E. sexangulare var. *australe* (R.Br.) Praj. & J.Parn.	✓	-	✓	-	-
E. truncatum Buch.-Ham. ex Mart.	-	-	✓	-	
E. ubonense Lecomte	-	-	✓	-	
E. willdenovianum Moldenke	-	-	✓	-	-
Total taxa	**5**	**1**	**14**	**1**	**2**

World Vector Map Data from Natural Earth Used in 'rnaturalearth' (rnaturalearthdata).

Taxonomic Treatment

Eriocaulon bokorense *Soulad. & Praj.*, **sp. nov.** Type: Cambodia, Kampot Province, Bokor National Park, 1000 m alt., 4 Dec. 1993, *E. Poilane* 23061 (holotype P! [P01762557]).

http://www.ipni.org/urn:lsid:ipni.org:names:77234371-1

Annual herbs. *Leaves* rosulate, linear, 0.8 – 2 cm long, 0.2 mm wide, glabrous, apex acute. *Scapes* 1 – 30, 5 – 7 cm long, 0.5 – 0.8 mm in diam., 3-ridged, twisted, glabrous. *Sheaths* 1 – 1.8 cm long, glabrous, apex acute. *Heads* globose, 2 – 3 × 3 – 3.5 mm, white. *Receptacles* convex, pilose. *Involucral bracts* incurved, obovate, 1.5 – 1.8 × 1.2 – 1.4 mm, brown, chartaceous, glabrous, apex obtuse. *Floral bracts* oblanceolate, 1.3 – 1.4 × 0.8 – 1 mm, light brown, dark brown in middle, chartaceous, hoary towards apex, apex acute. *Male flowers:* pedicellate, c. 0.2 mm long; sepals 3, free, obovate, boat-shaped, 1 – 1.2 × 1 – 1.2 mm, light brown, chartaceous, hoary dorsally towards apex, apex acute; petals 3, fused basally, lobes ovate to triangular, 0.3 – 0.5 mm long, light brown, chartaceous, hoary at margin, with a minute black gland, apex acute; stamens 6, filaments 0.2 – 0.3 mm long; anthers black. *Female flowers:* pedicellate, c. 0.2 mm long; sepals 3, free, obovate, boat-shaped, 2 – 2.5 × 1 – 1.2 mm, light brown, chartaceous, hoary dorsally towards apex, apex acute; petals 3, free, subequal, broadly elliptic, attenuate, 2 – 2.3 × 1.5 – 1.8 mm, brown, coriaceous, hoary at apex with a black gland, apex acute; ovary sessile, trilocular; style to 1 mm long; stigmas 3, 0.5 mm long. *Seeds* ovoid to ellipsoid, obtuse at both ends, 0.5 – 0.8 mm long, 0.5 – 0.7 mm in diam., reddish-brown; cells of seed coat transversely elongate, aligned in vertical rows; scale-like appendages present, solitary from the middle of transverse wall. Figs 1 & 2.

RECOGNITION. *Eriocaulon bokorense* is morphologically similar to *E. laosense* Moldenke (Moldenke 1950; Prajaksood *et al.* 2017; type specimens, *Poilane* 15468, holotype NY102707!; isotype, P00224174!) in its small (up to 7 cm long), glabrous leaves, scape and involucral bracts, but differs in the shape of the heads (globose in *E. bokorense* vs hemispherical in *E. laosense*), involucral bracts (obovate vs elliptic), floral bracts (oblanceolate vs linear to oblong), male sepals (obovate, boat-shaped with acute apex vs obovate, uncurved with obtuse apex), female petals (broadly elliptic, coriaceous vs lanceolate, chartaceous), and the presence of appendages (presence vs absence). A comparison of these two taxa is shown in Table 2.

DISTRIBUTION. Asia: Cambodia (Map 1).

