

# *Sirdavidia*, an extraordinary new genus of Annonaceae from Gabon

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## Abstract

A distinctive new monotypic genus from Gabon is described in the tropical plant family Annonaceae: *Sirdavidia*, in honor to Sir David Attenborough. Molecular phylogenetic analyses confirm that *Sirdavidia*, which is very distinct from a morphological standpoint, is not nested in any existing genus of Annonaceae and belongs to tribe Piptostigmateae (subfamily Malmeeoideae), which now contains a total of six genera. The genus is characterized by long acuminate leaves, fully reflexed red petals, 16–19 bright yellow, loosely arranged stamens forming a cone, and a single carpel topped by a conspicuous stigma. With just three known collections, a preliminary IUCN conservation status assessment is provided as “endangered” as well as a distribution map. The discovery of *Sirdavidia* is remarkable at several levels. First, it was collected near the road in one of the botanically best-known regions of Gabon: Monts de Cristal National Park. Second, its sister group is the genus *Mwasumbia*, also monotypic, endemic to a small area in a forest in Tanzania, some 3000 km away. Finally, the floral morphology is highly suggestive of a buzz pollination syndrome. If confirmed, this would be the first documentation of such a pollination syndrome in Magnoliidae and early-diverging angiosperms in general.

## Résumé

Un nouveau genre monotypique du Gabon est décrit dans la famille tropicale des Annonaceae : *Sirdavidia*, en honneur à Sir David Attenborough. Des analyses phylogénétiques confirment que *Sirdavidia*, caractérisé par une morphologie unique, n'appartient à aucun genre connu d'Annonaceae et se place au sein de la tribu des Piptostigmateae (dans la sous-famille des Malmeoideae), laquelle compte désormais un total de six genres. Le genre est caractérisé par des feuilles avec un long acumen, des pétales rouges réfléchis, 16–19 étamines jaunes qui forment un cône lâche et un carpelle surmonté d'un stigmate bien visible. Avec seulement trois récoltes connues, un statut de conservation préliminaire de "endangered" est proposé sur la base des critères de l'UICN. Une carte de distribution est également fournie. La découverte de *Sirdavidia* est remarquable pour plusieurs raisons. Tout d'abord le nouveau genre a été collecté près de la route dans l'une des régions les plus connues botaniquement du Gabon : le Parc National des Monts de Cristal. Ensuite, son groupe-frère est le genre, *Mwasumbia*, également monotypique, endémique d'une petite région en Tanzanie à plus de 3000 km. Enfin, les caractères floraux suggèrent un syndrome de pollinisation appelé « buzz pollination ». Si cela se confirme, ce sera la première documentation de ce type de syndrome pour les Magnoliidae et les Angiospermes basales en général.

## Keywords

Piptostigmateae, Monts de Cristal, buzz pollination, vicariance, Annonaceae, Central Africa, Magnoliidae

## Introduction

The Central African country of Gabon is merely 270 000 km<sup>2</sup> in size, but is home to an incredible botanical diversity (Sosef et al. 2006). Around 82% of its territory is covered with tropical rain forest and with around 5000 vascular plant species, Gabon is an important center of plant biodiversity in Central Africa (Sosef et al. 2006). The country is botanically one of the best known in the region (Sosef et al. 2006; Wieringa and Sosef 2011) with several parts of its territory well inventoried, such as the Monts de Cristal area (Wieringa and Sosef 2011).

Annonaceae (Magnoliidae) is a pantropical flowering plant family of trees, shrubs and lianas. With around 2500 species (Chatrou et al. 2012; Couvreur et al. 2011) it is one of the most diverse plant families in tropical rain forests, and the largest in order Magnoliales (Haywood et al. 2009). Recently a new phylogenetic classification of the family recognizes four subfamilies and 14 tribes (Chatrou et al. 2012). This was followed by a scratchpad website (World Annonaceae; Couvreur 2014b) documenting Annonaceae diversity and taxonomy worldwide. Taxonomic understanding of African Annonaceae has been increasing since the publication of "Flore du Gabon, Annonaceae, volume 16" (Le Thomas 1969) more than 40 years ago (Botermans et al. 2011; Couvreur 2009; Couvreur 2014a; Deroin and Luke 2005; Fero et al. 2014; Versteegh and Sosef 2007). As a consequence, several new species and a new genus have been described in Africa these past years, mainly from Tanzania (Couvreur et al. 2006; Couvreur et al. 2009; Johnson et al. 1999; Luke and Deroin 2005; Marshall et al. in press). New species, however, from Central Africa, and in particular Gabon, have been rarer with only a few such descriptions (Jongkind 2002).

A probable new genus of Annonaceae was collected during field work in Monts de Cristal National Park, as part of a larger field trip focusing on the study Magnoliidae floral diversity. The objective of this paper was to confirm its status as a new species and its classification in a new genus. The taxon was first seen near the Kinguélé dam, and further prospection in the area revealed several individuals. It is the unusual floral structure of this species for Annonaceae that led us to suspect it might represent a new taxon and to undertake both a phylogenetic analysis and more thorough morphological observations. As we show here, interesting tropical taxa unknown to science can still be discovered in places even considered to be well known botanically.

## Material and methods

Herbarium, alcohol and photographic materials were used to produce the descriptions. In order to identify other specimens of this new genus, we looked at all undetermined Annonaceae specimens in the herbaria located at BR, BRLU, LBV, P and YA (herbarium acronyms according to Thiers 2012). We also looked at sterile plot specimens of Annonaceae for Gabon held at BRLU. The conservation status was assessed by calculating the extent of occurrence (EOO) and the area of occupancy (AOO) using the GeoCAT tool (Bachman et al. 2011) and applying the IUCN Red List Category criteria (Standards-and-Petitions-Working-Group 2006).

A preliminary phylogenetic analysis indicated that the new taxon was nested in tribe Piptostigmateae of the Malmeoideae subfamily. Therefore, the data matrix of Couvreur et al. (2009) was used to undertake the analyses. The matrix was based on two plastid markers (*rbcL* and *trnL* intron / *trnL-trnF* spacer) and contains 35 out of the 47 genera of Malmeoideae, representing all major lineages. Representative species from all other subfamilies were also sampled: Anaxagoreoideae (1 genus), Ambavioideae (2 genera out of 8), Annonoideae (17 genera out of 50). *Eupomatia bennettii* (Eupomatiaceae) was chosen as the outgroup (Massoni et al. 2014; Sauquet et al. 2003). All six genera currently recognized in Piptostigmateae were sampled. Sampling within genera was restricted to one species in the Annonoideae and Ambavioideae, and varied from one to two species in the Malmeoideae.

DNA extractions of silicagel-dried leaf samples from two individuals of *Sirdavidia solannona* Couvreur & Sauquet were performed using a DNeasy Plant Mini Kit (Qiagen, Valencia, CA). The universal primers C/D and E/F (Taberlet et al. 1991) were used to amplify and sequence the *trnL* intron and *trnL-trnF* spacer. The *rbcL* marker was amplified using two primer combinations, 1F/724R and 636F/1460R (Fay et al. 1998). PCR amplifications were conducted using the FailSafe kit with Premix E (Epicentre, Madison, WI), according to manufacturer's instructions and by adding 0.5 U of *Taq* DNA polymerase (Promega, Madison, WI) in a total volume of 50  $\mu$ L. The PCR program was as follows: 35 thermal cycles at 94 °C for 1 min, 50–55 °C for 50 s, 72 °C for 50 s and a final extension at 72 °C for 3 min. Sequencing was performed at Macrogen (The Netherlands). Sequences were edited using Geneious 1.5.6

(Drummond et al. 2010) and manually aligned in the PAUP\* text editor (version 4.10b; Swofford 2002). Gaps were coded following the simple coding model of Simmons and Ochoterena (2000). Microsatellites and ambiguously aligned regions (in the *trnL* intron and *trnL-trnF* spacer) were excluded from the analyses.

Maximum Parsimony (MP) analyses were performed using PAUP\* (version 4.10b; Swofford 2002). Heuristic searches were performed with 100 random taxon addition sequence iterations, saving 100 trees at each iteration, with tree bisection-reconnection branch swapping. Relative support for each node was assessed by performing 1000 bootstrap (BS) replicates (Felsenstein 1985) with TBR branch swapping (20 random addition sequences, saving 20 trees per replicate).

Maximum likelihood analyses were conducted using RAxML version 7.2.7 (Stamatakis 2006) on the CIPRES portal teragrid (Miller et al. 2009). ML bootstrap analyses and the inference of the optimal tree were conducted simultaneously. The optimal tree was inferred using a GTR+ $\Gamma$  model, whereas a similar yet more computationally efficient model (GTR+CAT) was employed for the 1000 bootstrap iterations (Stamatakis et al. 2008).

## Results

All Genbank numbers used can be found in Couvreur et al. (2009). The Genbank numbers of the newly sequenced *Sirdavidia solannona* are : Couvreur 596, *trnLF*: KP144079; *rbcl*: KP144081; Couvreur 597, *trnLF*: KP144080; *rbcl*: KP144082.

Both markers represented 2669 total characters, 187 of which were excluded because of ambiguity in the alignment and 407 (16.5%) were parsimony informative. Both MP and ML phylogenetic analyses led to the same topology, with similar levels of support (Fig. 1). In these trees, *Sirdavidia solannona* is nested in Piptostigmatetea with strong support and is sister to *Mwasumbia alba* Couvreur & Johnson (MP-BS = 95%; ML-BS = 97%).

## Taxonomic description

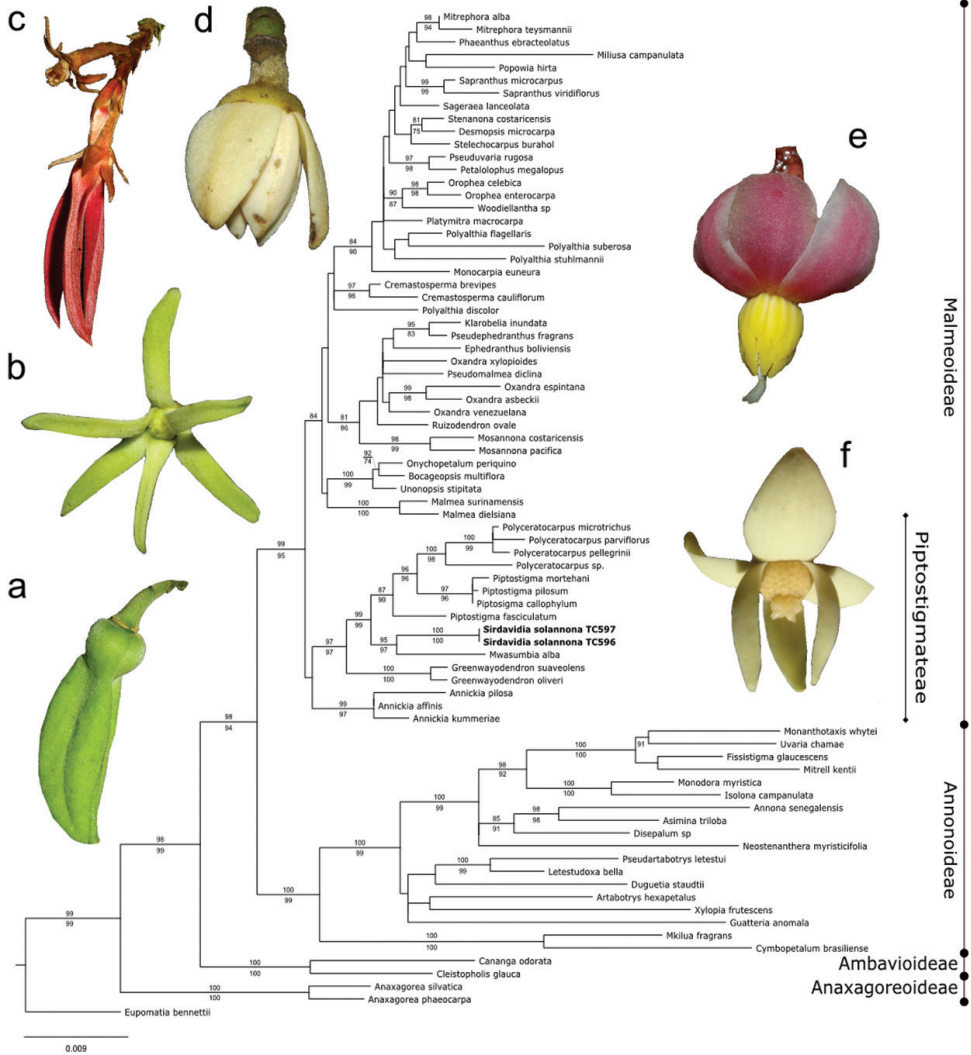
### *Sirdavidia* Couvreur & Sauquet, gen. nov.

urn:lsid:ipni.org:names:77145065-1

**Diagnosis.** Genus with *Solanum*-like flowers, inflorescences axillary or cauliflorous, sepals valvate, petals valvate, subequal, recurved at anthesis, red; stamens bright yellow; carpel single; monocarp sessile, placentation lateral, ovules uniseriate.

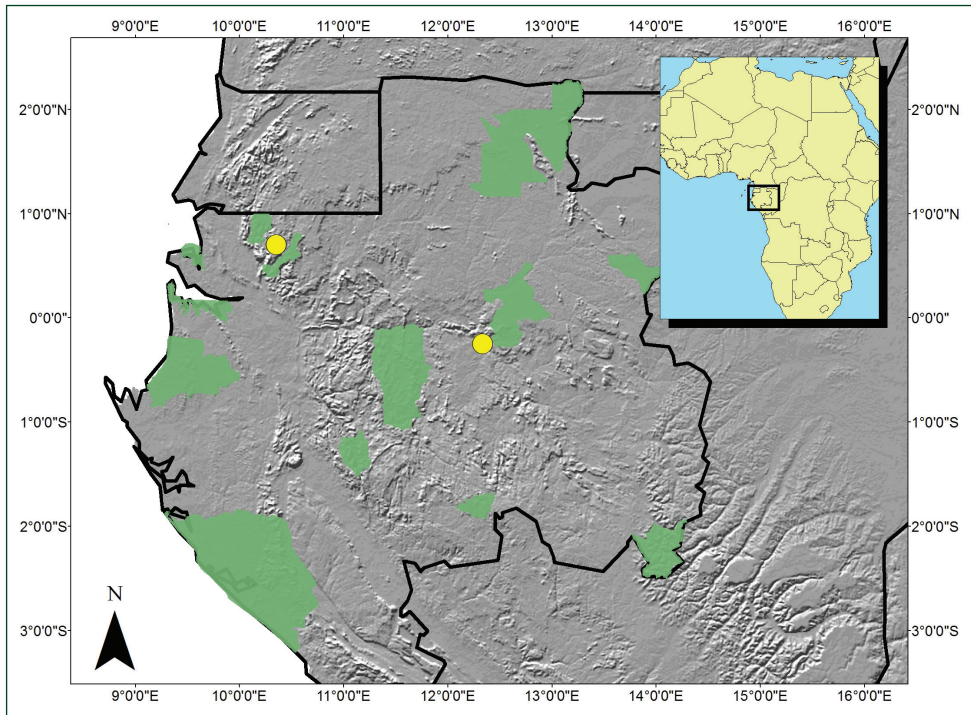
**Type species.** *Sirdavidia solannona* Couvreur & Sauquet.

Small trees with distichous, simple pinnately veined leaves with an entire margin and reticulate third-order venation. Species androdioecious (?) (flowers unisexual staminate or bisexual). Inflorescences one to three-flowered, axillary on old branches



**Figure 1.** Maximum likelihood tree with support values indicated on branches (ML bootstrap above; MP bootstrap below). Flower morphology of the genera in the Piptostigmateteae tribe. **a** *Annickia affinis* (Exell) Versteegh & Sosef **b** *Greenwayodendron suaveolens* (Engl. & Diels) Verdc **c** *Piptostigma multinerivium* Engl. & Diels **d** *Polyceratocarpus parviflorus* (Baker) Ghesq **e** *Sirdavidia solannona* **f** *Mwasumbia alba*. Photos: TLP Couvreur. Note: there is some confusion around the proper identification of the accession Lugas 111 (*Woodiellantha* sp in this study).

or at base of trunk, with one to three short sympodial rachilla. Flowers actinomorphic. Perianth of 9 free tepals in 3 alternate, valvate whorls of 3 each, differentiated in outer tepals (sepals) and middle and inner tepals (petals). Petals similar (subequal in length), spreading horizontally or reflexed at anthesis. Stamens 16-19, free, basifixed with a very short filament. Anthers introrse, probably opening by two longitudinal



**Figure 2.** Distribution map of *Sirdavidia solannona*. Grey scale color shows elevation variation; Gabonese National Parks highlighted in green.

slits, connectives tongue shaped, yellow. Carpel one, densely pubescent, stigma cylindrical coiled, ovules 7–10, uniseriate. Monocarp sessile, cylindrical densely pubescent.

A single species only known to Gabon (Fig. 2).

**Etymology.** We dedicate this new genus to Sir David Attenborough, British broadcaster and naturalist, in honor of his lifelong dedication to nature, conservation, evolution and natural history programs. His passion for nature have influenced and inspired a generation of biologists and naturalists, including the first and senior authors of this paper.

***Sirdavidia solannona* Couvreur & Sauquet, sp. nov.**

urn:lsid:ipni.org:names:77145066-1

**Type.** Gabon, Estuaire, Monts de Cristal, near first bridge after Kinguele, 0°46'66"N, 10°27'81"E, *T.L.P. Couvreur 596*, 15 Nov 2013, Fl. & Fr., holotype: WAG!; isotypes: LBV!, P!, YA!.

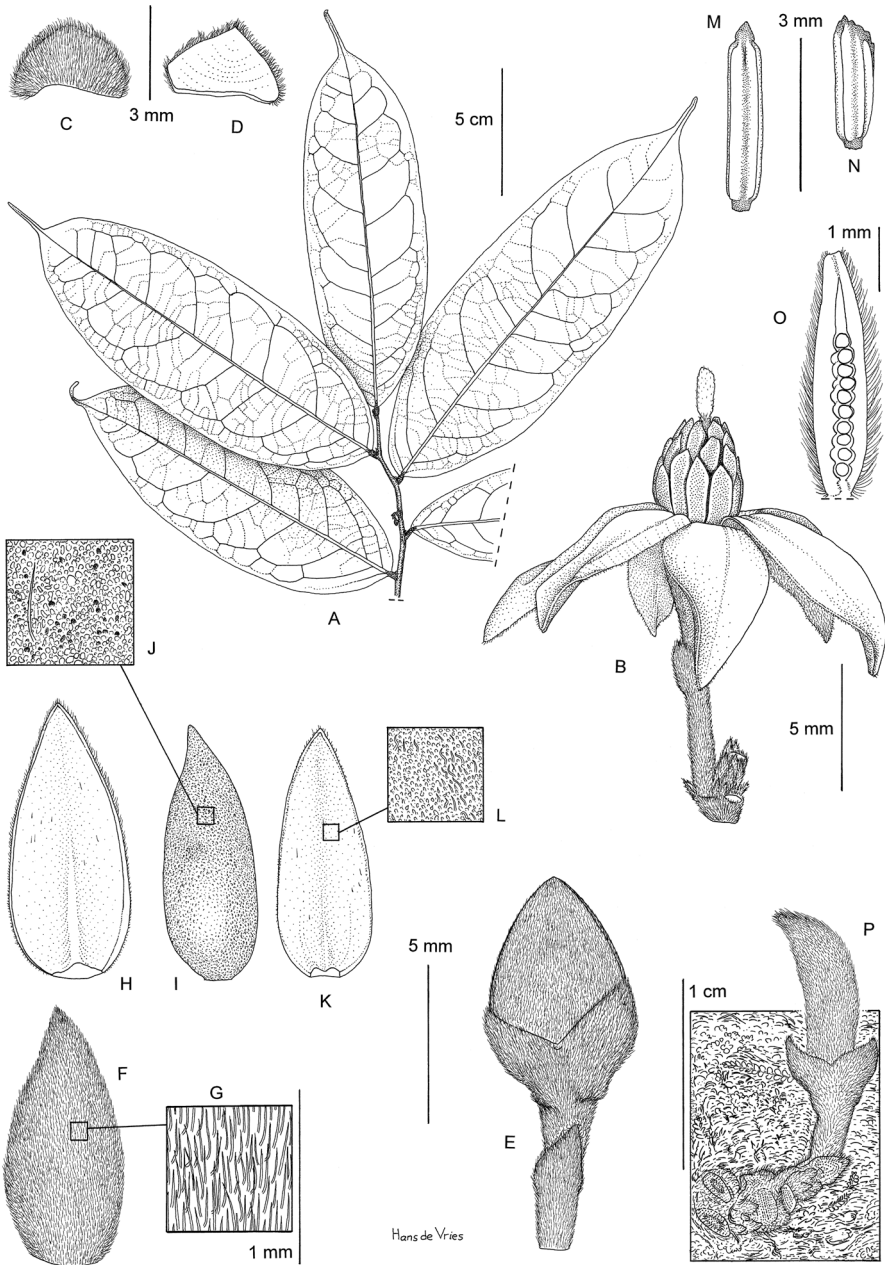
Tree 4–6 m tall, 2 to 4 cm in diameter at breast height (d.b.h.), bark dark brown with patches of green, old branches black, glabrous, young branches black, sometimes pubescent. Leaves distichous, simple, entire, pinnately veined. Petiole 3–4 mm long,

2–3 mm in diameter, glabrous or sparsely pubescent when young, slightly grooved on top, leaf lamina inserted on top. Lamina 20–26 cm long, 4.5 to 9 cm wide, length:width ratio 2.5 to 4.5, narrowly elliptic to elliptic to narrowly ovate to ovate, apex long acuminate, acumen 2–3 cm long, base obtuse, coriaceous, young sparsely pubescent to glabrous above, glabrous below, old leaves glabrous above and below, mid rib sunken above, sparsely pubescent when young below, glabrous above, glabrous above and below when old, secondary veins 9–12 pairs. Inflorescences axillary, on old branches and cauliflorous towards the base of the trunk. Sympodial rachis up to 6 mm long, but sometimes up to 1.5 cm long, densely covered with short appressed hairs, with 0–10 minute densely packed lower bracts densely pubescent brown. Flowering pedicels 2 to 10 mm long, densely covered with short appressed hairs, red, upper bract inserted at base or up to ½ of pedicel, covered with short appressed hairs, red. Flowers actinomorphic, bisexual or unisexual staminate (androdioecious), with 9 tepals in total, differentiated in one whorl of 3 sepals and 2 whorls of 3 petals, all alternate. Sepals 2–3 mm long, 1.5–2 mm wide, length:width ratio 1.5, ovate, valvate, apex acute, base truncate, densely covered with short appressed hairs outside, glabrous inside, red. Outer petals 4–10 mm long, 2.5 to 5 mm wide, length:width ratio 2 to 2.5, elliptic, apex acute, base truncate, densely pubescent with appressed hairs outside, densely pubescent with short tomentose hairs inside, deep red. Inner petals 4–9 mm long, 2–4 mm wide, length:width ratio=2 to 2.5, elliptic, apex acute, base truncate, densely pubescent with short tomentose hairs outside, densely pubescent with short tomentose hairs inside along margins, glabrous towards center, deep red. Petals spreading horizontally or recurving backwards at anthesis. In staminate and bisexual flowers, stamens 16–19, 3–4 mm long, outer ones shorter than inner ones, filament shorter than 0.2 mm, narrow, connective umbonate (tongue shaped), glabrous, bright yellow. Anthers introrse, probably opening by two longitudinal slits. In bisexual flowers, carpel one, 4–5 mm long, ca. 1 mm wide, densely pubescent with silvery long appressed hairs, ovules uniseriate, 7–10, stigma cylindrical coiled, 2–3 mm long, sparsely pubescent towards the top, white cream. Mature fruits not seen, young fruiting pedicel 6 mm long, densely pubescent with appressed hairs. Young monocarp cylindrical, densely pubescent with silvery appressed hairs. Seeds not seen. (Figs 3 and 4)

**Phenology.** Flowers collected in April and November, young fruits collected in November.

**Distribution and habitat.** *Sirdavidia* is endemic to Gabon, with three known collections: two near the Kinguele dam in the Monts de Cristal National Park, Mbé sector, and one south of the Ivindo National Park (Fig. 2). Floristic comparisons in Gabon emphasize that the Monts de Cristal flora has a high resemblance with many other areas across Gabon, including the Ivindo NP region (Wieringa and Sosef 2011). Thus it is not unusual to find species occurring in Monts de Cristal and elsewhere in the county. *Sirdavidia* grows in the understory of mature to old secondary rain forests around 300–600 m, near rivers or on inundated soils.