SPECIMENS EXAMINED. CAMBODIA. Kampot Province, Bokor National Park, at alt. 1000 m, 4 Dec. 1993, *E. Poilane* 23061 (holotype P! [P01762557]); ibid., 15 Dec. 1954, *M. Schmid* s.n. (P! [P01721448]); ibid., 20 Nov. 1999, *S. Hul, L. Yok, S. Lim & C. Seng* 742 (P! [P06172806]); ibid., 10°39'16.88"N, 104°03'25.1"E, alt. 992 m, 22 Dec. 2011, *Toyama et al.* 2518 (FU!; TNS; Herbarium of the Forest Administration of Cambo-

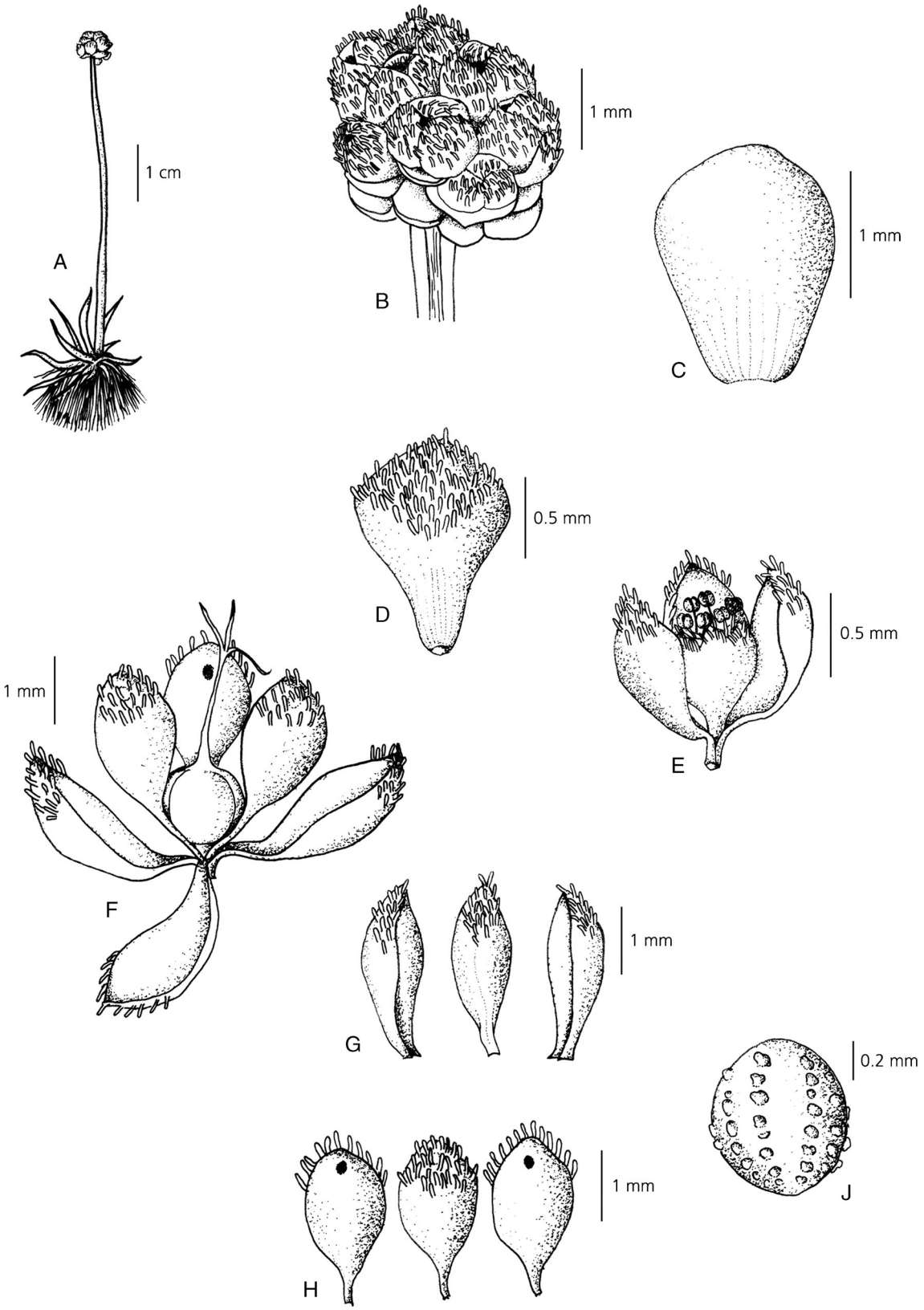


Fig. 1. *Eriocaulon bokorense*. **A** habit; **B** head; **C** involucral bract; **D** floral bract; **E** male flower; **F** female flower; **G** female sepals; **H** female petals; **J** seed with scale-like appendages. From *E. Poilane* 23061 (holotype P! [P01762557]). DRAWN BY S. KHORNGTON.

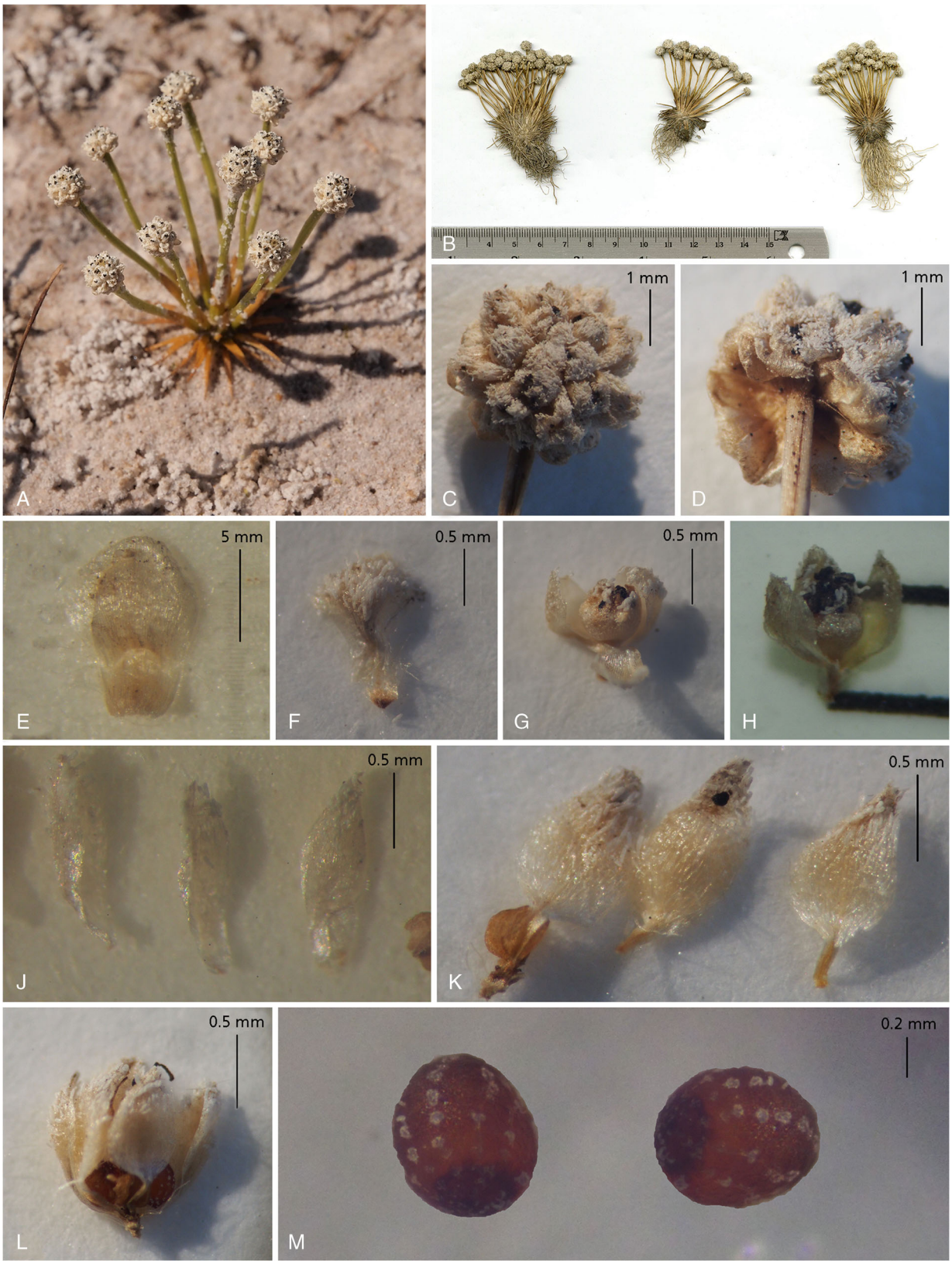


Fig. 2. *Eriocaulon bokorense*. **A** – **B** habit; **C** – **D** heads (**C** front view & **D** back view showing involucral bracts); **E** involucral bract; **F** floral bract; **G** – **H** male flowers (**G** deciduous anther & **H** with anthers); **J** female sepals; **K** female petals; **L** female flower; **M** seeds with scale-like appendages. **A** – **B** & **H** from *Fuse et al.* 6353 (FU!); **C** – **G**, **J** – **M** from *E. Poilane* 23061 (holotype P! [P01762557]). PHOTOS: **A** – **B** S. TAGANE; **C** – **M** P. SOULADETH.

Table 2. Diagnostic morphological characters of *Eriocaulon bokorense* sp. nov. and *E. laosense* Moldenke (Moldenke 1950, holotype NY102707! and isotype, P00224174!). The seed information of *E. laosense* from Prajaksood *et al.* (2017).

Characters	*E. bokorense* **sp. nov.**	*E. laosense* Moldenke
Leaves	linear, 0.8 – 2 cm long, 0.2 mm wide, apex acute	narrowly lanceolate, 5 – 7 cm long, 1 mm wide, apex acute
Scapes	5 – 7 cm long, 3-ridged, twisted	1.7 – 3 cm long, 3-ridged, slightly twisted
Heads	globose, 3 – 3.5 mm in dia.	hemispherical, 2 – 3 mm in dia.
Involucral bracts	obovate, 1.5 – 1.8 × 1.2 – 1.4 mm, apex obtuse	elliptic, 1.3 – 1.5 × 0.3 mm, apex subacute
Floral bracts	oblanceolate, 1.3 – 1.4 × 0.8 – 1 mm	linear to oblong, 0.3 – 0.9 × 0.1 mm
Male sepals	obovate, boat-shaped, 1 – 1.2 × 1 – 1.2 mm, apex acute	obovate, 0.8 – 0.9 × 0.4 mm, apex obtuse