**Preliminary conservation assessment.** Endangered [EN B1ac]. Two localities in Gabon are known for this species: Monts de Cristal N.P. and south of the Ivindo N.P. The population found in Kinguele (Monts de Cristal) was close to the road and several



**Figure 3.** Illustration of *Sirdavidia solannona* Couvreur & Sauquet. **A** Flowering branch (flower bud just above second leaf from the bottom) **B** Flower **C** One sepal, outer side view **D** One sepal, inner side view **E** Flower bud **F** Outer petal, outer side view **G** detail of pubescence of outer petal, outer side **H** Outer petal, inner side view **I** Inner petal, outer side view **J** detail of pubescence of inner petal, outer side **K** Inner petal, inner side view **L** detail of pubescence of inner petal, inner side **M** Stamen from inner whorl **N** stamen from outer whorl **O** Longitudinal section of carpel showing uniseriate row of ovules (stigma missing) **P** detail of young fruit. Drawing by Hans de Vries based on Couvreur 596 and Couvreur 597.





**Figure 4.** *Sirdavidia solanonna*. **a** Opened flower and flower buds (Couvreur 596) **b** Flower with recurved petals at anthesis (Couvreur 596) **c** Staminate flower (Couvreur 597) **d** Flower with all petals and part of the stamens removed, showing the silvery aspect of the carpel and the long stigma (Couvreur 596) **e** Cauliflorous flower and flower bud (Couvreur 596) **f** Young fruit, cauliflorous (Couvreur 596). Photos: TLP Couvreur.

(around 10) individuals were seen. We also looked for this species in other parts of the Park (around Tchimbélé) and did not see it again. The herbarium specimen collected from Ivindo indicates “en peuplement” (in population) suggesting that several individuals were seen. However, the coordinates on the herbarium sheet place this collection outside the national park. The Area of occupancy (AOO) is 12,000 km<sup>2</sup> and the Extent of occurrence (EOO) is 6.2 km<sup>2</sup>, suggesting a very restricted overall distribution. We thus suggest a status of endangered given that only a handful of individuals have been seen and that these populations are quite close to disturbances.

**Etymology.** The species name epithet highlights the striking resemblance with flowers of some species of *Solanum*, an unusual and new feature for a flower of Annonaceae.

**Note.** The androdioecious nature of *Sirdavidia solannona* has yet to be properly confirmed. We only saw two individuals one of which appeared to have only staminate flowers. Because other members of the tribe Piptostigmateae are known to have this condition, it would not be surprising.

**Paratypes.** GABON: **Estuaire**, Monts de Cristal National Park, near first bridge after Kinguele, 0°46'64"N, 10°27'80"E, T.L.P. Couvreur 597, Fl., 15 Nov 2013, Fl. & Fr. (LBV!, P!, WAG!, YA!); **Ougoué-Ivindo**, Ivindo National Park, camp elephant, A. Mounhazi 1544, Fl., 10 Avr 204 (BR!, LBV, WAG).

## Discussion

### Molecular and morphological characterization of *Sirdavidia*

The molecular phylogenetic analyses presented here confirms that *Sirdavidia solannona* belongs to tribe Piptostigmateae, which now contains a total of six accepted genera (though *Piptostigma* is paraphyletic, Couvreur et al. 2009). This new taxon was found to be sister with strong support to the monotypic East African genus *Mwasumbia* Couvreur & Johnson (see below, Fig. 1). The two genera, together with *Polyceratocarpus* Engl. & Diels and *Piptostigma* Oliv., form a strongly supported clade (Fig. 1), referred to here as the SMPP clade.

*Sirdavidia* differs morphologically from *Mwasumbia* in several important respects, warranting its status as a new species and a new genus. Tertiary venation is a useful character for distinguishing genera within the tribe Piptostigmateae (Couvreur et al. 2009) and contains useful phylogenetic information at the family level (Doyle and Le Thomas 1996). All three major tertiary venation types in Annonaceae (reticulate, parallel and intermediate between the two first ones) are found in Piptostigmateae (Table 1). Parallel tertiary venation occurs in both *Piptostigma* and most *Polyceratocarpus* species whereas *Mwasumbia* has an intermediate tertiary venation. In contrast, *Sirdavidia* is characterized by a reticulate tertiary venation and in this sense resembles *Greenwayodendron* (Table 1). This type of venation appears to be rare in Annonaceae and was reconstructed as being ancestral for the family as a whole (Doyle and Le Thomas 1996). Sepal aestivation in *Sirdavidia* is valvate like in most other genera in

**Table 1.** Morphological characters of the six genera found in tribe Piptostigmateae. Modified from Couvreur et al. (2009). *Piptostigma* is represented by two columns because it is paraphyletic (Fig. 1).

Character	<i>Annickia</i>	<i>Greenwayodendron</i>	<i>Mtwasumbia</i>	<i>Sindavidia</i>	<i>Piptostigma fasciculatum</i>	<i>Piptostigma</i>	<i>Polyacrotacarpus</i>
Species diversity/ distribution	8 / West and Central Africa, 1 species in East Africa	2 / West and Central Africa	1 / Tanzania	1 / Gabon	1 / Central Africa	-14 / Central and West Africa	8 / West and Central Africa, 2 species in East Africa
Tertiary venation	intermediate	reticulate	intermediate	reticulate	parallel	parallel	parallel
Inflorescence position	terminal	terminal	axillary	axillary, cauliflorous	axillary	axillary, cauliflorous	axillary, cauliflorous
Sex distribution	bisexual	androdioecious	bisexual (?)	androdioecious (?)	bisexual	bisexual	androdioecious
Sepal aestivation	valvate	imbricate	imbricate	valvate	valvate	valvate	valvate
Petal number	3	6	6	6	6	6	6
Petal disposition	Upright, appressed forming a pollination chamber	Spreading horizontally, no pollination chamber	Outer petals recurved backwards, inner petals erect upwards, no pollination chamber	Recurving backwards to spreading horizontally, no pollination chamber	Pendulous, no pollination chamber	Upright, appressed forming a pollination chamber	Outer petals recurved backwards or erect upwards, inner petals erect upwards, pollination chamber possible
Petal relative length	outer absent	outer=inner	outer=inner	outer=inner	outer<inner	outer<inner	outer=inner
Torus (stamen portion)	flat/conical	flat/conical	short cylindrical	short cylindrical	short cylindrical	short cylindrical	short cylindrical
Torus (carpel portion)	flat/convex	flat/convex	concave	concave	concave	concave	concave
Apex of connective	discoid/tongue-shaped	discoid/tongue-shaped	discoid	discoid/tongue-shaped	discoid	discoid	discoid
Nr of carpels	numerous	13-20	4	1	4	3-14	2-20
Number of ovules per carpel	1	2	5-8	7	- 18	6-10	20-30
Ovule arrangement	basal	1-seriate lateral	1-seriate lateral	1-seriate lateral	2-seriate	2 or 1-seriate lateral	2-seriate lateral
Monocarps	stipitate	stipitate	sessile	sessile	sessile	sessile	sessile

Piptostigmateae except for *Greenwayodendron* and *Mwasumbia* which both have an imbricate aestivation (Table 1). Aestivation was considered an important character to separate genera in Annonaceae (Chatrou et al. 2012), but phylogenetic studies have underlined its homoplastic nature (Couvreur et al. 2008c; Doyle and Le Thomas 1996). The presentation of petals at anthesis is also very different between *Sirdavidia* and *Mwasumbia*. In *Mwasumbia*, the outer petals are reflexed, whereas the inner petals are pendulous and sometimes connivent at the tips. A similar configuration is observed in some species of *Polyceratocarpus* (Marshall et al. in press). In contrast, the petals in *Sirdavidia* are horizontally spreading to highly reflexed at anthesis, a condition not found in any other genera within Piptostigmateae (Table 1, Figs 1e, 3B, 4a, b, c). Stamen number and connective shape have played an important part in Annonaceae classification (Chatrou et al. 2012). In *Sirdavidia* they are very distinct to those in *Mwasumbia*. *Sirdavidia* has 16–19 stamens with, in general, a tongue shaped connective apex (Fig. 3M), while *Mwasumbia* has numerous stamens (more than 30) with a discoid or flat connective apex (Figure 3L of Couvreur et al. 2009).

We suggest that the morphological differences outlined above are sufficient to erect a new species for *Sirdavidia solannona* and also justify the creation of a new genus, distinct from *Mwasumbia*, given the morphological characters that discriminate among genera of Annonaceae in general (Chatrou et al. 2012; Le Thomas 1969).

### Morphological similarities and differences of *Sirdavidia* with Piptostigmateae genera

Table 1 summarizes the morphological similarities and differences of *Sirdavidia* with the other genera within Piptostigmateae. Two characters appear important for delimiting the SMPP clade:

- Inflorescence position: Within Piptostigmateae both terminal or axillary types of inflorescences can be found (Fries 1959). In *Sirdavidia*, inflorescences are axillary, a character also found in *Mwasumbia*, *Piptostigma* and *Polyceratocarpus* (Table 1) confirming it as a good synapomorphy for the SMPP clade within Piptostigmateae. The position of inflorescences has also previously been recognized as a good character for separating genera in Annonaceae (Chatrou et al. 2000).
- Monocarp base: Another synapomorphy for the SMPP clade is the sessile monocarps. In contrast, *Annickia* Setten & Maas and *Greenwayodendron* Verdc. have monocarps with conspicuous stipes. Even though immature fruits were only observed for *Sirdavidia* to date, it is clear that the single monocarp is sessile (Fig. 3P; Fig. 4f). Although this character was previously thought to contain little taxonomic information, it has proven useful in delimitating other African tribes of Annonaceae such as Monodoroideae (Chatrou et al. 2012; Couvreur et al. 2008c).

Other characters appear to have little taxonomic use but are interesting as they underline the important floral morphological variability within Piptostigmateae.

- Androdioecy in Annonaceae is not unusual (van Heusden 1992). Within tribe Piplostigmatheae two other genera are documented as being androdioecious: *Greenwayodendron* and *Polyceratocarpus* (Couvreur et al. 2009). However, with only two individuals seen, it is difficult to conclude precisely on the type of reproductive strategy for *Sirdavidia*.
- *Sirdavidia* is unique within the tribe in having a single carpel, a feature found in only 10% of Annonaceae (Derooin 1991). Other genera such as *Sanrafaelia* Verdc., *Dielsiothamnus* R.E.Fr., and *Tridimeris* Baill. are also monocarpellate (van Heusden 1992; Verdcourt 1996).

### A fascinating new genus

*Sirdavidia* is fascinating at a number of other different levels. First, it had remained undescribed until now, even though it occurred in a well known and well inventoried region of Gabon; second, its closest relative is another monotypic genus restricted to Tanzania, some 3000 km away; and, finally, it could be the first documentation of a buzz pollination syndrome in Magnoliidae.

### A hidden genus

*Sirdavidia* was discovered in the Monts de Cristal National Park (N.P.), one of the most species-rich and botanically best collected regions in Gabon (Wieringa and Sosef 2011). Moreover, it was collected just a few meters from the main road that connects Kinguele to Tchimbele. This discovery suggests that there may still be a number of undescribed species and genera in this region and thus might not be as well collected as suggested. Interestingly, the small population was located near a recent botanical inventory of the Monts de Cristal (Sunderland et al. 2004). Because it is a tree that so far has been observed to be smaller than 6 m and is less than 10 cm in diameter, it is likely that it was not collected during the inventories (in general such inventories only focus on trees with a diameter larger than 10 cm). This underlines the importance of collecting woody individuals with a diameter less than 10 cm when undertaking inventory plots (Gentry and Dodson 1987; Kenfack et al. 2007). An alternative explanation is that because it superficially doesn't look like an Annonaceae flower, putative collections might have been identified under different plant families.

### An incredible disjunction

The closest relative to *Sirdavidia* is another recently described monotypic genus, *Mwasumbia* (Couvreur et al. 2009). This rain forest genus is endemic to a small locality in the east African forests of Tanzania, corresponding to a biogeographic disjunction

of ca. 3000 km with *Sirdavidia*. East West/Central disjunctions between rain forest restricted species are a common feature in African plants (Burgess et al. 2007; Couvreur et al. 2008b; Lovett 1993). However, this might represent an extreme disjunction between two locally restricted rain forest monotypic genera on opposite sides of Africa. Several disjunctions between East and West/Central African Annonaceae have been dated to occur at significantly different periods of increased aridity suggesting a repeated continental scale fragmentation of a once pantropical rain forest (Couvreur et al. 2008b). These two genera provide another example of the role of this vicariant pattern in generating endemism (both faunistic and floristic) across tropical Africa (Couvreur et al. 2008b; Tolley et al. 2013). It will be interesting to estimate the temporal origin of this disjunction in order to measure the evolutionary time these two species represent and to determine whether their splitting coincides with those of other East/West African disjunctions in Annonaceae and other tropical plant families.

#### *A possible new pollination syndrome type for Magnollideae*

Though the flower has all the structural characters of a typical Annonaceae flower (3 sepals, 2 whorls of 3 petals), the overall aspect is very unusual, resembling flowers of some species of *Solanum* L. (Solanaceae). The morphological appearance is strongly suggestive of a special type of pollination syndrome referred to as buzz pollination syndrome. Buzz pollination relies mostly on sonicating bees that use vibrations to extract pollen from the anthers (De Luca and Vallejo-Marín 2013). The flowers of *Sirdavidia* are characterized by several traits typically associated with the evolution of buzz pollination.

**Reflexed petals.** Most buzz pollinated flowers show strongly reflexed petals exposing the stamens and the carpels. Reflexed petals are quite common in Annonaceae, occurring in a number of genera such as *Uvaria* and *Isolona*.

**Stamens:** The stamens of *Sirdavidia* are bright yellow, a color known to attract bees (De Luca and Vallejo-Marín 2013). Such a color is unusual for Annonaceae, at least in Africa. In general, stamens are pale in color, varying between red, green and yellow. In addition, typical stamens of Annonaceae are never fully exposed as they are in *Sirdavidia*, being generally tightly packed together and appressed by the petals. Non appressed stamens by the petals are also found in the sister genus *Mwasumbia* (Couvreur et al. 2009). In *Sirdavidia* the stamens form a “cone” of loosely arranged stamens (relative to other Annonaceae species) around the single carpel, a feature also found in buzz pollinated *Solanum*-type flowers (De Luca and Vallejo-Marín 2013).

**Anthers.** In typical buzz pollinated flowers, the anthers generally have apical pores or short slits that release the pollen grains during vibration. However, non-poricidal anthers have also been linked with buzz pollination in a number of other genera (Buchmann 1985; de Oliveira and Sazima 1990). Based on macromorphological observations, no evidence of apical pores can be seen in *Sirdavidia*, which would thus rather represent a case of non-poricidal buzz pollination. It is possible that the structural longitudinal slits we have observed only effectively dehisce apically, thus functioning

as short apical slits. However, detailed anatomical observations will have to confirm this. In addition, buzz pollination will only be effective if pollen grains are very small and extremely numerous (dust like). To date, we have no information about the size and quantity of pollen grains in *Sirdavidia*. Pollen in Annonaceae is generally large in size compared to other angiosperms (Doyle and Le Thomas 2012). Pollen grains in the sister genus *Mwasumbia* are monads and were measured to be ca. 59  $\mu\text{m}$  in length for the polar axis, which ranks as a medium-sized pollen grain in Annonaceae (Couvreur et al. 2008a; Doyle and Le Thomas 2012). However, pollen size is highly homoplastic in Annonaceae (Doyle and Le Thomas 2012), and thus it is hard to speculate on the size of the pollen grains in *Sirdavidia*.

Long stigma. The conspicuous stigma sticking out of the stamens in *Sirdavidia* is also a typical feature of buzz pollinated flowers (De Luca and Vallejo-Marín 2013). The stigma rubs against the abdomen of the visiting bee allowing the potential pollination.

Annonaceae flowers are visited by a large variety of insects (Saunders 2012; Silberbauer-Gottsberger et al. 2003) such as beetles, thrips flies and even cockroaches, suggesting a large array of pollination systems. In contrast, bees have rarely been documented to pollinate or visit Annonaceae flowers (Silberbauer-Gottsberger et al. 2003). Bee pollination is suspected in *Unonopsis guatterioides* (A.DC.) R.E.Fr. and *Uvaria concava* Teijsm. & Binn. However, flowers of these two species are apparently not buzz pollinated, and are very different in morphology than those of *Sirdavidia*. Additional field observations will be required to determine whether *Sirdavidia* is indeed buzz pollinated. In addition to observations of pollinator behavior, it would be particularly interesting to learn more about the floral biology of this species. Indeed, nearly all early-diverging angiosperms (including Annonaceae) are protogynous, a feature commonly associated with wind, beetle, fly, and thrips pollination, whereas the remaining angiosperms are predominantly protandrous and bee or butterfly pollinated (Endress 2010). Therefore, one would expect that *Sirdavidia* might have shifted away from protogyny to allow effective buzz pollination by pollen collecting bees. If the buzz pollination syndrome was to be confirmed for *Sirdavidia*, it would be the first record in Annonaceae and for Magnoliidae and early-diverging angiosperms in general (Endress 2001). In any case, this represents the first “*Solanum*-type” flower described in Magnoliidae to date (De Luca and Vallejo-Marín 2013; Endress 2001).

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# *Thismia hongkongensis* (Thismiaceae): a new mycoheterotrophic species from Hong Kong, China, with observations on floral visitors and seed dispersal

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## Abstract

A new species, *Thismia hongkongensis* S.S.Mar & R.M.K.Saunders, is described from Hong Kong. It is most closely related to *Thismia brunonis* Griff. from Myanmar, but differs in the number of flowers per inflorescence, the colour of the perianth tube, the length of the filaments, and the shape of the stigma lobes. We also provide inferences on the pollination ecology and seed dispersal of the new species, based on field observations and interpretations of morphology. The flowers are visited by fungus gnats (Mycetophilidae or Sciaridae) and scuttle flies (Phoridae), which are likely to enter the perianth tube via the annulus below the filiform tepal appendages, and exit via small apertures between the filaments of the pendent stamens. The flowers are inferred to be protandrous, and flies visiting late-anthetic (pistillate-phase) flowers are possibly trapped within the flower, increasing chances of pollen deposition on the receptive stigma. The seeds are likely to be dispersed by rain splash.

## Keywords

Burmanniaceae, China, mycoheterotrophic, pollination, rain splash dispersal, *Thismia*, Thismiaceae, new species

## Introduction

*Thismia* Griff. species are small herbaceous plants with a highly reduced vegetative structure. They are invariably mycoheterotrophic, relying on fungal symbionts to obtain nourishment from decaying organic material, and they therefore lack chlorophyll. Individuals remain underground throughout most of the year, only emerging briefly to flower and fruit after periods of heavy rain; as a consequence, *Thismia* species are rarely collected and relatively little is known of their taxonomy, distribution and reproductive biology.

The floral morphology of the genus is complex. The tepals are congenitally fused (Caddick et al. 2000) to form a perianth tube with apically free lobes that are arranged in two whorls of three. These tepal lobes are often morphologically very elaborate, sometimes apically coherent and forming a mitre or dome, and often adorned with elongated tentacles that are either free or united. Although the functional significance of these morphologically complex tepals is obscure, they presumably perform a role in pollinator attraction. The aperture at the apex of the perianth tube is surrounded by a prominent annulus. Each flower has six stamens, the lateral margins of which are often postgenitally connate with each other, forming a ring that is suspended from the annulus. Since the stamens are pendent, the abaxial surface faces the centre of the flower, and the adaxial surface, which bears the thecae, faces the inner surface of the perianth tube. The flowers are epigynous, with the fused carpels surrounded by an expansion of the receptacle (Caddick et al. 2000).

Although *Thismia* was historically classified in the tribe Thismieae Miers (Miers 1847) within the Burmanniaceae (e.g., Jonker 1938; Maas-van der Kamer 1998), recent molecular phylogenetic analysis of nuclear and mitochondrial DNA sequences have revealed that it is more closely aligned with the Taccaceae (Merckx et al. 2006, 2009). The third iteration of the Angiosperm Phylogeny Group classification (APG 2009) adopts a very conservative approach in which *Thismia* is retained within the Burmanniaceae; we follow the majority of contemporary taxonomists, however, in separating *Thismia* and related genera (*Afrothismia* Schltr., *Haplothismia* Airy Shaw and *Oxygyne* Schltr.) in the Thismiaceae.

Govaerts et al. (2007) listed 41 *Thismia* species in their global checklist of the Dioscoreales, of which 24 were recorded from Asia; these statistics increase to 42 and 25, respectively, if *Geomitra clavigera* Becc. is recognized as a *Thismia* species, as suggested by morphological data (Stone 1980) and molecular phylogenetic analysis (Merckx et al. 2006). The discovery of new species in the genus has accelerated significantly in recent years, with 10 new *Thismia* species described from Asia (Larsen and Averyanov 2007; Chantanaorrapint 2008, 2012; Chiang and Hsieh 2011; Tsukaya and Okada 2012; Dančák et al. 2013; Li and Bi 2013; Nuraliev et al. 2014; Truong et al. 2014) since the publication of the checklist by Govaerts et al. (2007). In addition to these newly described species, there are several reports of significant extensions to distributional ranges in Asia, including *T. alba* Holttum ex Jonker (Peninsular Malaysia and Peninsular Thailand: Chantanaorrapint and Sridith 2007), *T. clavigera* (Becc.)

F. Muell. (Borneo, Langkawi, Sumatra and Peninsular Thailand: Stone 1980; Chantanaorrapint and Chantanaorrapint 2009), and *T. tentaculata* K. Larsen & Aver. (Vietnam and southern China: Ho et al. 2009).