Female sepals	obovate, boat-shaped, 2.3 – 3 × 1 – 1.2 mm, apex acute	spatulate, 0.9 × 0.2 mm, apex cuspidate to acute
Female petals	broadly elliptic, 2.5 – 3 mm long, coriaceous	lanceolate, 1.3 – 1.5 mm long, chartaceous
Seeds	ovoid to ellipsoid, reddish-brown; appendages present	yellow, appendage absent

dia); ibid., 10°39'15.1"N, 104°00'16.4"E, alt. 1013 m, 19 Nov. 2013, *Cho et al.* CB-2736 (HHU!); ibid., near transect line 5, edge of bog evergreen forest, on the plateau, 10°39'09.06"N, 104°03'38.68"E, alt. 935 m, 12 Dec. 2013, *Fuse et al.* 6353 (FU!; TNS; Herbarium of the Forest Administration of Cambodia).

HABITAT. In open areas in montane evergreen forest, at 935 – 1013 m altitude.

CONSERVATION STATUS. Critically Endangered (CR B1a+B2a, IUCN 2020). This species has an area of occupancy (AOO) of 12 km^2. It is known from only one sub-population in one locality (Bokor Plateau, Bokor National Park, Kampot Province), with an estimate of less than 1000 mature individuals. The extent of occurrence (EOO) is 12 km^2. The summit of the plateau is characterised by well-developed sphagnum bog (known as Popokvil bog; Fig. 3). This type of bog is relatively rare in mainland Southeast Asia (Tagane *et al.* 2017; Rundel & Middleton 2017). Since this plateau is a well-known tourist attraction, the presence of people may increase disturbance in the area and affect the future survival chances of this species.

PHENOLOGY. Flowering and fruiting from November to December.

ETYMOLOGY. The epithet "*bokorense*" refers to Bokor National Park, Kampot Province, south-eastern Cambodia.

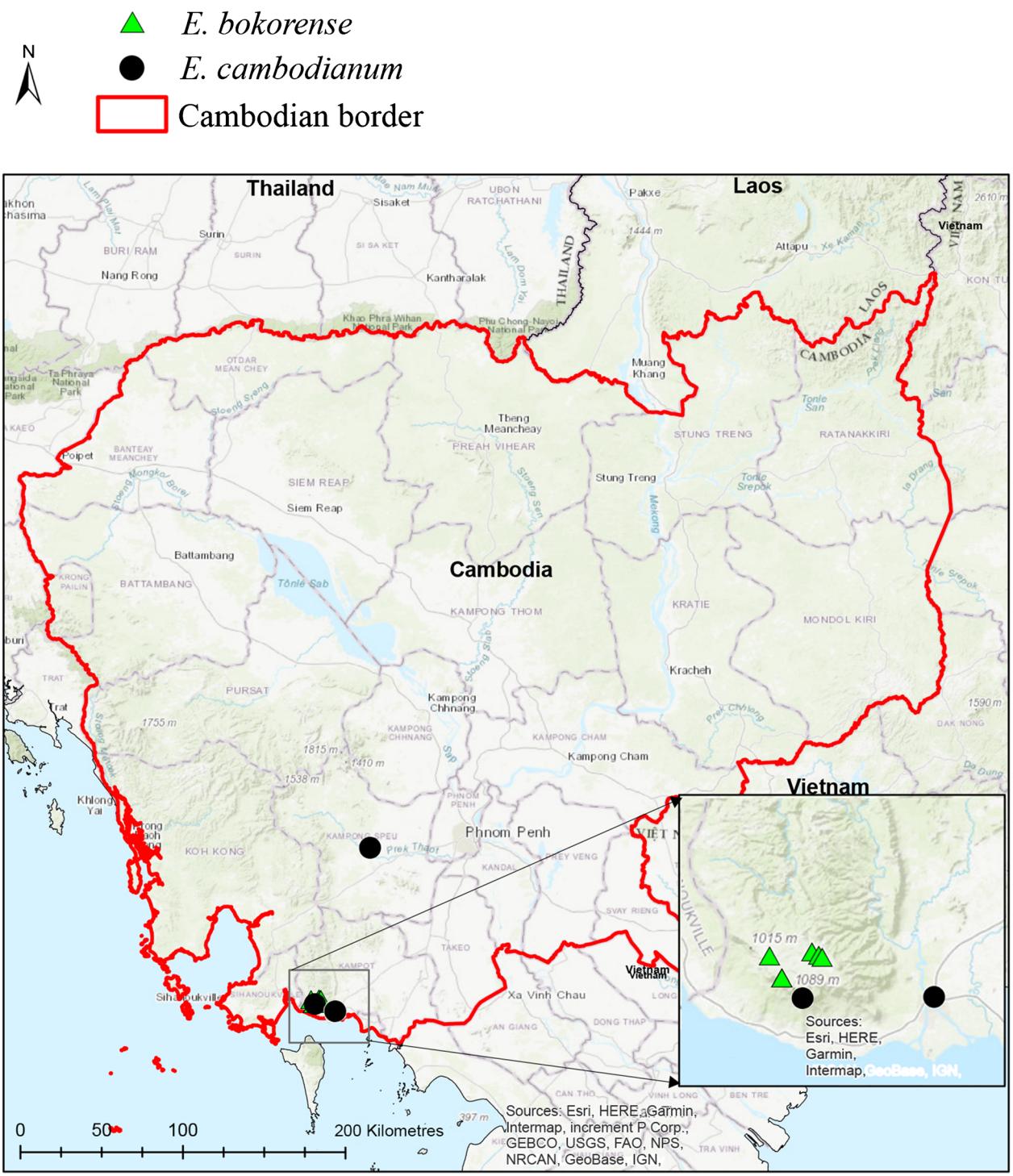
NOTE. This species is characterised by its small size, white globose heads and female petals broadly elliptic, attenuate and coriaceous. Material from *Toyama et al.* 2518, *Cho et al.* CB-2736 and *Fuse et al.* 6353 (TD4997, CB2736 and TD5003 in Fig. 2 of Larridon *et al.* 2019, respectively) was used for phylogenetic analyses of *Eriocaulon* using chloroplast DNA (*matK*, *rbcL*, *rpoB* and *rpoC1*) and PHYC (Larridon *et al.* 2019). The results support the recognition of this species as new to science.