In this paper we describe a new species, *T. hongkongensis*, recently collected from Hong Kong. This is the fourth species in the genus recorded from China, supplementing earlier reports of *T. taiwanensis* S.Z. Yang, R.M.K. Saunders & C.J. Hsu from Taiwan (Yang et al. 2002; Wu et al. 2010), *T. tentaculata* from Hong Kong (Ho et al. 2009; Wu et al. 2010; Zhang and Saunders 2011), and *T. gongshanensis* H.Q. Li & Y.K. Bi from Yunnan (Li and Bi 2013). We also present some new observational data and inferences on the pollination ecology and seed dispersal mechanism of the new species. Although this information is limited in scope, it is of significance given the paucity of existing data on the reproductive biology of the genus.

## New species description

*Thismia hongkongensis* S.S. Mar & R.M.K. Saunders, sp. nov.

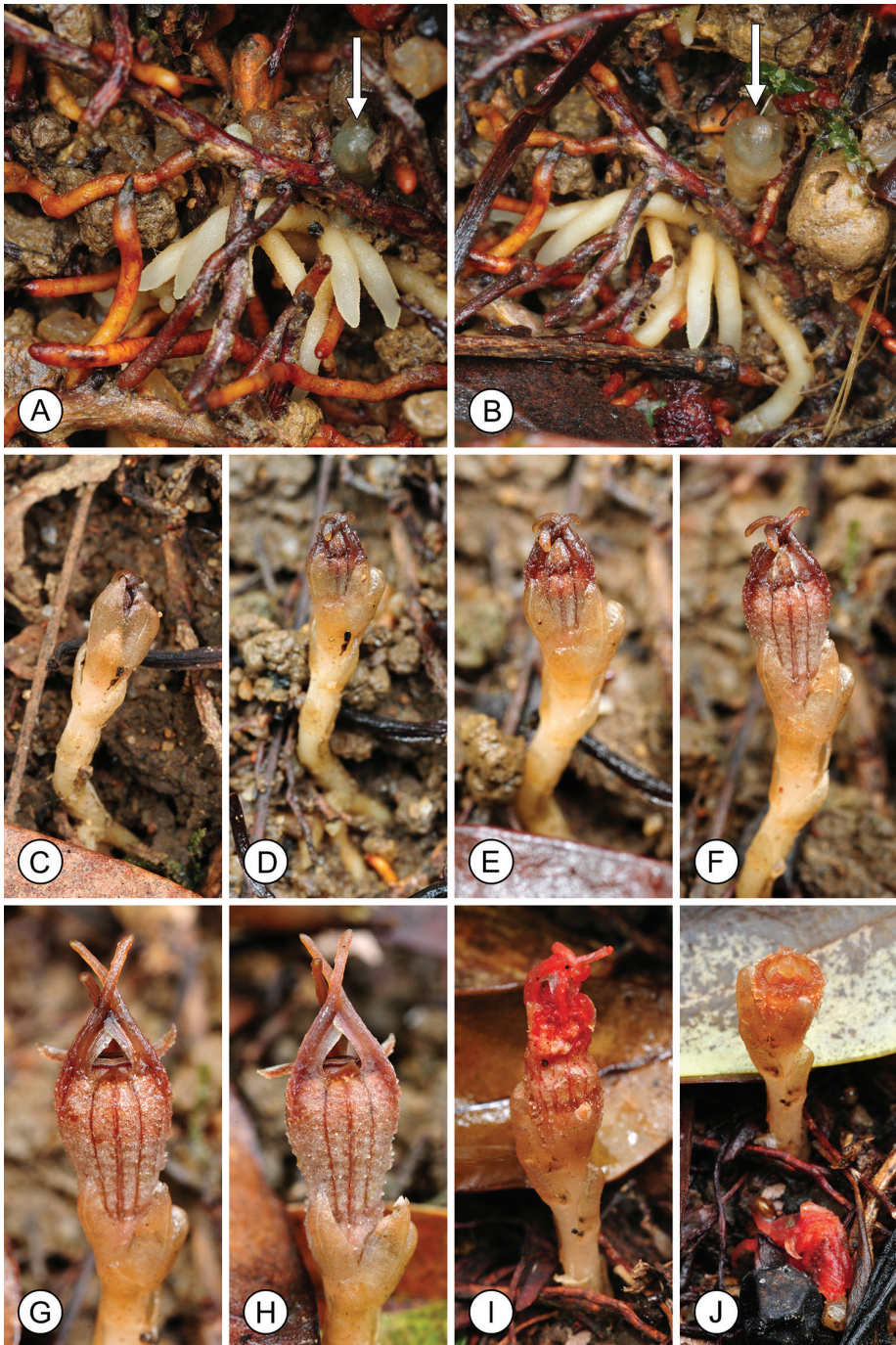
urn:lsid:ipni.org:names:77145069-1

Figs 1–4

**Diagnosis.** Similar to *Thismia brunonis* Griff., but differing in bearing a maximum of only three flowers (with a single flower at anthesis), and having a dark red perianth tube with the filiform appendages on the outer tepals remaining upright and forming a loose mitre over the annulus, longer staminal filaments with two distinct teeth at connective apex, and rounded stigmas.

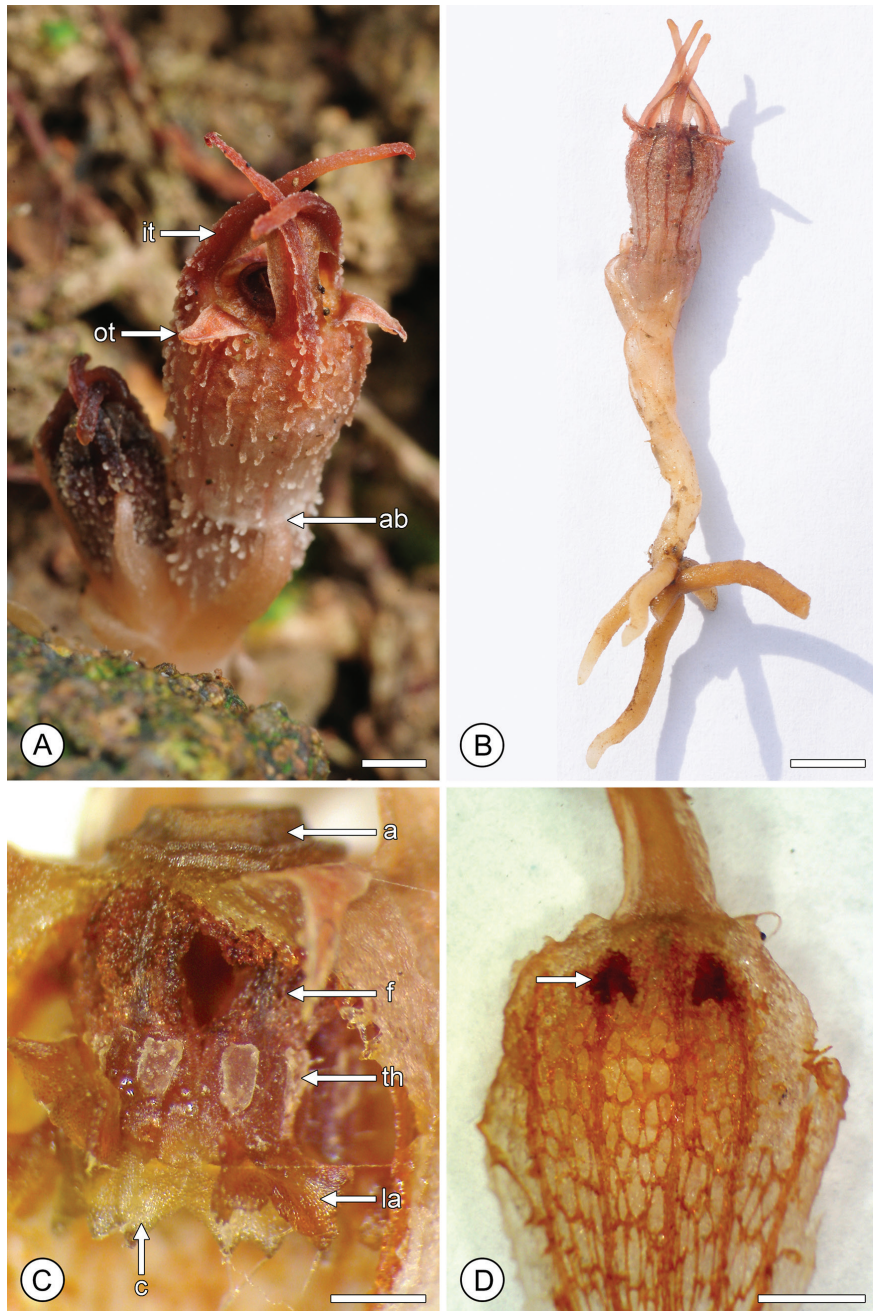
**Type. China:** 22°25'N, 114°11'E, Tai Po Kau Nature Reserve, New Territories, Hong Kong, 19 May 2014, S.S. Mar 1 (holotype: HK, in spirit).

**Description.** Small achlorophyllous holomycotrophic herbs. Roots clustered, ± horizontal, vermiform, fleshy, 1.2–1.3 mm in diameter, cream-coloured. Stem cream-coloured, unbranched, erect, ca. 1.7 cm tall, 1.8–2 mm in diameter, glabrous, terete, with ca. 12 longitudinal ridges. Leaves white, appressed, clasping stem, narrowly triangular with acute apex, scale-like, 3–5.5 mm long, 1.7–2 mm wide; basal leaves smallest, upper leaves (equivalent to floral bracts) largest. Flowers in clusters of up to 3, developing sequentially with only one anthetic. Perianth actinomorphic, of 6 fused tepals, forming a perianth tube with free apical lobes. Perianth tube pinkish-white, membranous, urceolate, ca. 6.7 mm long, ca. 6.1 mm in diameter, with 12 dark red vertical ribs, abaxial surface distinctly verrucose; apex of perianth tube fused to form a dark red, rounded-hexagonal annulus, ca. 1.4 mm wide (top, externally), ca. 2.3 mm wide (base, externally) and ca. 1 mm (internal aperture); dark red, inverted V-shaped structures (putative nectaries) at apex of adaxial surface of perianth tube, opposite apertures between staminal filaments. Outer tepal lobes triangular, ca. 1.8 mm long, ca. 1.5 mm wide at base; inner tepal lobes spatulate, concave adaxially, ca. 3.3 mm long, ca. 1.7 mm wide at widest point, bearing a dark red filiform appendage on the abaxial surface,



**Figure 1.** Flower development in *Thesium hongkongensis* sp. nov. **A, B** Root system, with young flowering stalk developing (arrowed). **C–H** Developing flower, photographed over a 17-day period (10<sup>th</sup>, 14<sup>th</sup>, 16<sup>th</sup>, 19<sup>th</sup>, 23<sup>rd</sup> and 27<sup>th</sup> May, respectively) (S.S. Mar 1, HK). **I, J** Post-fertilization flower, showing abscission of perianth tube. Photos by S.S. Mar.





**Figure 2.** Flower structure in *Thismia hongkongensis* sp. nov. **A** Mature flower, showing outer tepals (ot), inner tepals (it) and abscission zone (ab) at the base of the perianth tube. **B** Entire plant (S.S. Mar 1, HK). **C** Perianth tube with annulus (a), following removal of the proximal face of the tube, exposing pendent stamens with filament (f), thecae (th), connective (c) and lateral appendage (la) (S.S. Mar 2, HK). **D** Inner face of perianth tube, showing network patterning and putative nectaries (arrowed) (S.S. Mar 2, HK). Scale bars: **A, D** = 2 mm; **B** = 5 mm; **C** = 1 mm. Photos: **A, B** S.S. Mar; **C, D** R.M.K. Saunders.

ca. 4 mm long, ca. 0.5 mm in diameter (towards base), 0.4 mm in diameter (towards apex); the three filiform appendages remain upright and cross each other, forming a persistent mitre. Stamens 6, pendent from the inner margin of perianth annulus, ca. 2.9 mm long, ca. 1.1 mm wide at widest point; filaments free, ca. 1 mm long; stamens laterally connate, forming an anther tube; individual stamens with two thecae (adaxial, dehiscing towards inner surface of perianth tube), ca. 0.7 mm long; apical connective of stamens ca. 1 mm long, with two distinct teeth, adorned with trichomes, ca. 0.5 mm long. Ovary inferior, obconical, ca. 2.7 mm long, ca. 4 mm wide towards apex; style ca. 0.6 mm long, ca. 0.6 mm in diameter, with three bilobed, rounded stigmas; stigmatic head ca. 1 mm long, ca. 1 mm in diameter. Fruit a capsule ca. 4 mm long, ca. 4.8 mm wide, cup-shaped, carnose, pale orange-brown, dehiscing apically; fruiting peduncle ca. 2.5 mm diameter. Seeds numerous, yellow-brown.

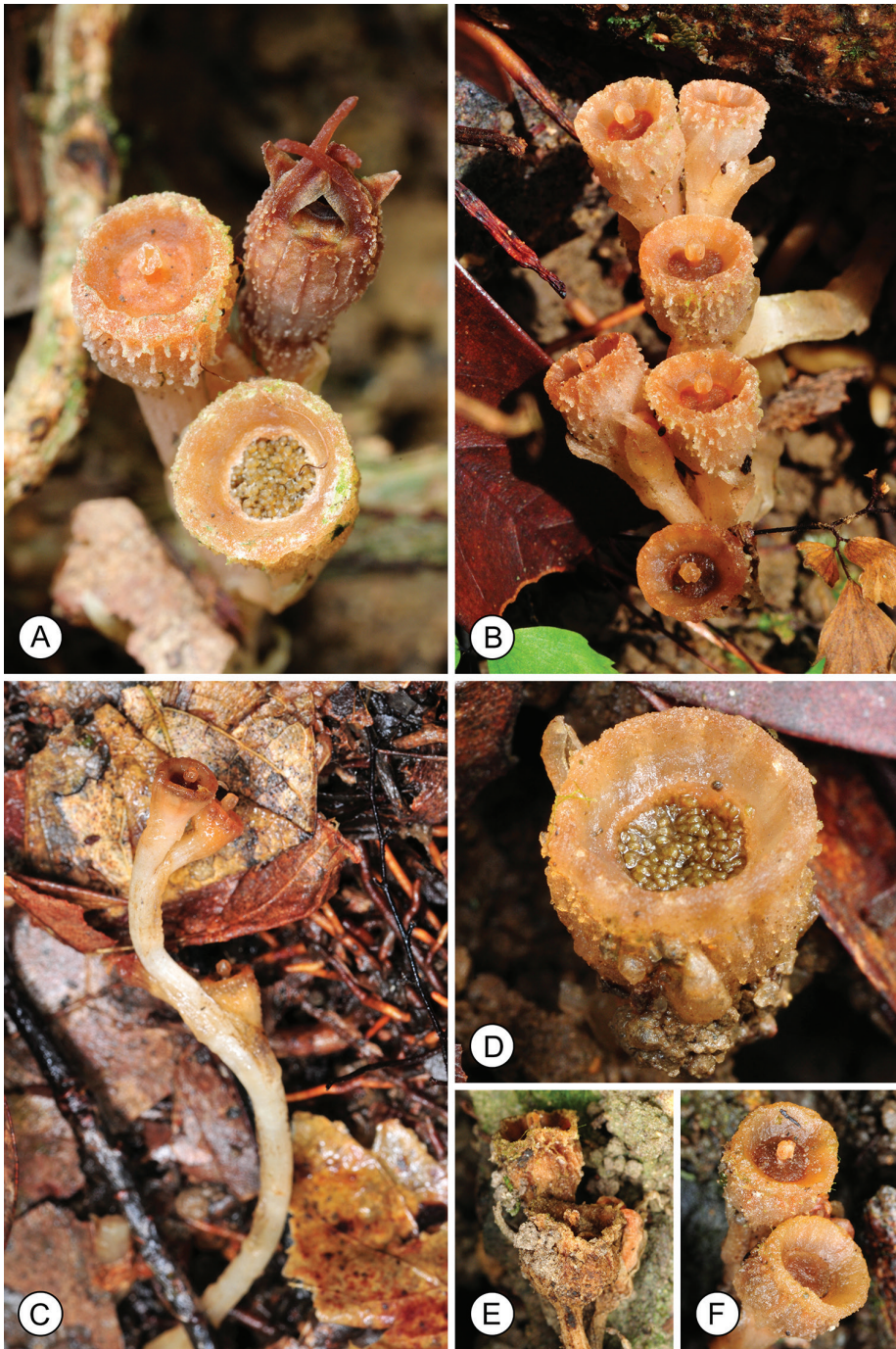
**Phenology.** Flowering was observed between May and September. Flower development extends over several weeks (Fig. 1C–H). Based on our field observations, mature flowers are functional for up to three weeks, with up to three flowers developing successively in each individual (Fig. 3A). The perianth tube abscises after fertilization (Fig. 1I, J), with a clear abscission zone (*ab* in Fig. 2A); the epidermis on the upper surface of the carpel subsequently disintegrates and the stigma is shed, exposing the seeds (Fig. 3A, D). Fruiting was observed between June and October.

**Distribution and habitat.** *Thismia hongkongensis* is only known from the type locality in Hong Kong. The habitat is lowland secondary forest (west-facing slope, ca. 240 m above sea level); the site is not close to a stream and is therefore likely to dry out during periods of low precipitation. Co-occurring species include *Adiantum flabelulatum* L. (Adiantaceae), *Ardisia quinquegona* Blume (Myrsinaceae), *Breynia fruticosa* (L.) Hook.f. (Euphorbiaceae), *Burmannia wallichii* (Miers) Hook.f. (Burmanniaceae), *Clematis meyeniana* Walp. (Ranunculaceae), *Cratoxylum cochinchinense* (Lour.) Blume (Clusiaceae), *Desmos chinensis* Lour. (Annonaceae), *Diplospora dubia* (Lindl.) Masam. (Rubiaceae), *Garcinia oblongifolia* Champ. ex Benth. (Clusiaceae), *Lindsaea orbiculata* (Lam.) Mett. ex Kuhn (Lindsaeaceae), *Lophatherum gracile* Brogn. (Poaceae), *Lygodium japonicum* (Thunb.) Sw. (Lygodiaceae), *Machilus chekiangensis* S.K.Lee (Lauraceae), *Psychotria asiatica* L. (Rubiaceae), *Psychotria serpens* L. (Rubiaceae), *Rourea microphylla* (Hook. & Arn.) Planch. (Connaraceae), *Sarcandra glabra* (Thunb.) Nakai (Chloranthaceae), and *Sciaphila ramosa* Fukuy. & T.Suzuki (Triuridaceae).

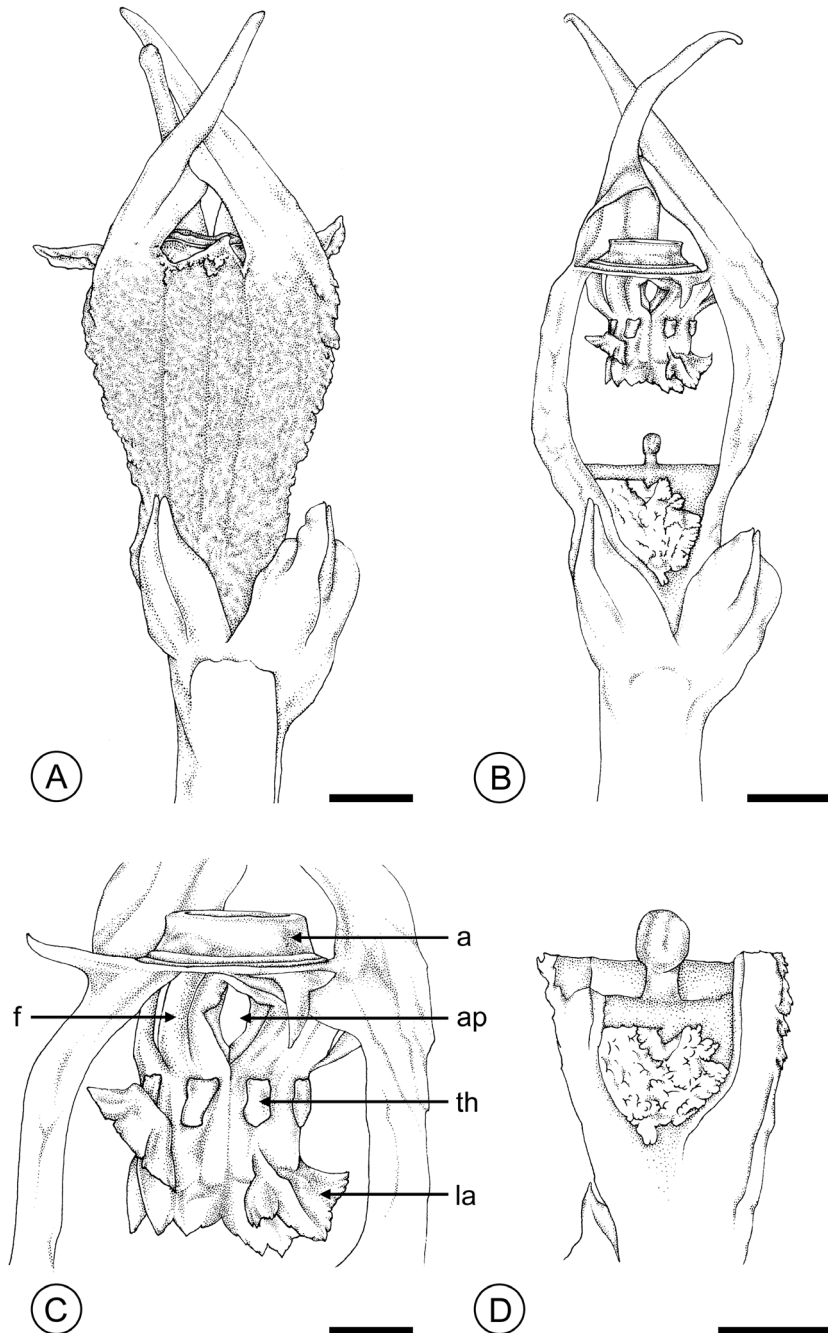
**Etymology.** The specific epithet reflects the geographical origin of the species in Hong Kong.

**Additional specimens examined (paratypes).** China. Hong Kong: 22°25'N, 114°11'E, Tai Po Kau Nature Reserve, New Territories, 29 May 2014, *S.S. Mar* 2 (HK, dissected flower in spirit); idem, 2 October 2014, *S.S. Mar* 3 (HK, immature fruit in spirit).

**Discussion.** *Thismia hongkongensis* is most similar to *T. brunonis* Griff. (1844, 1845; as '*T. brunoniana*' in the latter), the type species in the genus. *Thismia brunonis* is only known from a single collection from Tenasserim in Myanmar, dating from October 1834. According to Jonker's (1938) supraspecific classification of the genus,



**Figure 3.** Fruit structure in *Thismia hongkongensis* sp. nov. **A** Flower (rear right), immature fruit, shortly after fertilization (left), and mature fruit with exposed seeds (front). **B** Two fruiting individuals, each with three fruits. **C** Lateral view of fruiting specimen, illustrating elongated fruit stalk. **D** Mature fruit with exposed seeds. **E** Dehydrated fruit. **F** Rehydrated fruit, after rainfall. Photos by S.S. Mar.