Eriocaulon cambodianum *Soulad. & Praj.*, **sp. nov.** Type: Cambodia. Kampot, 800 m alt., 5 Feb. 1928, *E. Poilane* 14702 (holotype P! [P01762571]).

http://www.ipni.org/urn:lsid:ipni.org:names:77234372-1

Perennial herbs, stems shortly rhizomatous, 1 – 3 cm long. *Leaves* rosulate, linear, (3 –) 20 – 30 cm × 3 – 4 mm, glabrous, apex obtuse to acute. *Scapes* few, to 50 cm long, 1 – 1.8 mm in diam., strongly 8-ridged, not twisted, glabrous. *Sheaths* 10 – 15 cm long, glabrous, apex acute. *Heads* globose, 5 – 6 × 6 – 7 mm, greyish-brown. *Receptacles* concave, pilose. *Involucral bracts* incurved, broadly ovate, 3 – 3.2 × 2 – 2.1 mm, yellowish-brown, coriaceous, glabrous, apex acute. *Floral bracts* elliptic, keeled, 3 – 4 × 1.5 – 2 mm, greyish-brown at base, blackish-brown from middle towards apex, coriaceous, long brown hairs dorsally towards apex, apex acute. *Male flowers:* pedicellate, c. 0.3 mm long; sepals 3, free, obovate, boat-shaped, keeled, 2 – 2.7 × 0.6 – 0.8 mm, greyish-brown at base, blackish-brown from middle towards apex, coriaceous, hoary dorsally towards apex, apex obtuse; petals 3, fused basally, lobes triangular, 1 – 1.2 × 0.5 mm, brown, hoary towards apex, with a black gland, apex acute; stamens 6, filaments c. 0.5 mm long; anthers black. *Female flowers:* pedicellate, c. 0.3 mm long; sepals 3, free, dissimilar, the middle one broadly elliptic, slightly curved, the two laterals boat-shaped, keeled, 2 – 2.5 × 1.1 – 1.5 (– 1.8) mm, greyish-brown at base, blackish-brown from middle towards apex, coriaceous, hoary dorsally towards apex, apex acute; petals 3, free, subequal, elliptic, 3.5 – 3.7 × 0.8 – 1.2 mm, coriaceous, brown, dense long brown hairs, short white hairs ventrally towards apex, with a black gland, apex acute; ovary sessile, trilocular; style 0.6 mm long; stigmas 3, 1.2 mm long. *Seeds* ellipsoid, obtuse at both ends, 0.4 – 0.5 × 0.3 – 0.4 mm, light brown; cells of seed coat transversely elongate, aligned in vertical rows; minute appendages present. Figs 4 & 5.

RECOGNITION. *Eriocaulon cambodianum* resembles *E. fluviatile* Trimen (Ansari & Balakrishnan 2009; Prajaksood *et al.* 2017); type specimen of *E. tonkinense* Ruhland [synonym of *E. fluviatile* (*Balansa* 247, K000873549!)] in having a rhizomatous stem, leaves to 30 cm long; globose and greyish-brown heads, the similar shape of the female sepals, and the blackish-



Map 1. Distribution map of *Eriocaulon bokorense* (closed green triangle) and *E. cambodianum* (closed black circle). MADE BY S. BOUTTHAVONG.

brown colouring of the floral bracts, male and female sepals but differs in the nature of the receptacles (concave and pilose in *E. cambodianum* vs elongate and glabrous in *E. fluviatile*), colour of the anthers (black vs white or pale yellow), the nature of the female sepals (dissimilar, the middle one broadly elliptic, the two laterals boat-shaped, keeled and coriaceous vs similar, oblanceolate, shallowly curved and chartaceous), and the presence of appendages (presence vs absence). Additional characters are shown in Table 3.

DISTRIBUTION. Asia: Cambodia (Map 1).

Fig. 3. Bokor National Park. **A** open area of montane evergreen forest; **B** wetland in open areas (September 2017). PHOTOS: P. SOULADETH.

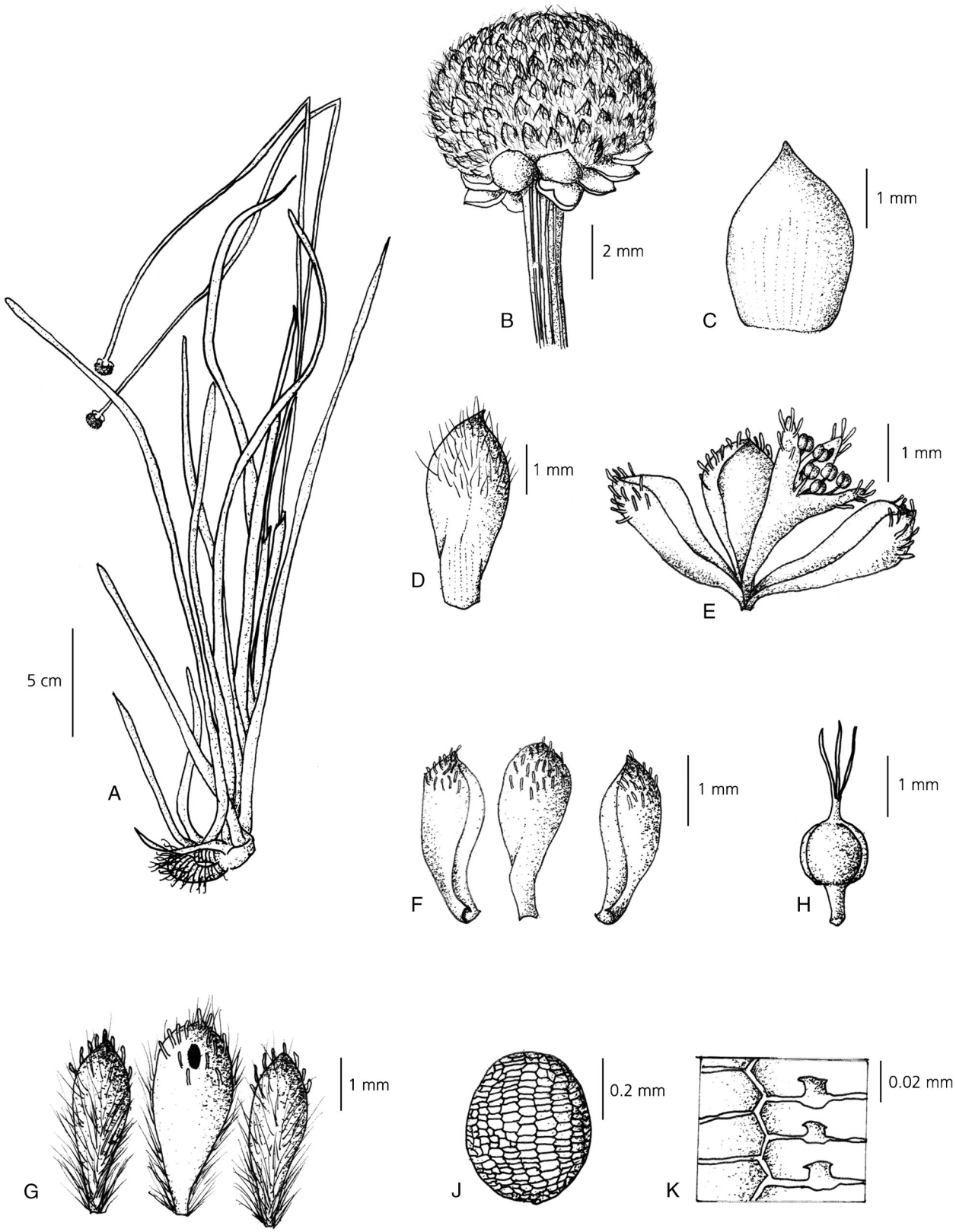


Fig. 4. *Eriocaulon cambodianum*. **A** habit; **B** head; **C** involucral bract; **D** floral bract; **E** male flower; **F** female sepals; **G** female petals; **H** pistil; **J** seed; **K** seed with minute appendages. From *E. Poilane* 14702 (holotype P! [P01762571]). DRAWN BY S. KHORNGTON.

Fig. 5. *Eriocaulon cambodianum*. **A** type specimen showing the habit; **B** – **C** heads (**B** young head & **C** mature head); **D** scape; **E** involucral bract; **F** floral bract; **G** male flower; **H** female sepals; **J** female petals; **K** pistil and petals; **L** seed. **A**, **C** – **L** from *E. Poilane* 14702 (holotype P! [P01762571]); **B** from *Kira et al.* 158 (KYO!). PHOTOS: P. SOULADETH.

Table 3. Diagnostic morphological characters of *Eriocaulon cambodianum* sp. nov. and *E. fluviatile* Trimen (Prajaksood *et al*. 2017). The seed information of *E. fluviatile* from Ansari & Balakrishnan (2009).

Character	*E. cambodianum*	*E. fluviatile*
Rhizomatous stems	up to 3 cm long	3 – 5 cm long
Leaves	20 – 30 cm long, apex obtuse to acute	15 – 20 cm long, apex acute
Scapes	up to 50 cm long	up to 23 cm long
Receptacles	concave, pilose	elongate, glabrous
Involucral bracts	broadly ovate, 3 – 3.2 × 2 – 2.1 mm, yellowish-brown	obovate, 2.5 × 1 mm, brown
Floral bract	elliptic, keeled, 3 – 4 × 1.5 – 2 mm, long brown hairs towards apex	obovate, 2.5 × 1 – 1.3 mm, white hairs towards apex
Colour of anthers	black	white or pale yellow