**Figure 4.** *Thismia hongkongensis* sp. nov. (S.S. Mar 2, HK). **A** Entire flower. **B** Flower with proximal part of perianth tube removed, showing pendent stamens. **C** Apex of the perianth tube, showing annulus (a) and pendent stamens, with filament (f), thecae (th), lateral appendage (la), and aperture (ap) between filaments. **D** Longitudinal section through fused carpels. Scale bars: **A, B, D** = 2 mm; **C** = 1 mm. Drawings by Caren Pearl Shin.

both species would be included in sect. *Thismia* ('*Euthismia*') subsect. *Brunonithismia* Jonker as they have unequal and free tepal lobes. Comparison of the two species reveals several significant differences, however, including flower number per inflorescence. The protologue of *T. brunonis* includes reference to flowers clustered in a terminal raceme ("Flores pauci, in racemum brevem terminalem dispositi": Griffith 1845: 341) with the accompanying illustration in the same publication (Fig. 1 in Pl. XXXIX) showing inflorescences with four and six flowers; Jonker (1938) subsequently described the species as bearing 3–8 flowers per raceme. In contrast, *T. hongkongensis* invariably has fewer flowers, with a maximum of three per inflorescence, reaching anthesis consecutively. The perianth tube of *T. brunonis* is pale yellow with red ribs (Griffith 1845), whilst it is pink with red ribs in *T. hongkongensis* (Figs 1G–J, 2A, B). The filiform appendages on the outer tepals of *T. brunonis* appear to be spreading at maturity (Griffith 1845: Pl. XXXIX), whereas those of *T. hongkongensis* invariably remain upright and cross each other to form a loose mitre over the annulus (Figs 1G–J, 2A, B, 4A). *Thismia brunonis* also differs from *T. hongkongensis* as it has a much shorter filament: although a measurement was not included in Griffith's descriptions of *T. brunonis*, the accompanying plate (Griffith 1845: Fig. 7 in Pl. XXXIX) indicates that it is considerably shorter than the rest of the stamen. The shape of the stigma lobes also differs: it is acute in *T. brunonis* (Griffith 1845: Fig. 9 in Pl. XXXIX; Jonker 1938), but rounded in *T. hongkongensis* (Fig. 4D).

*Thismia hongkongensis* is strikingly different from its congener in Hong Kong. *Thismia tentaculata* has a white perianth tube with a bright yellow annulus, and three divergent orange-red filiform appendages on the inner tepals (Ho et al. 2009).

**IUCN conservation status.** CR D (IUCN 2001). Only one population is known, consisting of ca. 10 individuals, covering an area of approximately 4–5 m<sup>2</sup>. The population is located within the Tai Po Kau Nature Reserve, but is close to a major hiking path and the population is therefore susceptible to human disturbance and vegetation clearance.

### Pollination ecology

Although the Burmanniaceae s.l. (inclusive of *Thismia*) are reported to be protandrous (Vogel 1998), this inference was based on a paraphyletic circumscription of the family and it is unclear whether protandry has specifically been observed in *Thismia*. Dissections of late-anthetic flowers of *T. hongkongensis* allow tentative confirmation of protandry, however, as the thecae are completely devoid of pollen (*th* in Fig. 2C).

Little is known of the pollinators of *Thismia*, although several authors have suggested that the flowers may be visited by small flies (Vogel 1962; Stone 1980; Rüb-samen 1986). These inferences were based on perianth morphology, the presence of osmophores on the tepals (Vogel 1962), the presence of nectaries either at the base of the perianth (Poulsen 1890) or along the suture between contiguous anthers (e.g., Groom 1895; Pfeiffer 1918; Jonker 1938, 1948; Cribb 1986, 1995; Thiele and Jordan

2002; Ho et al. 2009), and the formation of sticky pollen (Cranwell 1953). The only previous observational report of insect visitors to *Thismia* flowers is of small, unidentified flies entering the perianth tube of *T. gongshanensis* (Li & Bi, 2013).

Several researchers have inferred that fungus gnats are likely to pollinate *Thismia* flowers based on structural mimicry (e.g., tepal extensions and reticulate patterning on the inner surface of the perianth tube), perianth colour and the emission of fungus-like floral scents (Vogel 1978; RübSamen 1986; Thiele and Jordan 2002). We retrieved a fungus gnat (belonging to either the Mycetophilidae or Sciaridae) from within the perianth tube of a late-anthetic specimen of *T. hongkongensis*; unfortunately the poor state of preservation of the fly precluded further identification. We also retrieved an isolated insect wing from within the floral chamber which had the characteristic venation typical of a scuttle fly (Phoridae). Fungus gnats and scuttle flies are generally associated with decaying organic matter and are often reported to feed on fungi (Hill et al. 1982).

The pollinators presumably enter the floral chamber of *T. hongkongensis* via the aperture within the annulus (*a* in Figs 2C, 4C). Assuming that the flower is protandrous as suggested, the movements of the pollinators are likely to differ depending on whether the flower is in its early anthetic (staminate) or late anthetic (pistillate) phase. In staminate-phase flowers, the flies are likely to be attracted to the putative nectaries (arrowed in Fig. 2D) located at the apex of the perianth tube, behind the pendent staminal ring. We hypothesize that the irregular surface on the adaxial surface of the perianth tube resulting from the reticulate venation (Fig. 2D) possibly enables the insects to climb and access these nectaries. The flies are likely to make contact with the thecae (*th* in Figs 2C, 4C) and inadvertently collect pollen whilst feeding from the nectaries, before departing via the small apertures (ca. 0.5 mm diameter) located between the filaments (*f* in Figs 2C, 4C) of adjacent stamens. If the flies enter late-anthetic pistillate-phase flowers, however, it is possible that they might be prevented from accessing the nectaries because of the raised lateral appendages of the stamens (*la* in Figs 2C, 4C), thereby increasing the time in which contact with the stigma is possible. The possible trapping of flies may explain the frequency with which flies are observed inside the perianth tube of late-anthetic flowers. Similar interpretations of pollinator movement, involving climbing the inner wall of the perianth tube and exiting via the apertures between the filaments, has previously been suggested by Maas et al. (1986) and Thiele and Jordan (2002) for other *Thismia* species.

### Seed dispersal

Several different interpretations of seed dispersal have been proposed for *Thismia*, including movement by earthworms with secondary dispersal possible if the worms are eaten by birds (Beccari 1890). Stone (1980) suggested that *Thismia* seeds are likely to be dispersed by raindrops that splash seeds out of the fruit-cup. The size and shape of the fruit-cups of *T. hongkongensis* closely resemble functionally similar rain-splash

dispersal structures in phylogenetically disparate groups (Nakanishi 2002): the upper surface of the fruit disintegrates at maturity (Fig. 3A), resulting in an upright, cup-like hypanthium (ca. 4.8 mm in diameter) with seeds that are fully exposed (Fig. 3D). Studies of other plant groups indicate dispersal of up to 1 m (Nakanishi 2002), although there are inevitably many variables (including plant height, seed weight, etc.) that affect potential dispersal distance; it is perhaps significant that the stem of *T. hongkongensis* elongates as the fruit matures (Fig. 3C), thereby possibly increasing seed dispersal distance.

Brodie (1951) observed that seeds of species that are rain-splash dispersed are often coated with a hydrophilic colloid that rapidly absorbs water, and which may act as a lubricant, facilitating separation of seeds by rain drops. *Thismia hongkongensis* seeds are surrounded by a conspicuous mucilage-like substance (Fig. 3D) that may function in this way.

The fruits of *T. hongkongensis* appear to remain functional for several weeks. Although the plants are inevitably subjected to periods of desiccation, the fruits appear to be able to rehydrate effectively (Fig. 3E, F), thereby prolonging the period for seed dispersal.

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# Taxonomic updates in *Dolichandra* Cham. (Bignoniaceae, Bignoniaceae)

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## Abstract

*Dolichandra* is a genus of lianas found in dry and wet Neotropical forests. The genus currently includes eight species and is well characterized by molecular and morphological synapomorphies. Here, *Macfadyena hispida* (DC.) Seemann is removed from synonymy with *Dolichandra uncata* (Andrews) L.G. Lohmann based on the presence of the hispid indument, vinaceous ovary, long fruits, and winged seeds. The combination *Dolichandra hispida* (DC.) L.H. Fonseca & L.G. Lohmann, **comb. nov.** is proposed, increasing the number of accepted species of *Dolichandra* to nine. A taxonomic key for all species of *Dolichandra* is presented.

## Keywords

Taxonomic key, Neotropical lianas, *Dolichandra hispida*

## Introduction

*Dolichandra* Cham. is a genus of lianas that belongs to the tribe Bignoniaceae, in the plant family Bignoniaceae (Lohmann 2006; Lohmann and Taylor 2014). The family comprises ca. 80 genera and 840 species of trees, lianas and shrubs (Lohmann and Ulloa 2006, onwards), representing an important component of Neotropical forests

and dry areas. The tribe Bignoniae includes 21 genera and 393 species of lianas and is centered in Brazil (Lohmann and Taylor 2014).

The current circumscription of *Dolichandra* is based on molecular phylogenetic data (Lohmann 2006) and morphological synapomorphies (Lohmann and Taylor 2014). In this circumscription, the genus is composed of eight species (Lohmann and Taylor 2014), one of which was previously included in *Dolichandra*, three in *Macfadyena* DC., one in *Melloa* Bureau, and three in *Parabignonia* Bureau ex K. Schum (Gentry 1973a, 1973b). Under the new circumscription, *Dolichandra* is characterized by unique multiple dissected phloem wedges, trifid and uncinatate tendrils, fruits with four lines of dehiscence, a dimorphic growth form, a large and membranaceous calyx, and colpate pollen with a psilate exine (Gentry 1973a, 1973b; Gentry and Tomb 1979; Lohmann and Taylor 2014).

The genus is distributed in wet and dry Neotropical forests, from Mexico to northern Argentina (Gentry 1973a, 1973b; Lohmann and Taylor 2014), being a conspicuous component of seasonally dry forests. The geographic distribution of *Dolichandra* is centered in southern Brazil, northern Argentina and Paraguay, where up to seven species are found. The geographic distribution of members of *Dolichandra* is highly variable, with species found throughout the Neotropics, like the ubiquitous *D. unguis-cati* (L.) L.G.Lohmann, and species with restricted distributions such as *D. dentata* (K. Schum.) L.G.Lohmann, found in riverbanks of the Uruguay river basin (Lohmann and Taylor 2014).

*Dolichandra cynanchoides* (cham.) L.G.Lohmann is cultivated as ornamental in Argentina (García 1992) and *D. unguis-cati* in the USA (Gentry 1982). *Dolichandra unguis-cati* is also an invasive in some countries, like Australia and South Africa (Sparks 1999; Dhileepan et al. 2007). Attempts to reduce population size and control the invasiveness of *D. unguis-cati* are underway in both countries (Sparks 1999; Dhileepan et al. 2007).

During phylogenetic and taxonomic studies of *Dolichandra*, it became clear that *Macfadyena hispida* (DC.) Seem. is morphologically distinct from *D. unguis-cati* (Andrews) L.G.Lohmann and should be recognized as a separate taxon. We here present the necessary new combination. We also provide a taxonomic key for the genus, thus facilitating the identification of the species.

## Material and methods

This study was based on botanical collections from nine herbaria (ESA, FUEL, INPA, MBM, MO, NY, SP, SPF, and UPCB). Morphological studies were carried out under a stereomicroscope using dried and fresh specimens. Morphological terminology for leaves follows Hickey (1973) and flowers and inflorescences follows Weberling (1989). Other morphological structures follow Harris and Harris (2001).

## Taxonomic treatment

### *Dolichandra hispida* (DC.) L.H.Fonseca & L.G.Lohmann, comb. nov.

urn:lsid:ipni.org:names:77145082-1

Fig. 1

*Spathodea hispida* DC., Prodr. 9: 205. 1845.

*Macfadyena hispida* (DC.) Seemann, J. Bot. 1: 227. 1863.

Type: Brazil. Mato Grosso: Cuiabá, 1832, A. Silva Manso 105A (holotype: G-DC [G00133604]!).

*Spathodea mollis* Sond., Linnaea 22: 561. 1849.

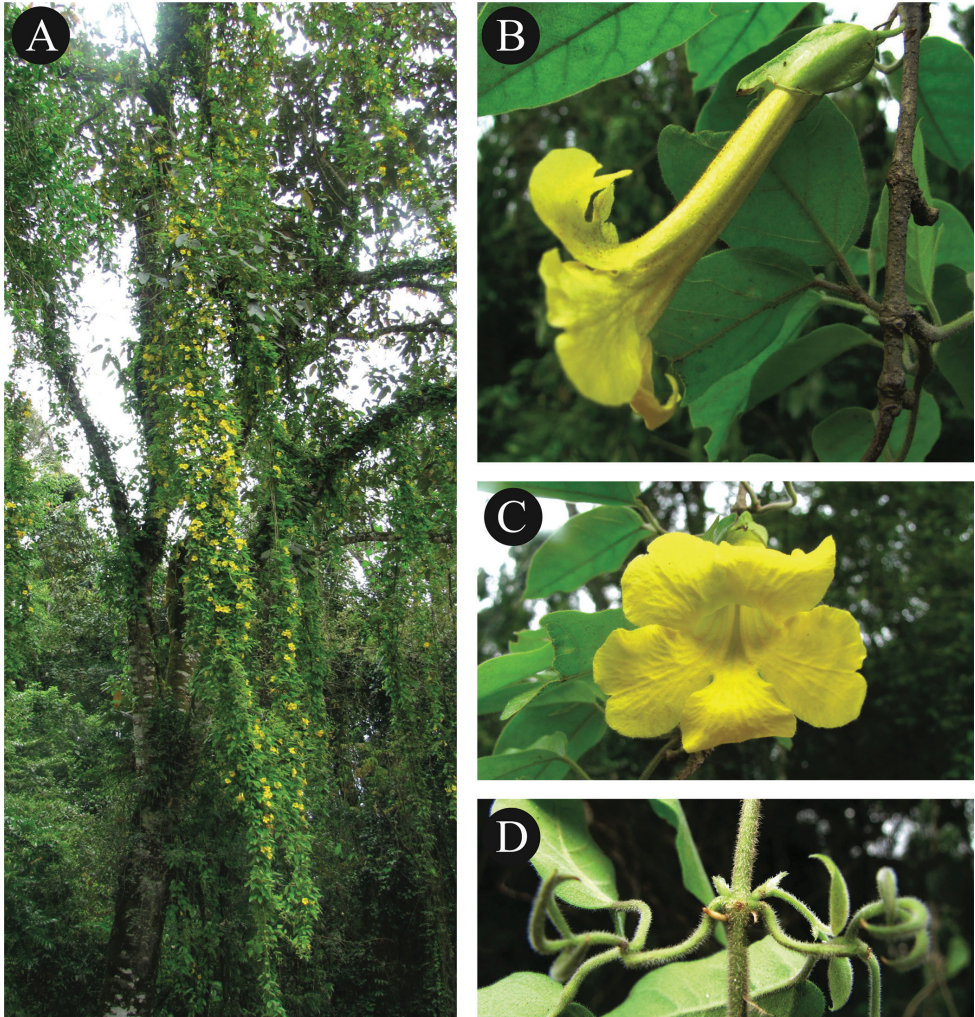
*Macfadyena mollis* (Sond.) Seemann, J. Bot. 1: 227. 1863.

Type: Brazil. Minas Gerais: Caldas, 1855, A.F. Regnell I-292 (lectotype, designated here: MO [2229711]!).

*Macfadyena pubescens* Moore, Trans. Linn. Soc. London, Bot. ser. 2, 4: 418. 1895.

**Type.** Paraguay. “inter Villa Maria et Corumbá”, Dec 1891–92, S. Moore 1021 (holotype: BM image [578432]!).

**Description.** *Liana.* Stems terete, striate, interpetiolar region with ridges and glandular fields, eglandular and glandular trichomes covering the stem surface, eglandular trichomes simple, densely distributed in a hispid indument, glandular trichomes peltate and pateliform, flaky bark absent; prophylls 1.6–3 mm long, subulate, apiculate, smooth, hispid. *Leaves* bifoliolate with a terminal tendril; petioles semi-terete, hispid and with peltate trichomes, 0.95–4.49 cm long; petiolules terete, hispid with simple and peltate trichomes, 0.3–2.9 cm long, with equal length; tendrils trifid and uncinat; leaflets ovate, obovate or elliptic, apex acute to short acuminate with a drip tip, base rounded, symmetric or slight asymmetric, 3.2–8.6 × 1.2–7.14 cm, margin entire, membranaceous, the abaxial surface hispid with simple trichomes more concentrated on the veins, peltate trichomes throughout and pateliform glandular trichomes concentrated at the base, the adaxial surface hispid, primary venation straight, unbranched, secondary venation brochidodromous and tertiary venation percurrent. *Inflorescence* an axillary 3-flowered cyme, rarely reduced to one flower; pedicels 0.5–4.3 cm long, hispid and with peltate glandular trichomes; receptacle with pateliform trichomes; bracts deciduous, floral bracts filiform, deciduous, rarely present, elliptic to obovate, 0.7–5.5 mm long, membranaceous. *Calyx* green, bi-lobed, spathaceous with an incurved apicule, 1.4–3.2 × 0.7–1.6 cm, membranaceous, glabrate to hispidulous, with peltate trichomes. *Corolla* yellow, bilabiate with the upper 2 lobes reflexed and the lower 3 lobes forward, tubular-infundibuliform, glabrate, hispidulous 5.1–9.1 cm long, 1.3–2.2 cm, 4–5.7 cm wide; lobes obcordate, 1.2–2 cm long, 1.2–2.15 cm wide, margin entire. *Androecium* inserted at the tube, with simple trichomes at the insertion; short filaments 1.15–1.7 cm long, longer filaments 1.74–2.4 cm long, glabrous, attached at the same height from the base of the corolla, 4.5–9.4 mm from the base; staminode 8–9 mm long; anthers pale-yellow or white, 3–3.9 mm long. *Gynoecium* inserted at the tube, glabrous; pistil 3.3–3.8 cm



**Figure 1.** **A** Habit of *Dolichandra hispida* **B** Lateral view of flower **C** Flower frontal view showing the opening of the flower tube **D** Node branch showing the hispid indument (Photos L.H.M. Fonseca).

long; ovary vinaceous, linear, 7–9 × 1.4 mm long; style 2.6–3 cm long; stigma rhombic. *Fruits* linear, attenuate toward base and apex, 77–125.8 × 1.17–2.2 cm, smooth, with lenticels, glabrous. *Seeds* with hyaline wings, thin, 2.2–3.8 × 1.4–1.8 cm wide, seed body oblong to ovoid, woody, 6–9 × 8–15 mm.

**Nomenclatural notes.** A single specimen was cited by Sonder for *Spathodea mollis* labeled 292 in Regnell’s first series of collections from Brazil. Four specimens labeled as Regnell I-292 were located, one at K [000449792], two at BR [876279] [876378] and one at MO [2229711]. The best quality material is selected here as lectotype.

**Taxonomic notes.** *Dolichandra hispida* is easily differentiated from all other species of *Dolichandra* by the unique hispid indument found on the vegetative and repro-

**Table 1.** Comparison of *Dolichandra hispida* and *D. uncata*; non-overlapping characters are shown in bold.

Characters	<i>Dolichandra hispida</i>	<i>Dolichandra uncata</i>
Leaflet form	Ovate, obovate (rare elliptic)	Elliptic (rare Ovate, obovate)
Leaflet apex	Acute to short acuminate	Long acuminate (rare short acuminate)
<b>Indument</b>	<b>Hispid</b>	<b>Pubescent (rare glabrous)</b>
Calyx	Short apiculate (1.2–2.3 mm)	Long apiculate (1.8–3.4 mm)
<b>Ovary color</b>	<b>Vinaceus</b>	<b>Green</b>
<b>Fruit length</b>	<b>9.2–38.5 cm</b>	<b>77–125.8 cm</b>
<b>Seed texture</b>	<b>Hyaline</b>	<b>Corky/woody</b>

ductive portions of this species, as well as the presence of a vinaceous ovary. *Dolichandra hispida* has been treated as a synonym of *D. uncata* since Gentry (1973a). However, the differences in indument (hispid vs. glabrous to puberulous), ovary color (vinaceous in *D. hispida* vs. green in *D. uncata*), and seed wing morphology (hyaline in *D. hispida* vs. woody in *D. uncata*) are clear, making the separation of these two species necessary. In addition, the difference in fruit length is also striking, with fruits being much longer in *D. hispida* (77–125.8 cm) than in *D. uncata* (9.2–38.5 cm). In fact, *D. hispida* presents one of the longest fruits of Bignoniaceae, and possibly one of longest capsules within the Angiosperms (Table 1).

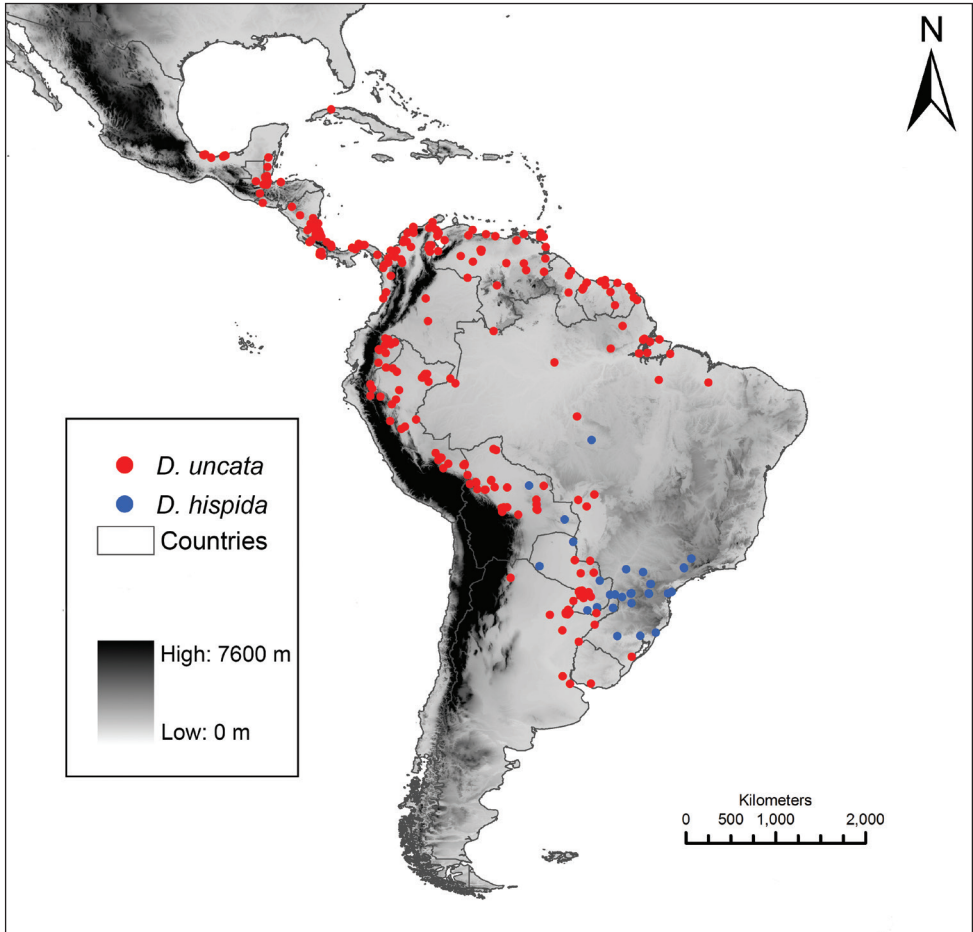
*Dolichandra uncata* occurs predominantly in riverbanks, swamps and mangroves, presenting seeds that are corky and supposedly adapted for water dispersal (Gentry 1973b). On the other hand, *D. hispida* is more common in non-flooded areas, presenting seeds adapted to wind dispersal.