Female sepals	dissimilar, the middle one broadly elliptic, the lateral two boat-shaped, keeled, coriaceous	similar, oblanceolate, shallowly curved, chartaceous
Female petals	3.5 – 3.7 mm long, long brown hairs and short white hairs towards apex	1 mm long, short white hairs towards apex only
Seeds	ellipsoid, light brown; minute appendages present	oblong-ovoid, reddish-brown; appendage absent

SPECIMENS EXAMINED. CAMBODIA. Kampot, 800 m alt., 5 Feb. 1928, *E. Poilane* 14702 (holotype P! [P01762571]); Kampot, Bokor National Park, Popokvil, 4 Dec. 1964, *T. Kira, K. Hozumi, K. Yoda & S. Kokawa* 158 (KYO!); ibid., 10°37'36"N, 104°01'39"E, at alt. 1014 m, 22 Nov. 2007, *V. D. Nguyen & Rattana* CB-VN 179 (K!); Kampong Speu, Kirirom, Mt Sral [Schral], at alt. 1000 m, 18 Feb. 1960, *T. Smitinand & E. C. Abbe* 6450 (K!).

HABITAT. On sandy soil mixed with rocks near streams in montane evergreen forest, at 800 – 1014 m altitude.

CONSERVATION STATUS. The preliminary assessment of this species is Endangered (EN), B1a+B2a (IUCN 2020). This species has an area of occupancy (AOO) of 16 km^2. It is known from three sub-populations in three localities (Bokor National Park in Kampot Province and Mt Sral in Kampong Speu Province). The extent of occurrence (EOO) is 650 km^2.

PHENOLOGY. Flowering and fruiting from November to February.

ETYMOLOGY. The species epithet "*cambodianum*" refers to the country of the type locality.

NOTE. This species is characterised by its shortly rhizomatous stem, greyish-brown heads, the female sepals dissimilar, the middle one broadly elliptic, the two laterals boat-shaped, keeled and coriaceous and anther black.

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