**Distribution.** *Dolichandra hispida* occurs in southern, southwestern and central Brazil, Paraguay and Bolivia, whereas *D. uncata* has its northern limit in Mexico and southern limit in Argentina and Uruguay (Fig. 2).

**Phenology.** This species was collected in flower in September, October, November, December and January and in fruit in September, November, December, January and February.

**Conservation status.** *Dolichandra hispida* is here considered as Least Concern [LC] according to IUCN criteria (IUCN 2012; IUCN Standards and Petitions Subcommittee 2014). The extent of occurrence estimated for the species is 2,209,625.833 km<sup>2</sup> and the estimated area of occupancy is 875.000 km<sup>2</sup> (cell width of 5 km). Therefore this classification was established based on the wide distribution of the taxon, since no population data is available.

**Specimens examined.** **Argentina.** Misiones: Guarani, 03 Mar 2000, *N. Deginani 1630* (MO); **Bolivia.** Santa Cruz: Estancia San Miguelito, 200 km al E de la ciudad de Santa Cruz, 02 Dez 1996, *A. Fuentes 1342* (MO); Las Trancas, Lomerio, las parcelas de Bolfor, Las Trancas '95, 16 Nov 1994, *A. Jardim 1204* (MO); **Brazil.** Mato Grosso: Alta Floresta, Fazenda Mogno, Ponte do 27, margem direita, mata de capoeira, solo arenoso, 18 Sep 1991, *Macedo et al. 3009* (INPA); Paraná: Antonina, Rio Mergulhão, 31 Oct 1973, *G. Hatschbach 29172* (MBM); Foz do Iguaçu, Parque Nacional das Cataratas do Iguaçu, 14 Oct 1962, *G. Hatschbach 9378* (MBM); Guaraqueçaba, Tagaça



**Figure 2.** Distribution of *Dolichandra hispida* (red dots) and *D. uncata* (blue dots).

de Cima, Rio Tagaçaba, orla da Floresta Atlântica, 20 Nov 2003, *G. Hatschbach et al.* 76720 (MBM); Irati, Riozinho, 01 Oct 1982, *G. Hatschbach* 45518 (MBM); Laranjeiras do Sul, Salto Santiago, 07 Mar 1991, *Silva et al.* 955 (UPCB, SP); Fazenda Santa Ana, 31 Oct 1985, *Dias s.n.* (FUEL, MO); Morretes, início da Estrada do Itupava, beira do Rio Nhundiaquara, próximo à ponte de Morretes, 29 m elev., 25°26'1.31"S, 48° 52'26.31"W, 12 Mar 2008, *L.H.M. Fonseca et al.* 27 (SPF, MBM); Pinhão, Vale do Rio Iguaçu, Córrego Estreito, 22 Feb 1996, *G. Hatschbach et al.* 64429 (MBM); Rio Bonito do Iguaçu, Fazenda Giacomet-Marodin, Pinhal Ralo, 23 Jun 1995, *Poliquesi & Cordeiro* 328 (MBM, SPF); Tibagi, 696 m elev., 12 Oct 1959, *G. Hatschbach* 6373 (MBM); Rio Grande do Sul: Morrinhos do Sul, Morro do Forno, trepadeira em borda de Mata Atlântica de encosta, 19 Oct 1997, *Jarenkow & Sobral* 3204 (MBM); Santa Catarina: Apiúna, floresta ombrófila densa, 549 m elev., 27°10'27"S, 49°18'08"W, 11 Oct 2009, *K. Knies* 561 (SPF); São Paulo: Iporanga, estrada entre Apiá e Iporanga, flo-



resta ombrófila densa, próximo ao Rio Bethary, 240 m elev., 24°32'55"S, 48°41'09"W, 23 Oct 2010, *L.H.M. Fonseca & D. Tarabay 157* (SPF, SP, MBM, MO); Iporanga, estrada entre Apiaí e Iporanga, floresta ombrófila densa, próximo ao Rio Bethary, 23 Oct 2010, *L.H.M. Fonseca & D. Tarabay 162* (SPF, SP, MBM, MO). **Paraguay.** Chaco: Bahia Negra, 13 Nov 1946, *T. Rojas 13743* (MO); Itapua: Pirapo, Cerca Pirapo. Sitio de plantaciones experimentales de CEDEFO, 10 Oct 1984, *D.R. Brunner & W. Buck 853* (MO); Alto Parana: Puerto Stroessner, Itaipu, Forest Reserve Noe. Pto. Puente Stroessner, 27 May 1989, *A.H. Gentry 66144* (MO).

### Key to all species of *Dolichandra*

- 1a Calyx 5-lobed; branchlets with flaky bark; leaflets chartaceous.....2  
 – Calyx 2–3-lobed; branchlets without flaky bark; leaflets chartaceous or membranaceous.....3
- 2a Floral bracts linear–lanceolate to subulate, < 1 mm wide; calyx lobes rounded and shortly mucronate, magenta, puberulent; corolla puberulent outside with peltate trichomes at the lobes; Colombia, Costa Rica, and Ecuador .....  
 ..... *D. steyermarkii*  
 – Floral bracts elliptic or lanceolate, 2–3 mm wide; calyx lobes ovate–lanceolate, attenuate and mucronate, green, glabrous (except at margin); corolla glabrous outside (sometimes sparsely pubescent at apex); Brazilian Atlantic Forest..... *D. unguiculata*
- 3a Leaflet margins toothed; seed wings woody with a narrow hyaline margin; prophylls subulate, and smooth; riverbanks of Uruguay River basin .....  
 ..... *D. dentata*  
 – Leaflet margins generally entire (rarely toothed); seed wings hyaline, rarely woody but then, never with a hyaline margin; prophylls generally ovate and lanceolate, if ovate then striate, if smooth then lanceolate or subulate ..... 4
- 4a Anthers and stigma exserted; corolla bilabiate with the upper 2 lobes forward and the lower 3 lobes reflexed, red; fruit elliptic and coriaceous .....  
 ..... *D. cyanchooides*  
 – Anthers and stigma included; corolla bilabiate with the upper 2 lobes reflexed and the lower 3 lobes forward, yellow or purple; fruit linear, rarely elliptic, but then woody ..... 5
- 5a Leaflet chartaceous; calyx 3-lobed, covering approximately 1/3 of the corolla; corolla purple..... *D. chodatii*  
 – Leaflet membranaceous; calyx 2-lobed or truncated, covering approximately 1/4 or 1/5 of the corolla; corolla yellow ..... 6
- 6a Floral bracts foliaceous; calyx with a recurved apicule; fruit an oblong-elliptic capsule..... *D. quadrivalvis*  
 – Floral bracts filiform; calyx without an apicule, if apiculated then the apicule is incurved and never recurved; fruit a narrow, linear capsule..... 7

- 7a Calyx cupular, truncate to sinuous, without an apicule; prophylls ovate and striate..... *D. unguis-cati*
- Calyx usually subspathaceously split, often with an incurved apicule; prophylls subulate-lanceolate or subulate and smooth..... **8**
- 8a Indument hispidous; ovary vinaceous; fruits 77–125.8 cm long; seeds with hyaline wings; deciduous forests of northern Argentina, southern, southwestern and central Brazil, Paraguay and Bolivia ..... *D. hispida*
- Species glabrous to puberulous, never hispid; ovary green; fruits 9.2–38.5 cm long; seeds woody and opaque, hyaline wings absent; mangroves and swamps from Mexico to Argentina and Trinidad..... *D. uncata*

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# A new species of *Cyanea* (Campanulaceae, Lobelioideae), from the Ko‘olau Mountains of O‘ahu, Hawaiian Islands

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## Abstract

*Cyanea konahuanuiensis* Sporck-Koehler, M. Waite, A.M. Williams, **sp. nov.**, a recently documented, narrowly endemic species from the Hawaiian Island of O‘ahu, is described and illustrated with photographs from the field. The closest likely relatives to the species, current conservation needs, and management future are discussed. It is currently known from 20 mature plants from two subpopulations and is restricted to a drainage below the Kōnāhua-nui summit (K1), the highest summit of the Ko‘olau Mountains, located on Windward O‘ahu. It differs from all other *Cyanea* species by its combination of densely pubescent leaves, petioles, and flowers; sparsely pubescent to glabrous stems, long calyx lobes, and staminal column being adnate to the corolla.

## Keywords

Campanulaceae, conservation, *Cyanea*, endemic, Hawai‘i, Hawaiian Islands, IUCN Red List, Kōnāhua-nui, Ko‘olau Mountains, Lobeliads, Lobelioideae, O‘ahu, rare plants, *Rollandia*

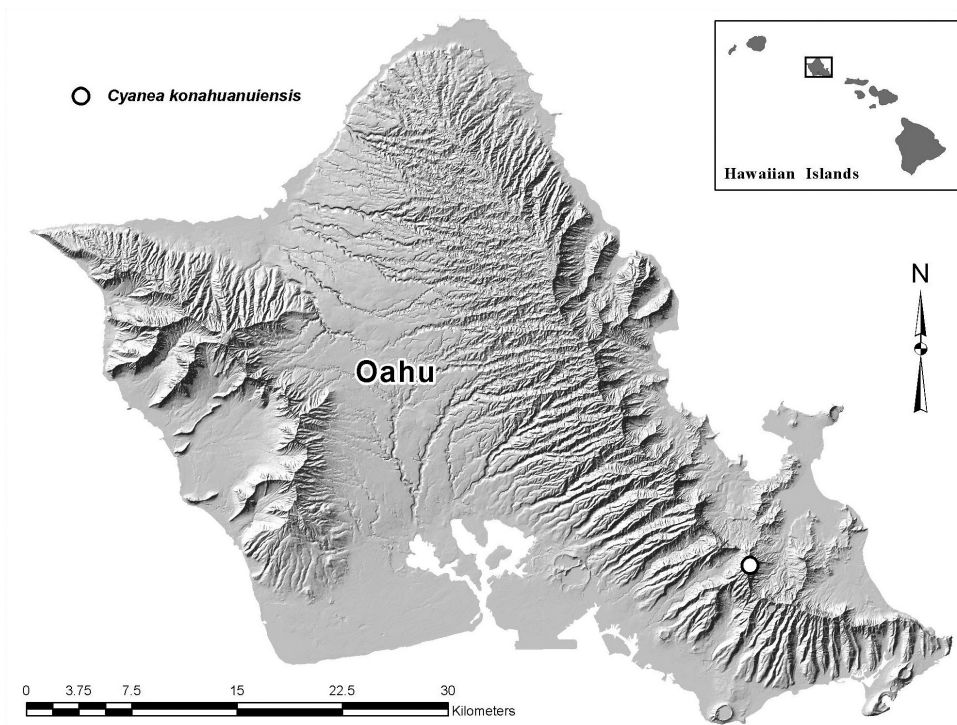
## Introduction

The Campanulaceae is a large, diverse, and cosmopolitan plant family with representatives inhabiting a wide range of ecosystems including tropical, subtropical, temperate, and even frigid zones with exceptional diversification in South Africa and Hawai'i (Lammers 2007). One of the most exceptional adaptive radiation events known in the family is the monophyletic lobelioid group in Hawai'i (Givnish et al. 2008). The Hawaiian lobelioids are a group of woody eudicots comprised of six genera, *Brighamia* A. Gray, *Clermontia* Gaudich., *Cyanea* Gaudich., *Delissea* Gaudich., *Lobelia* L., and *Trematolobelia* A. Zahlbr. Together they account for roughly ten percent of Hawaiian angiosperm diversity (Wagner et al. 1999, 2005) with a total of 128 taxa, 78 of which are currently recognized as Threatened and Endangered (T&E; USFWS <http://www.fws.gov/endangered/>). The lobelioids in Hawai'i represent the largest adaptive radiation from a single colonization event known from any plant group restricted to an oceanic island chain (Oppenheimer and Lorence 2012, Givnish et al. 2008). According to the most current treatment of the Hawaiian Lobelioids (Lammers 2007), *Cyanea* (including the merger of the genus *Rollandia*) is the most species-rich genus in the radiation, comprised of 79 currently recognized species (54 T&E). A possible explanation for the impressive speciation in this genus is that the fleshy fruits are poorly distributed by Hawai'i's native forest birds, which do not typically travel long distances, leading to parallel speciation events on multiple islands (Givnish 2008). *Cyanea* occurs in mesic to wet forests across the Hawaiian archipelago and includes many taxa with restricted distributions, most of which are single island endemics.

In September 2012, the Kōnāhua-nui summit area of the Ko'olau Mountains on the island of O'ahu was surveyed (Figure 1). The target species was *Cyanea humboldtiana* (Gaudich.) Lammers, Givnish & Sytsma, a species federally listed as Endangered, and endemic to the Ko'olau Mountains. It was hoped to locate additional individuals to monitor and manage as a part of species recovery efforts. We summited K1 (the highest of the two peaks of Kōnāhua-nui) and descended into a stream drainage and once near the bottom of the gulch, directly adjacent to the stream, several plants were discovered of a *Cyanea* with hairy leaves and petioles, glabrous stems, and long, hairy calyx lobes. There were no flowers present on the plants and only one immature infructescence. The specific taxon could not be confirmed in the field and it was decided to take photos and collect a dropped and decaying leaf for further investigation.

Preliminary research in the following weeks consisted of examining the plants using photos and the one fallen, partially decayed leaf collected from the field. After reviewing the current treatments of *Cyanea*, sharing the photos with local experts, and looking at specimens at the Bishop Museum, it was concluded that the species in question was most likely undescribed. To be certain, fertile specimen was required.

Thereafter, trips to the remote population were made every two to three months. These subsequent expeditions surveyed the surrounding area and revealed the presence of additional individuals. In June 2013, an automated game camera was installed

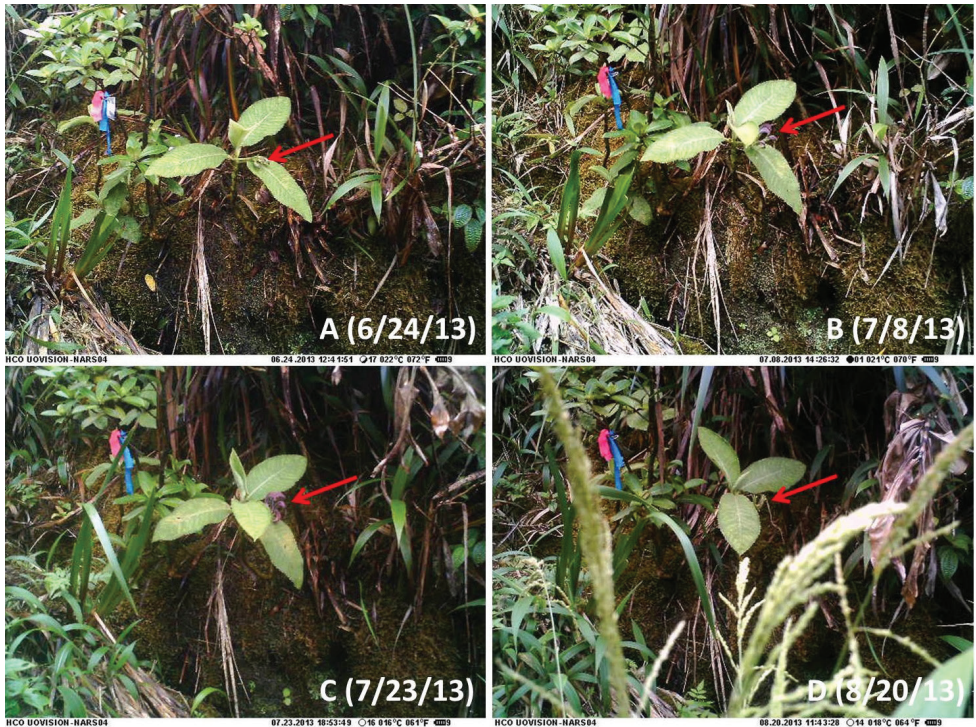


**Figure 1.** Distribution map of *Cyanea konahuanuiensis* showing site of population on South East O'ahu in the Ko'olau Mountain Range.

connected to cellular phone service that transmitted a photo of one of the plants three times per 24 hour period (Figure 2). This camera allowed us to monitor the flower development and visit the plants again when we were certain the flowers would be fully mature.

In addition, type specimens of all of the Hawaiian Lobeliads were examined in the Herbarium Pacificum of the Bernice Pauahi Bishop Museum (BISH) collection, with special attention given to *Clermontia*, *Cyanea*, *Delisea*, and the formerly recognized generic group, *Rollandia* Gaudich. None of the Hawaiian Campanulaceae was a match to the *Cyanea* under study.

There are several species that share some characteristics with *C. konahuanuiensis* including: *Cyanea crispa* Gaudich., *Cyanea calycina* Gaudich., *Cyanea humboldtiana* Gaudich., and *Cyanea pilosa* A. Gray (Table 1). For example, *C. crispa*, *C. calycina*, and *C. humboldtiana* all share a staminal column that is adnate to the corolla tube, similar overall stature and leaf shape, presence of some leaf pubescence (though not to the same degree as *C. konahuanuiensis*), and similar number of flowers in each inflorescence (*C. konahuanuiensis* also shares the characteristic of pendant inflorescences but to a lesser degree than *C. humboldtiana*). However, they all differ in the degree of leaf pubescence (*C. konahuanuiensis* being significantly more hairy), calyx lobe length, and corolla surface characteristics.



**Figure 2.** *Cyanea konahuanuiensis*. Game camera time lapse series illustrating flower and early fruit development over a nearly two month time frame. Panels **A–D** each illustrate a different stage of development. Red arrows point to developing flower and fruit features.

The Hawai‘i Island endemic *C. pilosa* shares a comparable leaf shape and is similarly pubescent (though dissection scope inspection revealed that hair structure differs) to *C. konahuanuiensis*, but the latter lacks hairy stems and has more abundant hair on both leaf surfaces. Also, flower color and calyx lobe length differ radically, *C. pilosa* usually having white flowers and much shorter calyx lobes (2–5 mm long) and *C. konahuanuiensis* having brilliant purple flowers. Lastly, unlike *C. konahuanuiensis*, the staminal column of *C. pilosa* is not adnate to the corolla tube (Figures 3, 4, 5, 6, 7, 8 and Table 1).

Because so few individuals of *C. konahuanuiensis* are known, collections were limited to two fertile vouchers, each including one inflorescence and two leaves. Flowers were also collected from three individual plants and preserved in alcohol for precise floral analysis (see Specimens Examined section). In order to ensure limited damage to the population and to further conserve the species, detailed measurements were taken of five, reproductively mature and flowering, live plants in the wild for most of the descriptive information in this paper. For corolla tube lobe length and width, surface characteristics, and anther length and surface characteristic data from the preserved flowers were utilized. Seed data are taken from living material deposited at the University of Hawai‘i Harold L. Lyon Arboretum micropropagation facility. Selected measurements from the dried holotype specimen are included parenthetically in the description.



**Table 1.** Selected traits for *Cyanea konahuaniensis* compared to four *Cyanea* taxa sharing some similar morphological characteristics. Abbreviations: O = O'ahu, H = Hawai'i Island.

Species	Plant height (m)	Leaf length (cm)	Leaf width (cm)	Leaf shape	Adaxial leaf surface char.	Abaxial leaf surface char.	Peduncle Length (mm)	Number of flowers in inflorescence	Calyx lobe shape	Calyx lobe length (mm)	Hypanthium length (mm)	Flower Color	Corolla surface char.	Island found on
<i>C. konahuaniensis</i>	0.57–0.69	20–33	10–16	elliptic–oblong	densely hirsute, juveniles subdeltate muriccate	densely hirsute, juveniles subdeltate muriccate	50–122	3–12	linear to linear-oblong	16–18	10–15	dark magenta/purple w/ some lighter streaking as flowers age	densely pubescent	O
<i>C. calycina</i>	1–3	15–60	5.5–14	elliptic–oblanccolate	glabrous, juveniles muriccate	densely pubescent w/ branched & clustered hairs	20–100	4–16	oblong-ovate	4–10	6–12	pale–dark magenta, rarely pale greenish w/ lighter or darker longitudinal stripes	pubescent	O
<i>C. crispa</i>	0.3–1.3	30–75	9–16	broadly obovate	glabrous	glabrous or pubescent	20–30	3–8	ovate–oblong	6–12	8–12	pale magenta w/ darker longitudinal stripes	pubescent	O
<i>C. humboldtiana</i>	1–2	18–45	7–16	obovate–broadly elliptic	glabrous	pubescent	80–250	5–12	oblong	4–10	8–12	dark magenta, rarely white	pubescent	O
<i>C. pilosa</i>	0.8–2	15–42	8–15	broadly elliptic–broadly obovate	pubescent	whitish green, densely pubescent	15–110	6–28	narrowly triangular	2–5	4–6	white	pubescent	H

## Systematics

### *Cyanea konahuanuiensis* Sporck-Koehler, M. Waite & A.M. Williams, sp. nov.

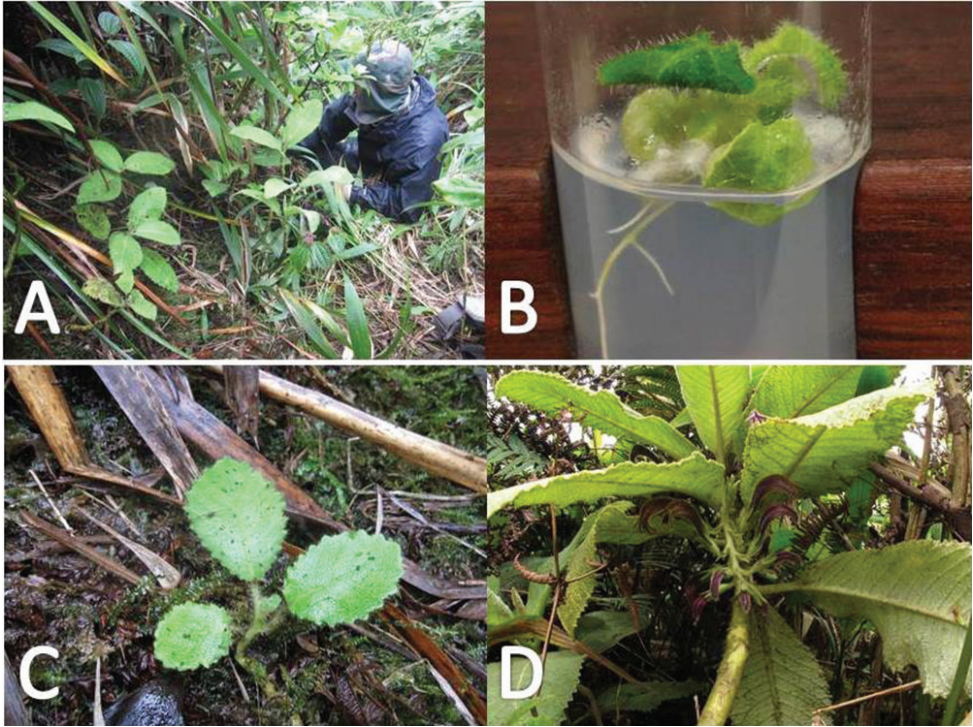
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Figures 3–7

**Note.** Species believed to be allied to *Cyanea humboldtiana* (Gaudich.) Lammers, Givnish & Sytsma, but primarily differs in its longer calyx lobes (16–18 mm long); and its more densely pubescent leaves, petioles, flowers, and differing flowering period. *C. humboldtiana* has leaves, petioles, and flowers that are more sparsely pubescent with shorter trichomes; leaf margins are callose-crenulate, floral bracts have acute apices, and its calyx lobes are ovate, acuminate and considerably shorter (4–10 mm long). The two species are reproductively isolated from each other due to lack of overlapping flowering periods (*C. konahuanuiensis* flowers from June–August and *C. humboldtiana* from October–December), and they are not known to intergrade.

**Type.** USA, Hawai'i, O'ahu Island, Ko'olau Range: Kōnāhua-nui, near summit, 912m (2991 ft), 9 July 2013, M. Sporck, T. Koehler, & M. Waite MJS 0019 (holotype: BISH 1049136), (Figure 9).

**Description.** *Unarmed shrubs* 57–69 cm high, with 1–6 stems originating at the base; stems light green and darkening to a light brownish gray closer to the base, erect to decumbent, 58–119 cm in length, some branches partially resting on the ground, occasionally rooting when in contact with the soil or moss producing aerial roots, leaf scars subcircular, 9.5–12 × 6.5–11.8 mm, upper end of leaf scar depressed, basal portion slightly raised; leaf scar with a protuberance; latex white. *Leaves* clustered distally near end of stems, petiolate; petioles 2–4.2 cm long, pubescent; blades elliptic to oblong, in adult plants 20–33 × 10–16 cm, base cuneate to rounded, occasionally slightly truncate, apex acute to sub-obtuse, margins serrate to serrate-dentate, dull grayish-green on adaxial surface and dull greenish white on abaxial surface, stiff, slightly fleshy, both surfaces densely hirsute and minutely muricate; in juvenile plants leaves are less stiff, margins dentate, and hairs softer. *Inflorescences* axillary just above the leaf, up to 4 per stem, young inflorescences roughly perpendicular to stem, larger and more developed inflorescences pendant, 3–12 flowered, peduncles 5–12.2 cm long (dried specimen 7.7 cm long), pubescent. *Flowers* on pedicels 7–14 mm long (5–10 mm when dried), pubescent, subtended by linear bracts 7–18 × 2–6 mm, apex obtuse, margins entire, densely pubescent; hypanthium 10–15 mm (9–14 mm when dried) × 7–10 mm (5–7 mm when dried), obovoid to cylindrical, pubescent; calyx lobes linear to linear-oblong, 16–18 × 5–7 mm (13–17 × 3–5 mm when dried), apex acute to subobtuse, retained on immature (green) fruits (no mature fruit seen); corolla dark purple with some lighter streaks developing with age, tubular, laterally compressed, curved, 86–99 mm long (80–95 mm when dried) × 12–13 mm wide medially (9–12 mm when dried), externally densely pubescent, internally glabrous, the lobes linear-subulate, 10–16 mm long × 5 mm wide at the base, reflexed, c. 1/4–1/3 as long as the tube; staminal column glabrous, adnate to corolla for half its

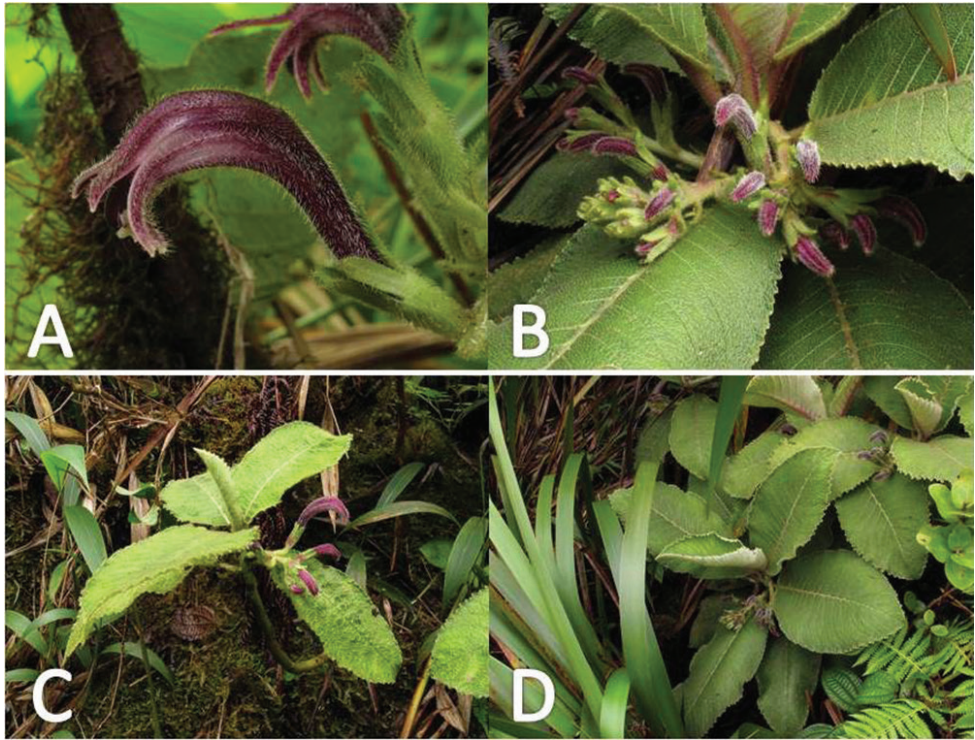


**Figure 3.** *Cyanea konabuanuiensis*. **A** habit, photo with Adam M. Williams crouched down next to plant for scale **B** Seedlings growing in test tube in micropropagation lab **C** juvenile plant in the field **D** flowering stem with pendent inflorescence captured (photos by Margaret J. Sporck-Koehler).

length, anthers 9–10 mm long, scantily pubescent, the lower two with apical tufts of white hairs 2–3 mm long. *Fruits* berries (mature fruits not seen), immature fruits densely pubescent, with calyx lobes persistent. *Seeds* from immature fruits numerous, embedded in green pulp, obovoid,  $0.74\text{--}0.84 \times 0.58\text{--}0.64$  mm, testa medium to dark brown, shiny and smooth.

**Distribution.** Known only from the Kōnāhua-nui summit area in the Ko‘olau Mountains of O‘ahu, Hawaiian Islands. The population is on land owned by the State of Hawai‘i, Department of Land and Natural Resources (DLNR), and is part of the Honolulu Watershed Forest Reserve (Figure 1).

**Habitat and ecology.** *Cyanea konabuanuiensis* occurs in wet forest sites at elevations from 884 to 932 m. The associated native Hawaiian plant species include *Broussaisia arguta* Gaudich., *Cheirodendron platyphylla* (Hook & Arn.) Seem., *Dubautia laxa* (Hook. & Arn.) *Machaerina angustifolia* (Gaudich.) T. Koyama, *Metrosideros rugosa* A. Gray, *Perrottetia sandwicensis* A. Gray, *Phyllostegia grandiflora* (Gaudich.) Benth., *Polyscias gymnocarpa* (Hillebr.) Lowry & G. M. Plunkett, *Sadleria pallida* Hook. & Arn., *Scaevola mollis* Hook. & Arn., and species of *Cibotium* Kaulf., *Kadua* Cham. & Schldtl., *Labordia* Gaud., *Melicope* J.R. Forst. & G. Forst., and *Wikstroemia* Endl. Introduced naturalized plant species include: *Ageratina adenophora* (Spreng.) R.M. King & H. Rob., *Clidemia hirta* (L.) D.



**Figure 4.** *Cyanea konahuanuiensis*. **A** detail of corolla tube in profile. Dense pubescence and long calyx lobes apparent **B** close up view of buds **C** view of plant habit depicting single-stalked individual **D** view of plant habit depicting multi-stalked individual (photos by Tobias B. Koehler).

Don, *Hedychium gardnerianum* Sheppard ex Ker Gawl., *Rubus rosifolius* Sm., and *Setaria palmifolia* (J. König) Stapf. Bryophyte species are prevalent and include *Distichophyllum freycinetii* (Schwägr.) Mitt., *Plagiochila diflexa* Mont. & Gottsche, and species of *Bazzania* S. Gray. The native arthropod, *Megalagrion oahuense* Blackburn (a Hawaiian endemic damselfly) has been observed on *C. konahuanuiensis*. Soil is of basaltic origin and typical of wet forest sites on O‘ahu and the average annual rainfall is approximately 2600 mm (Giambelluca et al. 2013). The plants occupy a gulch both at the base and middle of relatively steep slopes which results in direct sunlight exposure occurring for a few hours close to midday and varying seasonally. Plants occur on both northwest and south facing slopes of the gulch, mostly along the banks of intermittent streams, but can also be found several meters from the stream with no apparent preference. Small stem fragments that are detached from plant have been observed to take root, forming new clones.

**Phenology.** *Cyanea konahuanuiensis* has been observed flowering from June–August with fruit developing from August–October. All observed fruits have aborted, been eaten, or decomposed before maturity. The lifespan and time to maturity of the species is unknown. Immature, nearly aborted fruits have been collected when all others had aborted. Fruits have been submitted to the Lyon Arboretum Micropropaga-



**Figure 5.** *Cyanea konahuanuiensis*. Inflorescence/flowers illustrating pendant inflorescence, dense pubescence of flowers, and long calyx lobes. Pubescent petioles and hairless stems are also apparent (photo by Tobias B. Koehler).

tion lab where some of the seeds have germinated and it is interesting to note that the seedlings have densely pubescent leaves (Figure 3).

**Etymology.** The specific name pays homage to the twin-peaked (946 m and 960 m) Kōnāhua-nui Pu‘u (summit), the tallest peaks in the Ko‘olau Mountain range on windward (east) O‘ahu. *Lit.* Large fat innards (Pukui et al. 1974), + Latin suffix *-ensis*, indicating a place of origin or belonging. “In one story a giant threw his great testicles (*Kona hua nui*) at a woman who escaped him.” (Pukui et al. 1974). Kōnāhua-nui has significance not only because it is the highest peak in the Ko‘olau Range, but because the summit area is a largely intact native ecosystem in relative close proximity to Honolulu, the largest city in the State of Hawai‘i. To our knowledge, there has never before been a plant species named after this beautiful and biologically important locality. After seeking counsel with Hawaiian cultural practitioners Kaua Neumann and Kihei Nahale-a (pers. comm. 2014), it is proposed to give the species a Hawaiian name of *Hāhā mili‘ohu*, meaning “The *Cyanea* that is caressed by the mist”.

**Conservation.** *Cyanea konahuanuiensis* is a critically imperiled species (see Conservation status below) due to its low population numbers and exceptionally narrow endemism. Some of the conservation obstacles to overcome include probable loss of



**Figure 6.** *Cyanea konahuanuiensis*. Inflorescence/flowers illustrating dense pubescence of flowers, long calyx lobes. Pubescent leaves also apparent (photo by Chris A. Johns).

most, if not all, of its native avian pollinators and dispersers, and suspected herbivory by introduced taxa such as rats, terrestrial gastropod mollusks (slugs), and feral pigs (*Sus scrofa*). Invasive plant species are becoming increasingly common even in relatively hard to access sites along and near mountain summits in Hawai'i. Species such as *Ageratina adenophora*, *Clidemia hirta*, *Erigeron karvinskianus*, *Hedychium gardnerianum*, *Rubus rosifolius* and *Setaria palmifolia* are competing with *C. konahuanuiensis* and other native species for space and resources. It is conceivable that stochastic events such as landslides, hurricanes, and flash-flooding could obliterate the majority or all of the currently known plants with a single event. Approximately 20 mature plants and several immature plants have been observed in total. Plants that were observed ranged from seedlings to reproductively mature individuals. Seedlings are scarce, however, which suggests that the population may be declining.

The Hawai'i DLNR, Division of Forestry and Wildlife (DOFAW) has largely funded this research by providing staff time to further investigate this species. The Hawai'i Plant Extinction Prevention (PEP) Program focuses on conserving and restoring plants with less than 50 known wild individuals. Because *C. konahuanuiensis* falls within that threshold, O'ahu PEP is working closely with DOFAW staff to protect this critically rare taxon. The first goal of the PEP Program is to secure seeds or propagules from each individual mature plant for *ex situ* germplasm banking. The long-term goal for the PEP Program and DOFAW will be to collaborate in the effort to grow and out-



**Figure 7.** *Cyanea konahuaniensis*. Solitary stem illustrating typical leaf arrangement clustered distally near the stem terminus (photo by Chris A. Johns).

plant nursery stock into appropriate restoration sites. Currently there are no protected (fenced) areas in similar habitat with comparable elevation, rainfall, humidity, and species composition on O‘ahu. Our recommendation is that additional fenced out-planting sites be established in appropriate areas of the Ko‘olau Mountains in order to establish multiple populations of this species. The authors emphasize the importance of prioritizing staff time to carry out further vegetation surveys in areas that have not been explored in recent history as this exciting new find shows that even seemingly well botanized areas in Hawai‘i may yet yield new discoveries.

In October 2013, immature fruits from two plants were collected and have since germinated at the UH Harold L. Lyon Arboretum after being directly sown on an agar medium. This is valuable information since at this time all observed fruits seem to be aborting prior to maturity. We recommend collecting immature fruit (or mature fruit if possible) from all reproductive individuals during future fruiting seasons in order to secure genetic representation from all reproductively mature individuals in *ex situ* collections.



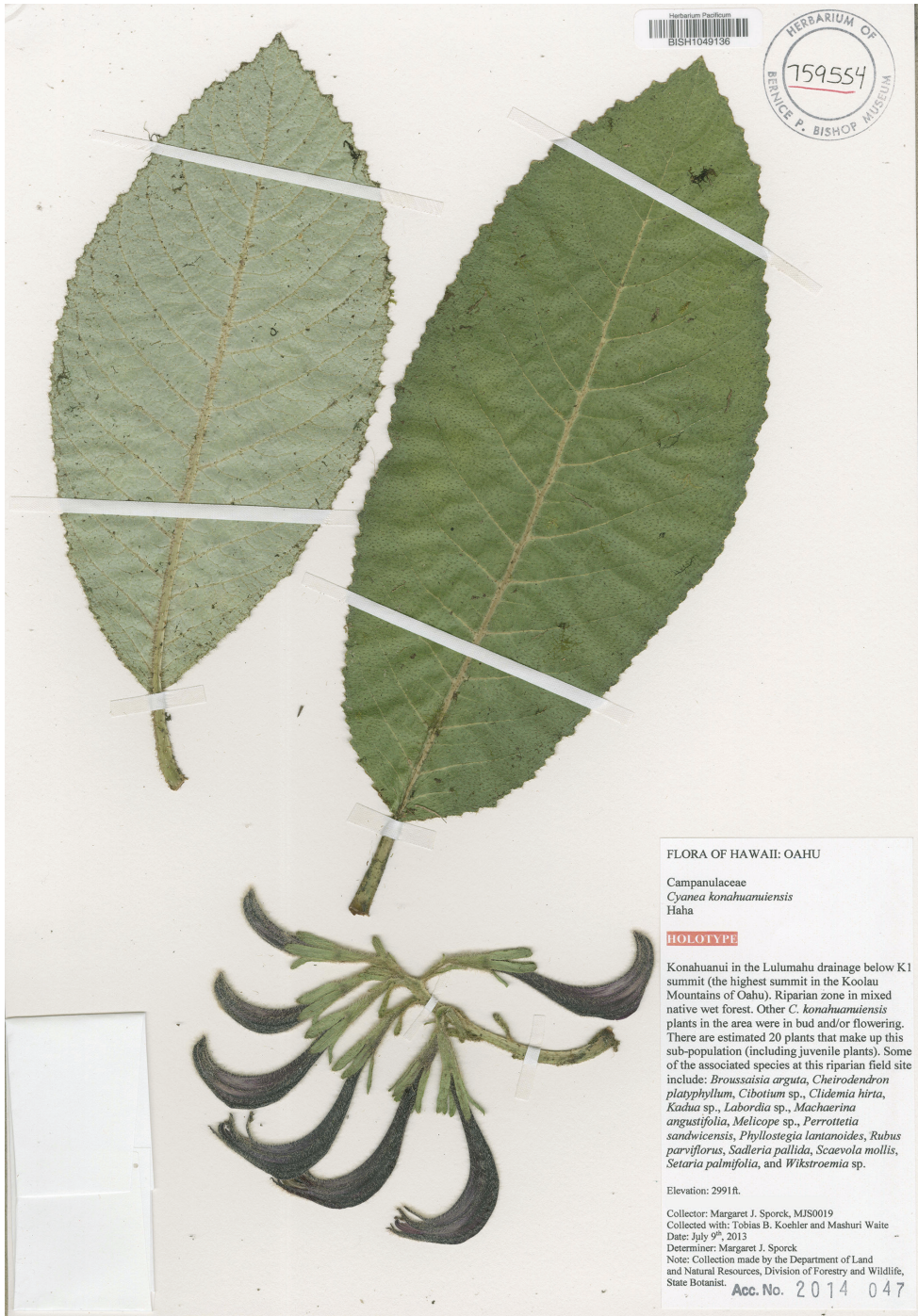
**Figure 8.** *Cyanea konahuanuiensis*. Photo of leaf illustrating dense pubescence on both adaxial and abaxial leaf surfaces (photo by Tobias B. Koehler).

The use of cellular phone-connected game cameras is recommended for monitoring of rare plants in remote locations. This novel use of game camera technology saved time and resources, optimizing the timing of visits and increasing the likelihood of making successful and representative observations required for the species description and fruit collections. This rapidly improving technology could have many positive impacts on monitoring rare plants for flower development, fruit development, herbivory impacts, and the effects of various seasonal events.

**Specimens examined.** USA. Hawaiian Islands O‘ahu [East O‘ahu]: Paratypes: dried herbarium specimen BISH 1049144; and spirit collections: BISH 1059013, BISH 1059014, and BISH 1059015.

**Discussion.** For over a century the taxa that currently comprise the genus *Cyanea* were recognized as two separate genera, *Cyanea* and *Rollandia*. The genus *Rollandia* was distinguished from *Cyanea* based on the single character of staminal column adnation to corolla in the former (Gaudichaud-Beaupré 1844; Hillebrand 1888; Lammers 1990; Rock 1919). Phylogenetic investigations of molecular data revealed that the taxa of *Rollandia* are embedded within the genus *Cyanea* (Lammers, 1993). Together with two species of *Cyanea* (*C. acuminata* and *C. grimesiana*), they form a clade referred to as the “*acuminata* clade” (Givnish et al. 1995). *Cyanea konahuanuiensis* most likely





**Figure 9.** *Cyanea konahuaniensis*. Photo of holotype (photo courtesy of Bishop Museum).

belongs in this clade based on the staminal column being adnate to the corolla tube. It is noteworthy to mention that *C. konahuanuiensis* shares close geographic proximity to several taxa of the *acuminata* clade. Eight out of the nine previously recognized *Rollandia* taxa from this clade are endemic to O‘ahu (the ninth taxon, *C. parvifolia* C. N. Forbes is only known from the type specimen collected on Kaua‘i) and six out of those eight are even more restricted, occurring only in the Ko‘olau Range. Of those six, one taxon (*C. humboldtiana*) is known to occur on the summit ridges near *C. konahuanuiensis*.

### Key to species

There is currently no published taxonomic key for *Cyanea* that includes the merger of the *Rollandia* clade. The following couplets can be inserted into the most recent revision of *Rollandia* (Lammers 1990 in Wagner et al. 1990) to separate *C. konahuanuiensis* from *C. humboldtiana*.

- 2(1) Inflorescence pendent, peduncles 50–250 mm long.....2'  
 2'(2) Upper leaf surface glabrous, calyx lobes 4–10 mm long..... *C. humboldtiana*  
 2' Upper leaf surface densely pubescent, calyx lobes 16–18 mm long.....  
 ..... *C. konahuanuiensis*

### Conservation status

Using the IUCN Red List criteria (IUCN 2012), *Cyanea konahuanuiensis* falls into the Critically Endangered (CR) category, a rank given to species facing the highest threat of extinction in the wild, fitting the following criteria defined by IUCN Red List: B1) Extent of occurrence estimated to be < 100 km<sup>2</sup> and D) number of mature individuals < 50. This species is currently known from only one population in two sub-gulches of a single stream drainage. It is our recommendation that *C. konahuanuiensis* be evaluated by the United States Fish and Wildlife Service to be added as a Candidate for listing as Endangered under the Endangered Species Act of 1973. A recovery plan should be written and implemented.

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Matthew J. Keir, Timothy I. Kroessig, Joel Q. C. Lau, Clifford W. Morden, Kihei Nahale-a, Kaua Neumann, Douglas O. Okamoto, Hank L. Oppenheimer, Richard J. Pender, Tom A. Ranker, Lara S. Reynolds, and Lauren A. Weisenberger for botanical expertise, assistance, encouragement, and thought-provoking discussions. Thank you to Yoshiko Akashi for making the species distribution map and thanks to Chris A. Johns for making a special trip to take descriptive photos. We thank Barbara H. Kennedy, the collection manager of the Bernice P. Bishop Museum herbarium (BISH) for access to specimens and assistance with preparing the Type specimens for this study and we thank the Lyon Arboretum for assistance with managing propagules that were obtained during the course of this study. This manuscript was greatly improved by suggestions from David H. Lorence (PTBG) who also provided encouragement and mentorship throughout the process from investigating the plants to writing the paper. Vicki A. Funk and Warren L. Wagner (US) are thanked for valuable suggestions on the manuscript.

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# *Syzygium pyneei* (Myrtaceae), a new critically endangered endemic species from Mauritius

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## Abstract

A new species of *Syzygium* Gaertn. (Myrtaceae), *S. pyneei* Byng, V. Florens & Baider, is described from Mondrain Reserve on the island of Mauritius. This species is endemic to the island and differs from any other species by its combination of cauliflory, relatively large flowers, light green to cream hypanthium, light pink stamens, short thick petioles, coriaceous leaves and round, cuneate or sub-cordate to cordate leaf bases. *Syzygium pyneei* Byng, V. Florens & Baider is known from only two individuals from the type locality and merits the conservation status of Critically Endangered (CR C2a(i,ii); D).

## Keywords

*Syzygium*, endemic, Mascarenes, Myrtaceae

## Introduction

*Syzygium* Gaertn. is the largest genus in Myrtaceae with about 1200 species distributed in the Old World tropics and subtropics (WCSP 2014). Scott (1990) described fourteen species native to Mauritius after which Bosser and Florens (2000) described another new *Syzygium* species, *S. guehoi* Bosser & Florens, from the island. During recent morphological and molecular work on the genus in the African-Indian Ocean

region by the first author it was noted that samples from Mondrain Reserve were quite different from any other known taxa. Therefore, the species is described here as a new species.

## Taxonomic treatment

### *Syzygium pyneei* Byng, V. Florens & Baider, sp. nov.

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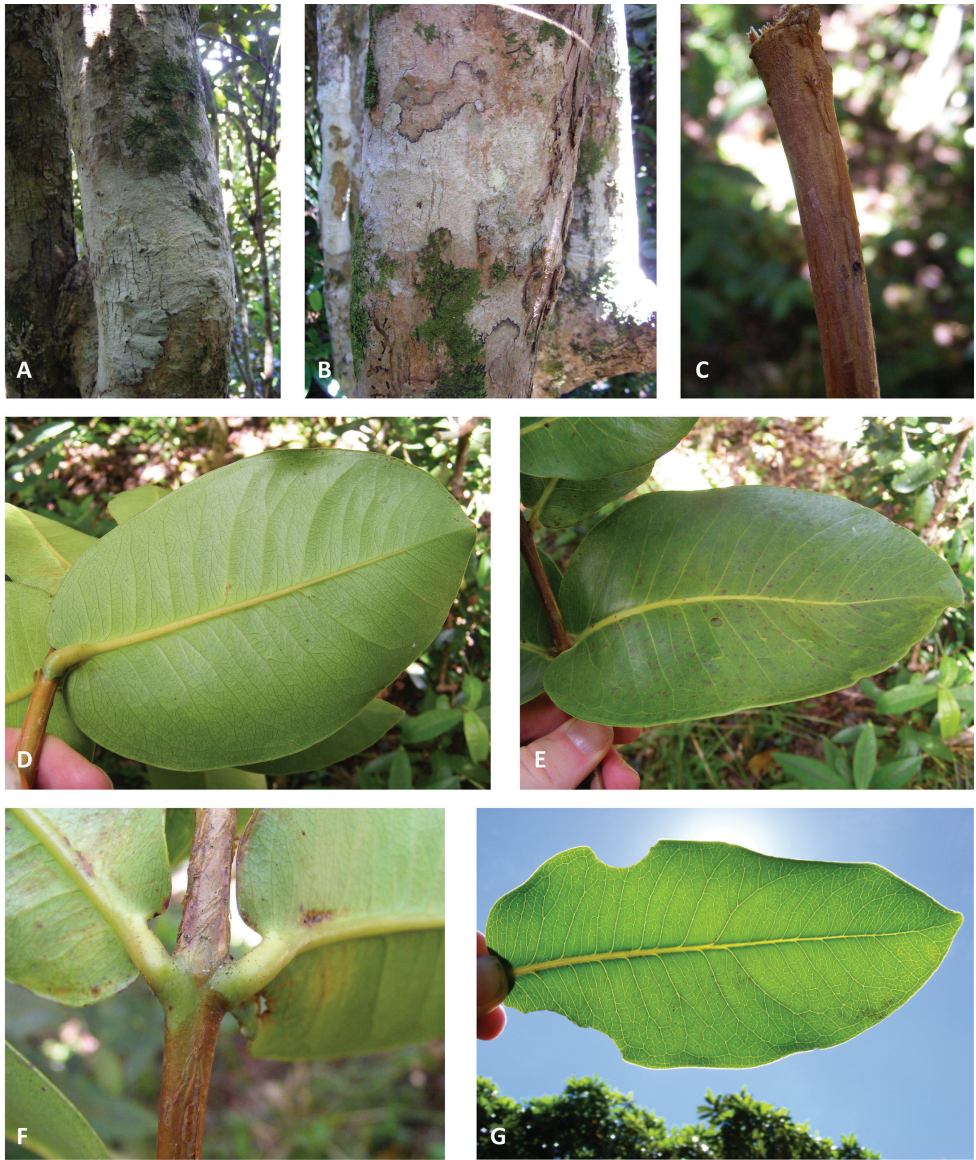
Figures 1, 2

**Type.** MAURITIUS, Mondrain Reserve, 30–35 m from main gate on left of path at 20°19.597'S; 57°27.241'E, 24 Nov 2006, G. D'Argent & K. Pynee MAU 25014 (holotype: MAU! [MAU 0014027; spirit MAU 0014029 fl.buds, fl.]).

**Diagnosis.** A cauliflorous species with relatively large flowers (> 2 cm long), light green to cream hypanthium, light pink stamens, short, thick petioles (4–8 mm long), and round, cuneate or sub-cordate to cordate leaf bases. The species could be confused with *S. mauritianum* but differs in the usually longer petioles, the variable leaf base and light green to cream hypanthium. *Syzygium pyneei* could also be confused with *S. cymosum* but differs from the latter species in the light green hypanthium, sepals 4–5 mm long and coriaceous leaves.

**Description.** Glabrous shrub to 3.5 m; bark grey to sometimes creamy-pink; branchlets terete, grey to reddish-brown. *Leaves* drying pale green above, light brown below; coriaceous, 10–15 × 4.5–9 cm, elliptic, oval-elliptic or oblong-elliptic, base round, cuneate or sub-cordate to cordate, apex acute to shortly acuminate, margin flat; 10–18 secondary vein pairs, 3–16 mm apart, prominent on both sides, tertiary veins few, faint; inner intramarginal vein 2–4 mm from leaf margin, outer intramarginal faint, 1–2 mm from leaf margin; petiole 4–8 mm long, robust, green when young, reddish-brown when old, 2–3 mm diameter. *Inflorescences* cauliflorous, ca. 6 cm long, axes terete, flowers up to 6, in clusters of 1–3; bracts and bracteoles deltoid, ca. 2 mm long, caducous. *Flowers* ca. 2 cm long; pseudostalk ca. 2 mm long; hypanthium 12–13 × 7–11 mm, pyriform, light green to cream; sepals 4–5 × 2–3 mm, obtusely triangular or obtuse; petals 8–9 × ca. 6 mm, orbicular; stamens 12–15 mm long, light pink; anthers ca. 1 mm; ovules few per locule; style 7–18 mm long. *Fruits* pyriform, 20 mm long × larger diameter 15.8–19.3 mm and smaller diameter (near calyx disc) 12.5–14 mm; colour not recorded, surface with few hairs. *Seeds* 1–2, globular when 1, half-moon shape when 2; 11.2–11.6 mm × 10.7–12.3 × 11–11.5 mm when globular or same height but 10 × 6 mm diameter when half-moon shape, testa bullate; not seen fresh.

**Flowering and fruiting.** The species was reportedly flowering for the first time in about 20 years (G. D'Argent pers. obs.) in November 2006. By 1 December 2006 most flowers (80%) were found on the ground and a few fruits were collected on 19 January 2007 after several visits monitoring the population.



**Figure 1.** Vegetative characters. **A** and **B** bark **C** close-up of branchlet **D** lower leaf surface **E** upper leaf surface **F** petioles **G** leaf venation. (**A** and **G** Byng 83; **B–F** Byng 84).

**Distribution.** This species is only known from Mauritius, and has not been recorded outside Mondrain Reserve. Only two individuals have been recorded and no seedlings have been seen.

**Ecology.** This species grows in a ridge forest, not fully exposed to sun and wind, at an elevation of around 520 m.



**Figure 2.** Floral and fruit characters. **A** and **B** Sole recorded images of flowering event **C** Close-up of dried inflorescence **D** Close-up of two fruits. (**A–C** D'Argent & Pynee MAU 25014; **D** D'Argent & K. Pynee MAU 26448; **A** and **B** courtesy of Kersley Pynee). Scale bar = 1 cm.

**Etymology.** *Syzygium pyneei* is named after Kersley Pynee who co-collected the type specimen and is a prominent local botanist.

**Additional specimens examined.** MAURITIUS, Mondrain Reserve, 10 Nov 2006, G. D'Argent & K. Pynee MAU 25013 (MAU [0014026]); 01 Dec 2006, G. D'Argent & K. Pynee MAU 26447, fl., (spirit, MAU [0014026]); 19 Jan 2007, G. D'Argent & K. Pynee MAU 26448, fr., (spirit, MAU [0014030]); 31 Mar 2011, J.W. Byng 83 (K, MAU) & 84 (E, MAU).

**Discussion.** *Syzygium pyneei* most closely resembles *S. cymosum* (Lam.) DC., and *S. mauritianum* J. Guého & A.J. Scott, sharing the cauliflorous habit, pinkish flowers and large leaves ( $\geq 10$  cm long). *S. mauritianum* individuals have sessile to very short petioles (0–5 mm long), bright pinkish-red hypanthia, usually very large leaves ((10–)17–30 cm long) and strongly cordate leaf bases, in contrast to the 5–8 mm long petioles, light green to cream hypanthium and round, cuneate or sub-cordate to



cordate leaf bases of *S. pyneei*. Scott (1990) suggested *Syzygium cymosum* was probably extinct on Mauritius, as no specimens had been collected for many years, but extant on La Réunion. Specimens of *S. pyneei* were originally thought to be related to *S. cymosum* when the flowering individual was first seen but *S. pyneei* differs by the light green to cream hypanthium (vs. light pink), sepals 4–5 mm long (vs. ca. 1 mm) and coriaceous leaves (vs. chartaceous).

In addition, molecular data (Byng unpublished data) suggests *Syzygium pyneei* is most closely related to *S. guehoi*; morphologically both species have several-flowered, cauliflorous inflorescences and are distributed on the western part of the island. However, *S. pyneei* has larger leaves, flowers and fruits and *S. guehoi* are much larger individuals, growing up to 15 m tall with conspicuous red petioles.

**Conservation status.** This species is currently known from only two individuals. The population at Mondrain is protected within a private reserve of around 5 ha, which has been cleared of invasive alien plants and fenced against alien deer. Outside the fenced area, which is potential habitat for further individuals, the forest is dominated by alien plants, notably *Psidium cattleianum* Afzel. ex Sabine, the main invader in moist to wet forests of the island and a species known to be very detrimental to native plants on Mauritius (Baider and Florens 2011; Monty et al. 2013). The reserve is adjacent to deer grazing lands to the east. *Syzygium pyneei* should be considered Critically Endangered (CR C2a(i,ii); D) according to the IUCN Red List Criteria (IUCN 2001).

## Acknowledgements

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# Notes on the genus *Chionolaena* in Colombia with a new species *Chionolaena barclayae* (Asteraceae, Gnaphalieae)

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## Abstract

A new species and a new record for *Chionolaena* are recorded from Sierra Nevada de Santa Marta, Colombia adding to the two species of the genus already known from that mountain complex.

## Keywords

*Chionolaena*, Colombia, Sierra Nevada de Santa Marta, new species

## Introduction

Specimens that had been sent to José Cuatrecasas over the years include many that have remained unidentified and were put aside for later work. One set reported here contained members of the tribe Gnaphalieae from the Sierra Nevada de Santa Marta, in northern Colombia, a still inadequately explored mountain area adjacent to but separate from the Andes. When specimens were first put aside, it was not certain to what genus they belonged. *Pseudoligandra* Dillon & Sagást. was suspected but *Chionolaena* DC. and *Gnaphaliothamnus* Kirpiczn. were possibilities. Recent publications by Freire (1993) and Nesom (2001) have totally resolved that problem by reducing all three genera to synonymy under the name *Chionolaena*. Thus, the position of the Santa Marta material is resolved, and is reinforced by some new observations.

## Results and discussion

Freire (1993) cited a number of features that were characteristic of *Chionolaena*, re-curved margins of the leaves, involucre bracts with an undivided stereome, and with spreading, pale, usually white tips on the inner bracts; heads with numerous female florets with reddish filiform corollas, the few usually bisexual florets in the centers of the heads, the connate bases of the pappus bristles and the inflated tips of the pappus bristles. Regarding the connate bases of the pappus bristles, I would offer confirmation, but connation is so short that it is easily missed. Still it is present, even in the type species of *Gnaphaliothamnus* in which Freire believed it was lacking. Nesom (2001) pointed out that the tips of the pappus bristles were not always inflated, but it should be noted that the apical cells are always blunt at the tips.

In a limited study based on hairs pulled from the leaves of numerous species, a possible unifying character has been observed. The hairs were only pulled, not dissected from the leaves, therefore the structure of the bases cannot be stated with certainty, but one feature was consistent as observed. Each hair from various *Chionolaena* species had a prominent swollen ring near the base at the point of a septation, and remnants of only one thin-walled cell was seen below the septation. This hair type is illustrated by Freire (1993) and the base is shown complete with one thin-walled cell, and one short thick-walled cell basal to that. Only one species of *Pseudognaphalium* Kirpiczn. *P. meridanum* (Aristeg.) Anderb., was tested in comparison, and the ring at the septation was much less prominent, and there were 2-3 longer thin-walled basal cells. Further studies on this are suggested.

In the monograph by Freire (1993), two species of *Chionolaena* were already recognized from The Sierra Nevada de Santa Marta, *C. chrysocoma* (Wedd.) Freire and *C. colombiana* S.F. Blake. The present study shows that two additional species of the genus occur on the mountain.

The new records of *Chionolaena* from the Sierra Nevada de Santa Marta are as follows:

### ***Chionolaena Salicifolia* (Bertol.) Nesom, SIDA 19(4): 850. 2001.**

*Helichrysum salicifolium* Bertol. Nov. Comm. Acad. Sci. Bonon. 4: 433. 1840.

*Gnaphalium seemannii* Sch.Bip. in Seemann, Not. Voy. Herald 309. 1856.

*Gnaphalium rhodanthum* Sch. Bip. in Seemann, Bot. Voy. Herald 310. 1856.

*Chionolaena corymbosa* Hemsley, Diagn. Pl. Nov. 2: 32. 1879

*Gnaphaliothamnus rhodanthus* (Sch.Bip.) Kirpiczn, Trudy Bot. Inst. Akad. Nauk SSSR, ser 1, Fl. Sist. Vyss. Rast. 9: 33. 1950 (type of *Gnaphaliothamnus*).

*Gnaphaliothamnus salicifolius* (Bertol.) Nesom, Phytologia 68: 378. 1990.

*Chionolaena seemannii* (Sch.Bip.) Freire, Ann. Missouri Bot. Gard. 80: 452. 1993.

The synonymy follows Nesom (2001) rearranged according to order of publication. Specimens from Santa Marta are as follows:

**Colombia.** Depto. Magdalena, Sierra Nevada de Santa Marta, on trail above San Pedro de la Sierra. Paramo 3900 m, small terrestrial herb, 29 Dec, 1974, ; *R.J. Robins & E.J. Kirby 618A* (Fielding Herbarium, OXF). *R.J. Robins 618B* (OXF, frag US)

The specimens differ from Mexican and Central American material examined of the species only in having glabrous achenes.

***Chionolaena barclayae* H. Rob., sp. nov.**

urn:lsid:ipni.org:names:77145081-1

**Type. Colombia.** Depto. Magdalena. Sierra Nevada de Santa Marta; alrededores de cabeceras de Río Ancho; Páramo de Macotama, above and west of second lake; above valley of Río Ancho, Sta. 15, alt. 4900-5000 m. On high outcrops of bedrock. Shrub, erect stems branching from woody base, to 20 cm tall, entire stem and leaves and involucre gray, hairy, heads yellowish, dry. 17 Feb. 1959. *Harriet G. Barclay & Pedro Juajibioy 7072* (holotype US, isotype COL).

**Description.** Small shrubs to 20 cm tall. Stems branched distally. Leaves alternate, imbricated, appressed, broadly inserted and membranous at base; blade oblong. 4 mm long by ca. 1.5 mm wide, coriaceous with narrowly recurved margins, dark green, covered with pale hairs on both surfaces, longer and more yellowish abaxially, abaxial pubescence dense and giving abaxial leaf surface rounded appearance, completely obscuring leaf margins, apex blunt. Inflorescence of mostly 1–3 heads at tips of unattenuated branches; heads hemispheric, ca. 7 mm high, to 4 mm wide; pale-tipped involucre bracts ca. 15, narrowly lanceolate, 4–5 mm long. ca. 0.8 mm wide. with distal ca. 1.5 mm usually reflexed and whitish inside, pale pink outside; peripheral functionally female florets ca. 20 or more; corollas reddish, filiform, ca. 3.5 mm long, with pair of minute lobes and small biseriate glands distally; style base enlarged, distal branches filiform, scarcely roughened; achenes ca. 1 mm long; glabrous; pappus bristles ca. 28–30, ca. 4 mm long, bases connate in basal row of cells, tips not or scarcely broadened, apical cells with blunt tips; bisexual florets 3–6; corollas reddish, narrowly funnelform, ca. 3.5 mm long, distally with 5 lanceolate lobes ca. 0.5 mm long; anther thecae ca. 0.7 mm long, with long basal tails, apical appendage oblong-lanceolate, ca. 0.5 mm long, glabrous; style base enlarged, distal branches narrowly lanceolate. acute at tip, papillose on sides and apex; achene ca. 1 mm long, glabrous; pappus bristles ca. 28, connate in basal row of cells, distally broadened with bulging cells.

The species is known only from the single collection by Harriet Barkley and Juajibioy. The species is evidently closest to *Chionolaena chrysocoma*, also from Santa Marta, which also has appressed imbricated leaves. The new species has much broader leaves with dense pubescence abaxially that makes the abaxial surface seem rounded and completely hides the recurved leaf margins. Although the collector stated the heads were yellowish, the bracts and corollas seem reddish or pink. The differentiated tips of the involucre bracts seem less white than in other members of the genus.

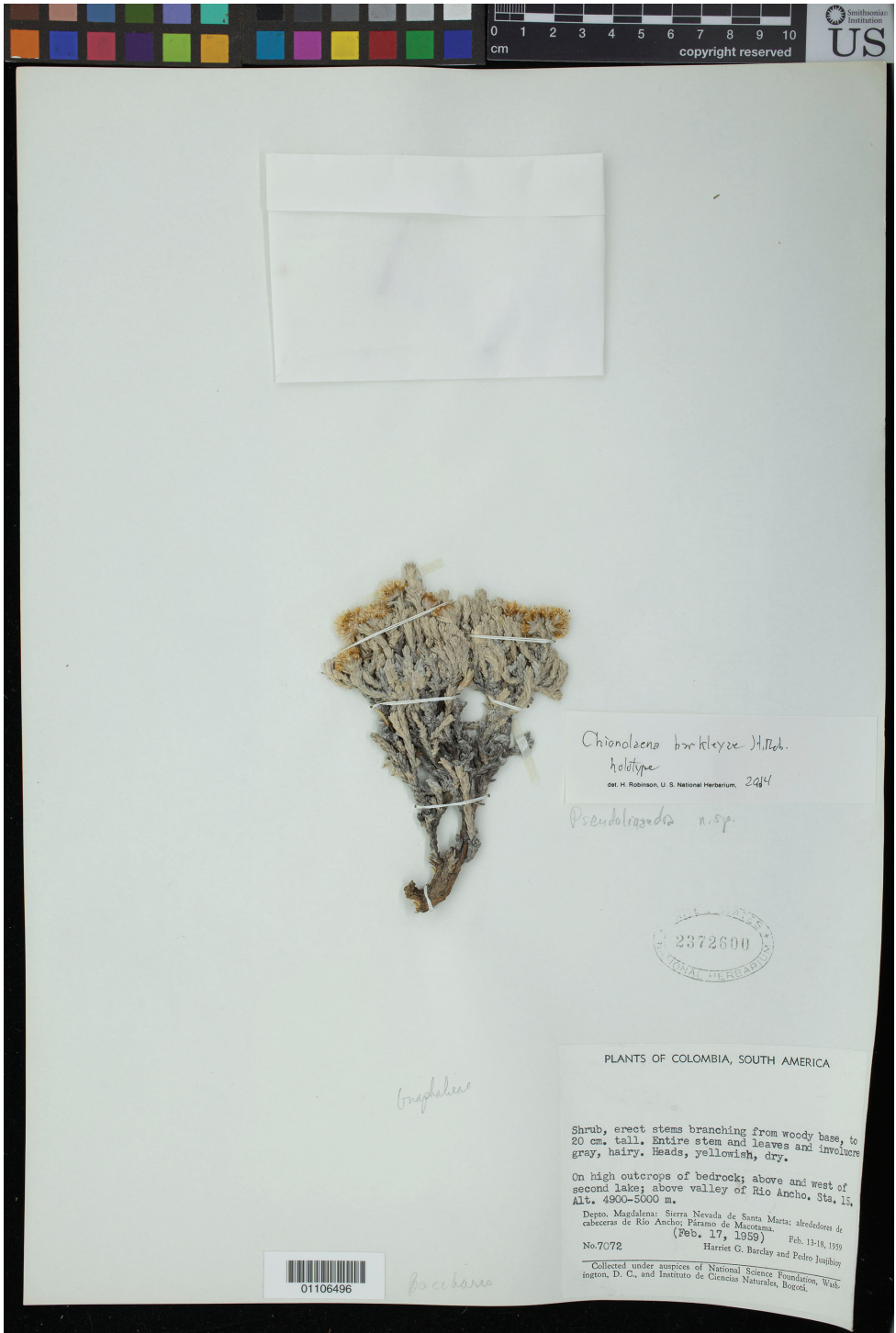


Figure 1. Holotype of *Chionolaena barclayae* H. Rob., *Barclay & Jujubio* 7072 (US).

The habit of the new species somewhat resembles that of *Chionolaena costaricensis* (Nesom) Nesom, but the Costa Rican species has much less densely pubescent leaves that are most often spreading rather than appressed to the stem.

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# Changes in the circumscription of *Deprea* (Physalideae, Solanaceae): thirty two new combinations

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## Abstract

According to the latest phylogenetic and cytogenetic results, *Larnax* and *Deprea* should be merged in order to form a natural group. Consequently, we propose 32 combinations of *Larnax* species names under *Deprea*: *D. abra-patriciae* (S.Leiva & Barboza) S.Leiva & Deanna, **comb. nov.**, *D. altomayoensis* (S.Leiva & Quip.) Barboza & Deanna, **comb. nov.**, *D. andersonii* (N.W.Sawyer) Deanna & S.Leiva, **comb. nov.**, *D. bongaraensis* (S.Leiva) Deanna & Barboza, **comb. nov.**, *D. chotanae* (S.Leiva, Pereyra & Barboza) S.Leiva, **comb. nov.**, *D. darciana* (N.W.Sawyer) Barboza & S.Leiva, **comb. nov.**, *D. dilloniana* (S.Leiva, Quip. & N.W.Sawyer) Barboza, **comb. nov.**, *D. grandiflora* (N.W.Sawyer & S.Leiva) Deanna & Barboza, **comb. nov.**, *D. harlingiana* (Hunz. & Barboza) S.Leiva & Deanna, **comb. nov.**, *D. hawkesii* (Hunz.) Deanna, **comb. nov.**, *D. kann-rasmussenii* (S.Leiva & Quip.) S.Leiva & Barboza, **comb. nov.**, *D. longipedunculata* (S.Leiva, E.Rodr. & J.Campos) Barboza, **comb. nov.**, *D. lutea* (S.Leiva) Deanna, **comb. nov.**, *D. macasiana* (Deanna, S.Leiva & Barboza) Barboza, **comb. nov.**, *D. maculatifolia* (E.Rodr. & S.Leiva) S. Leiva, **comb. nov.**, *D. nieva* (S.Leiva & N.W.Sawyer) Barboza & Deanna, **comb. nov.**, *D. parviflora* (N.W.Sawyer & S.Leiva) S.Leiva, **comb. nov.**, *D. pedrazae* (S.Leiva & Barboza) Deanna & S.Leiva, **comb. nov.**, *D. peruviana* (Zahlbr.) S.Leiva & Barboza, **comb. nov.**, *D. pilosa* (S.Leiva, E.Rodr. & J.Campos) Deanna, **comb. nov.**, *D. pomacochaensis* (S.Leiva) Barboza, **comb. nov.**, *D. psilophyta* (N.W.Sawyer) S.Leiva & Deanna, **comb. nov.**, *D. pumila* (S.Leiva, Barboza & Deanna) S.Leiva, **comb. nov.**, *D. purpurea* (S.Leiva) Barboza & S.Leiva, **comb. nov.**, *D. purpureocarpa* (S.Leiva, Deanna & Barboza) Deanna, **comb. nov.**, *D. sachapapa* (Hunz.) S.Leiva & Deanna, **comb. nov.**, *D. sagasteguii* (S.Leiva, Quip. & N. W.Sawyer) Barboza, **comb. nov.**, *D. sawyeriana* (S.Leiva, E.Rodr. & J.Campos) S.Leiva, **comb. nov.**, *D. schjellerupiae* (S.Leiva & Quip.) Barboza & Deanna, **comb. nov.**, *D. steyermarkii* (Hunz.) S.Leiva & Barboza, **comb. nov.**, *D. toledoana* (Barboza & S.Leiva) Barboza, **comb. nov.**, and *D. vasquezii* (S.Leiva, E.Rodr. & J.Campos) Deanna, **comb. nov.**

## Keywords

*Deprea*, new combinations, Solanaceae, *Larnax*

## Introduction

*Larnax* Miers and *Deprea* Raf. are two closely related genera of Physalideae tribe (Solanaceae) that include 35 and 10 species, respectively. Both genera are restricted to the neotropics mainly inhabiting pre-montane and montane cloud forest from Bolivia to Costa Rica. Both *Larnax* and *Deprea* include species ranging from herbs to small trees with funnel-shaped to stellate corollas, but always with accrescent fruiting calyces tightly or loosely enclosing the berries (Sawyer 2005, Deanna et al. 2014a). The main centre of diversity for both genera is Peru and Ecuador (Leiva González et al. 2008, Deanna et al. 2014a, Jørgensen and León-Yáñez 1999). Only one taxon extends north into Central America [*L. sylvarum* subsp. *sylvarum* (Standl. & C.V.Morton) N.W.Sawyer, Sawyer 2001] and one species is found at the south of their range in Bolivia [*L. subtriflora* (Ruiz & Pav.) Miers, Leiva González et al. 2013].

*Deprea* and *Larnax* are interesting for their chemical and medicinal value (Cardona et al. 2005, Misico et al. 2011, Casero et al. 2015), but also for their controversial circumscription and position within the Physalideae tribe (Olmstead et al. 2008, Särkinen et al. 2013, Carrizo García et al. submitted). Various authors have transferred species between the two genera for many years (Miers 1849, D’Arcy 1973, 1993, Sawyer 2001, Leiva González et al. 2005) and redefined their limits (Hunziker 2001, Sawyer 2005). Sawyer (2005) differentiated *Deprea* and *Larnax* based on six characters (filament base expansion, filament length, filament adnation, anther length, corolla shape, and pollen surface texture) according to morphological cladistic work, although some characters overlap in the two genera. Moreover, Sawyer (1999) obtained ambiguous results when attempting to set apart these genera using DNA sequence data in cladistic analysis, and the most recent phylogenetic analysis of the family (Särkinen et al. 2013) suggests they are not monophyletic.

Here we deal with the new circumscription of the two genera under *Deprea* and the consequent new combinations of *Larnax* based on recent phylogenetic evidence that show *Deprea* and *Larnax* to be monophyletic when their species are merged (100% bootstrap support), where species, as *L. sachapapa* Hunz., are resolved nested within a group of *Deprea* species, or vice versa (Carrizo et al. submitted). The phylogenetic evidence is further supported by results from recent extensive field collecting and taxonomic work which have shown that characters utilized to distinguish the two genera are not useful, and increasing number of species are found to have intermediate features between the two genera (see Table 1, Deanna et al. 2014b; Carrizo et al. submitted). Consequently, this paper synonymises *Larnax* under *Deprea*, expands the morphological circumscription of *Deprea*, and transfers the remaining *Larnax* species to *Deprea*, presenting all 32 new combinations, and a list of all currently accepted 45 names in *Deprea*. Type specimens are also cited with their corresponding barcode number if it is available or their sheet number where it is not (HUT, QCA, QCNE, QUSF, and W).

**Table 1.** Characters used to delimit *Larnax* and *Deprea* according to Barboza and Hunziker (1994), Leiva González et al. (2005), and Sawyer (2005), and Sawyer (2005), contrasting with type species of each genera and species recently described having intermediate features (marked in bold).

Character	<i>Deprea orinocensis</i> *(type species)	<i>Larnax subtriflora</i> *(type species)	<i>Deprea zamorae</i> Barboza & S.Leiva*	<i>Larnax pedrazae</i> S.Leiva & Barboza	<i>Deprea</i> sp. nov. (Deanna & Leiva 138)
Corolla shape	Funnel-shaped	Stellate	Narrowly campanulate	Stellate	Campanulate
Ratio corolla lobes/ corolla tube	0.4–0.9	2.8–3.3	(1–) 1.2–1.5	1–1.2	<b>0.8–1</b>
Filament length**	Equal	Equal	<b>Equal or slightly unequal</b>	Equal	Equal
Filament base expansion**	Gradually expanded	Gradually expanded	<b>Abruptly expanded</b>	Abruptly expanded	Abruptly expanded
Filament adnation	4.1±0.7	1.3±0.3	<b>1.7±0.2</b>	1.5±0.2	1±0.2
Anther length	Equal	Subequal	Equal	<b>Slightly unequal</b>	Subequal
Mucron in anthers**	Absent	Absent	Absent	Absent	Present
Annular ring of hairs on the inner corolla**	Present	Present	Present	Absent	Absent
Pollen surface texture	Unknown	Dense, minutely microechinate	Widely sparse, minutely microechinate	Unknown	Unknown

\* species included in the phylogenetic analysis (Carrizo et al. submitted)

\*\* characters which overlap in type species

## Systematics

### **Deprea Raf., Sylva Tellur. 57. 1838.**

*Larnax* Miers, Ann. Mag. Nat. Hist., ser. 2 (4): 37. 1849, **syn. nov.**

**Type.** *Deprea orinocensis* (Kunth) Raf. (Lectotype species, designated in D’Arcy 1973 [1974]. Flora of Panama, Part IX. Family 170. Solanaceae. Ann. Missouri Bot. Gard. 60 (3): 624).

Erect shrubs to small trees with spreading branches, exceptionally herbs with axillary inflorescences generally with three to 15 flowers per node, calyx lobes minute or short, exceptionally long and narrowly triangular, corolla funnel-shaped to stellate, stamen petalum broadening gradually to abruptly in width basipetally, with or without auricles, anthers dorsifixed, generally exerted and mucronate, ovary glabrous, fruiting calyx always accrescent, enveloping the fleshy berry tightly or loosely.

### ***Deprea abra-patriciae* (S.Leiva & Barboza) S.Leiva & Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145416-1

Basionym: *Larnax abra-patriciae* S.Leiva & Barboza, Araldoa 16(1): 30. 2009.

**Type.** PERU. Amazonas: Bongará, Área de Conservación Privada Abra Patricia-Alto Nieva, km 364–365, carretera Fernando Belaunde Terry, 2250 m, 5°41'28.2"S, 77°48'41.1"W, 16 May 2009 (fl, fr), *S.Leiva 4561* (lectotype, designated in Deanna et al. 2014a, pg. 19: Leiva González & Barboza, Araldoa 16(1): 32. Fig. 1. 2009).

### ***Deprea altomayoensis* (S.Leiva & Quip.) Barboza & Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145417-1

Basionym: *Larnax altomayoensis* S.Leiva & Quip., Araldoa 15 (2): 199. 2009 [2008 publ. Jan 2009].

**Type.** PERU. San Martin: Rioja, Bosque de Protección de Alto Mayo, 1010 m, 5°40'11.5"S, 77°37'48.5"W, 24 July 2008 (fl, fr), *S.Leiva, M.Zapata & V.Quipuscoa 4480* (lectotype, designated in Deanna et al. 2014a, pg. 21: Leiva González, Pereyra Villanueva & Barboza, Araldoa 15(2): 200. Fig. 1. 2008).

***Deprea andersonii* (N.W.Sawyer) Deanna & S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145432-1

Basionym: *Larnax andersonii* N.W.Sawyer, Novon 8 (1): 72. 1998.

**Type.** ECUADOR. Napo: km 25 of Hollín-Loreto road, finca entrance next to bridge over a quebrada in secondary pluvial forest, 950 m, 00°40'S, 77°40'W, 1 July 1995 (fl, fr), *N.W.Sawyer & M.Tirado 714* (holotype: MO n.v.; isotypes: CONN! [00054622], QCNE! [105520], US n.v.).

***Deprea bongaraensis* (S.Leiva) Deanna & Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145418-1

Basionym: *Larnax bongaraensis* S.Leiva, Araldoa 13 (2): 292. 2006.

**Type.** PERU. Amazonas: Bongará, km 328–329, carretera Pomacochas-Nuevo Cajamarca, arriba de laguna Pomacochas, 2400 m, 5 Feb 2006 (fl, fr), *S.Leiva 3543* (lectotype, designated in Deanna et al. 2014a, pg. 21: Leiva González & Rodríguez Rodríguez, Araldoa 13(2): 293. Fig. 1. 2006).

***Deprea chotanae* (S.Leiva, Pereyra & Barboza) S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145419-1

Basionym: *Larnax chotanae* S.Leiva, Pereyra & Barboza, Araldoa 15 (2): 203. 2008.

**Type.** PERU. Cajamarca: Chota, Bosque El Pargo, 3050 m, 30 Sep 2004 (fl, fr), *S.Leiva & J.Guevara 2883* (lectotype, designated in Deanna et al. 2014a, pg. 21: Leiva González, Pereyra Villanueva & Barboza, Araldoa 15(2): 204. Fig. 3. 2008).

***Deprea darcyana* (N.W. Sawyer) Barboza & S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145433-1

Basionym: *Larnax darcyana* N.W.Sawyer, Novon 11 (4): 463. 2001.

**Type.** COLOMBIA. Huila: forest around Mehrenberg, road from Popayan, 2350 m, 6 July 1984 (fl, fr), *W.G.D'Arcy, A.Gentry, M.Monsalve & P.Silverstone 15626* (holotype: MO n.v.; isotype: CONN! [00054625]).

***Deprea dilloniana* (S.Leiva, Quip. & N.W.Sawyer) Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145420-1

Basionym: *Larnax dilloniana* S.Leiva, Quip. & N.W.Sawyer, *Arnaldoa* 5 (1): 85. 1998.

**Type.** PERU. San Martín: Rioja, arriba del poblado Miraflores (ca. Nueva Cajamarca), 1260–1420 m, 3 Nov 1996 (fl, fr), *S.Leiva, M.Dillon, I.Sánchez, V.Quipuscoa & P.Lezama 1919* (lectotype, designated in Deanna et al. 2014a, pg. 21: CONN! [00066074]; isolectotypes: CONN! [00066075, 00168924!], CORD! [00004043], F! [2183234], HUT! [031930], MO! [05097641]).

***Deprea grandiflora* (N.W.Sawyer & S.Leiva) Deanna & Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145434-1

Basionym: *Larnax grandiflora* N.W.Sawyer & S.Leiva, *Novon* 11 (4): 463. 2001.

**Type.** PERU. Cajamarca: San Ignacio, in forest along road from San Martín to El Chaupe, 1700 m, 05°11'S, 79°03'W, 26 June 1997 (fl, fr), *N.W.Sawyer 827* (holotype: NY!; isotypes: CONN! [00054628], MO n.v.).

***Deprea harlingiana* (Hunz. & Barboza) S.Leiva & Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145435-1

Basionym: *Larnax harlingiana* Hunz. & Barboza, *Kurtziana* 24: 157. 1995.

**Type.** ECUADOR. Zamora-Chinchipe: Nudo de Sabanilla, E slope c. 5 km from pass on road Yanganá-Valladolid, 2700 m, 4 Apr 1985 (fl, fr), *G.Harling & L.Andersson 23646* (holotype: GB! [0008131]; isotypes: CORD! [00006738], QCA! [156713]).

***Deprea hawkesii* (Hunz.) Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145436-1

Basionym: *Larnax hawkesii* Hunz., *Kurtziana* 10: 9. 1977.

**Type.** COLOMBIA. Huila: Carretera a La Plata, región de Moscopán, Santa Leticia, 2230 m, 21 July 1948 (fl, fr), *H.García-Barriga & J.C.Hawkes 12919* (holotype: US! [00385927]; isotypes: COL! [000004223, 000004224]).

***Deprea kann-rasmussenii* (S.Leiva & Quip.) S.Leiva & Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145437-1

Basionym: *Larnax kann-rasmussenii* S.Leiva & Quip., *Arnaldoa* 9 (1): 29. 2002 [2003].

**Type.** PERU. San Martín: Huallaga, entre La Ribera y Añazco Pueblo, 1850 m, 1 Sep 2000 (fl, fr), 06°84.705'S 77°48.440'W, *S.Leiva & V.Quipuscoa 2470* (lectotype, designated in Deanna et al. 2014a, pg. 23: HUT! [40031, two sheets]).

***Deprea longipedunculata* (S.Leiva, E.Rodr. & J.Campos) Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145438-1

Basionym: *Larnax longipedunculata* S.Leiva, E.Rodr. & J.Campos, *Arnaldoa* 5 (2): 194. 1998.

**Type.** PERU. Cajamarca: San Ignacio, Caserío La Bermeja, bosques de neblina La Bermeja, Dist. Tabaconas, 1830 m, 4 Jan 1998 (fl, fr), *S.Leiva, J.Campos & E.Rodríguez Rodríguez 2098* (lectotype, designated in Deanna et al. 2014a, pg. 25: CONN! [00055675]; isolectotypes: CORD! [00004044], F! [2198658], HUT! [031885], MO! [04906479]).

***Deprea lutea* (S.Leiva) Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145439-1

Basionym: *Larnax lutea* S.Leiva, *Arnaldoa* 4 (1): 19. 1996.

**Type.** PERU. Cajamarca: Chota, 1 km del poblado de Paraguay (Querocoto-La Granja), 2250 m, 7 Aug 1994 (fl, fr), *S.Leiva González, P.Chuna & J.Cadle 1385* (lectotype, designated in Deanna et al. 2014a, pg. 25: CORD! [00004045]; isolectotype: F! [2177616]).

***Deprea macasiana* (Deanna, S.Leiva & Barboza) Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145421-1

Basionym: *Larnax macasiana* Deanna, S.Leiva & Barboza, *Phytotaxa* 167 (1): 3. 2014.

**Type.** ECUADOR. Morona Santiago: Macas, Cerro San José del Quílamo, 500 m antes de la Virgen Purísima de Macas en el Quílamo, 1369 m, 78°08'19.3"W 02°17'45.4"S, 23 Jan 2013 (fl, fr), *R.Deanna & S.Leiva 111* (holotype: QUSF! [29472]; isotypes: CORD! [00006797, 00006799], HAO!, QUSF! [29480]).

***Deprea maculatifolia* (E.Rodr. & S.Leiva) S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145422-1

Basionym: *Larnax maculatifolia* E.Rodr. & S.Leiva, *Arnaldoa* 9 (2): 102. 2003.

**Type.** PERU. Amazonas: Bagua, Imaza, Comunidad Aguaruna de Yamayakat, 390 m, 10 Jan 2001 (fl, fr), *E.Rodríguez Rodríguez, S.Leiva & R.Apanu 2384* (holotype: HUT! [38027]; isotypes: MO! [5763266], USM! [000899]).

***Deprea nieva* (S.Leiva & N.W.Sawyer) Barboza & Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145440-1

Basionym: *Larnax nieva* S.Leiva & N.W.Sawyer, *Arnaldoa* 10 (1): 106. 2003.

**Type.** PERU. Amazonas: Bongará, km 384 carretera Nueva Cajamarca-Pomacochas (Florida), 2000 m, 05.41 S, 77.46 W, 12 June 1997 (fl, fr), *S.Leiva & N.W.Sawyer 2045* (lectotype, designated in Deanna et al. 2014a, pg. 25: Leiva González & Barboza, *Arnaldoa* 16(1): 32. Fig. 1. 2009).

***Deprea parviflora* (N.W.Sawyer & S.Leiva) S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145441-1

Basionym: *Larnax parviflora* N.W.Sawyer & S.Leiva, *Novon* 11 (4): 466. 2001.

**Type.** PERU. Cajamarca: Cutervo, Bosque Cutervo, Parque Nacional Cutervo, NW border of Cordillera Tarros, Chorro Blanco sector, ca. 10 km WNW of San Andres de Cutervo, ca. 2650 m, 6°12'S, 78°46'W, 4 Nov 1990 (fl), *M.O.Dillon, I.Sanchez V. & J.Guevara B. 6141* (holotype: F! [2059067]; isotype: CONN! [00168928]).

***Deprea pedrazae* (S.Leiva & Barboza) Deanna & S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145423-1

Basionym: *Larnax pedrazae* S.Leiva & Barboza, *Arnaldoa* 16 (2): 14. 2009.

**Type.** PERU. Amazonas: Bagua, La Peca, Puente El Arenal (ruta La Peca-El Arenal), 1170 m, 5°35'27.2"S, 78°24'20.8"W, 12 Oct 2009 (fl, fr), *S.Leiva, M.Zapata & G.Gayoso 4579* (lectotype, designated in Deanna et al. 2014a, pg. 25: Leiva González, Bravi & Barboza, *Arnaldoa* 16(2): 16. Fig. 1. 2009).



***Deprea peruviana* (Zahlbr.) S.Leiva & Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145424-1

Basionym: *Athenaea peruviana* Zahlbr., Ann. K. K. Naturhist. Hofmus. 7 (1–2): 7–8. 1892. *Larnax peruviana* (Zahlbr.) Hunz., Kurtziana 10: 9. 1977.

**Type.** [PERU. Cajamarca: Cutervo, La Ramada]. Tambillo, 29 July 1878 (fl, fr), *C. de Jelski 54* (lectotype, designated in Deanna et al. 2014a, pg. 25: W! [1891-0004186]).

***Deprea pilosa* (S.Leiva, E.Rodr. & J.Campos) Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145442-1

Basionym: *Larnax pilosa* S.Leiva, E.Rodr. & J.Campos, Arnaldoa 5 (2): 200. 1998.

**Type.** PERU. Cajamarca: San Ignacio, San José de Lourdes, Estrella del Oriente, borde de camino, 1600 m, 8 Jan 1998 (fl, fr), *S. Leiva, J. Campos & E. Rodríguez 2108* (lectotype, designated in Deanna et al. 2014a, pg. 26: CONN! [00051759]); isolectotypes: CORD! [00004047], F! [2198655], HUT! [031894], M! [M-0171580], MO! [04908631], NY! [00328792], USM! [000900]).

***Deprea pomacochaensis* (S.Leiva) Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145425-1

Basionym: *Larnax pomacochaensis* S.Leiva, Arnaldoa 13 (2): 299. 2006.

**Type.** PERU: Amazonas: Bongará, km 328–329 carretera Bongará-Nueva Cajamarca, arriba de laguna Pomacochas, 2400 m, 5 Feb 2006 (fl, fr), *S.Leiva 3542* (lectotype, designated in Deanna et al. 2014a, pg. 28: Leiva González & Rodríguez Rodríguez, Arnaldoa 13(2): 300. Fig. 5. 2006).

***Deprea psilophyta* (N.W.Sawyer) S.Leiva & Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145443-1

Basionym: *Larnax psilophyta* N.W.Sawyer, Novon 8 (1): 74. 1998.

**Type.** ECUADOR. Zamora-Chinchipec: Nudo de Sabanilla, pass on road from Yanganá to Valladolid, elfin forest and clearings, 2800–2900 m, 5 Apr 1985 (fl, fr), *G.W.Harling & L.Andersson 23724* (holotype: NY! [00312927]; isotype: QCA! [95-13/83]).

***Deprea pumila* (S.Leiva, Barboza & Deanna) S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145426-1

Basionym: *Larnax pumila* S.Leiva, Barboza & Deanna, *Phytotaxa* 167 (1): 8. 2014.

**Type.** ECUADOR. Pastaza: Mera, rumbo hacia Río Anzú, sendero, 1340 m, 78°04'01.5"W, 01°25'31.6"S, 13 Nov 2011 (fl, fr), *C.I.Orozco, G.E.Barboza, A.Orejuela & S.Leiva 3890* (holotype: CORD! [0006758]; isotypes: COL!, QCA!).

***Deprea purpurea* (S.Leiva) Barboza & S.Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145444-1

Basionym: *Larnax purpurea* S.Leiva, *Arnaldoa* 4 (1): 16. 1996.

**Type.** PERU. Cajamarca: San Ignacio, Ruta San Ignacio-El Chaupe, riachuelo, entre abundantes arbustos, 1510 m, 4 Jan 1995 (fl, fr), *S.Leiva G., P.Lezama A. & P.Chuna 1560* (lectotype, designated in Deanna et al. 2014a, pg. 29: CORD! [00004049]; isolectotypes: F! [2177617], HUT! [031931], MO! [05077371], NY! [00076787], USM! [000901]).

***Deprea purpureocarpa* (S.Leiva, Deanna & Barboza) Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145427-1

Basionym: *Larnax purpureocarpa* S.Leiva, Deanna & Barboza, *Phytotaxa* 167 (1): 12. 2014.

**Type.** ECUADOR. Napo: carretera Cosanga-Baeza, 5.4 km al sur de Baeza, en borde de carretera, 1855 m, 77°52'20.2"W, 00°28'34.2"S, 25 Jan 2013 (fl, fr), *R.Deanna & S.Leiva 125* (holotype: QCNE! [0233491]; isotypes: CORD! [00006800], HAO!).

***Deprea sachapapa* (Hunz.) S.Leiva & Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145445-1

Basionym: *Larnax sachapapa* Hunz., *Kurtziana* 10: 13–15. 1977.

**Type.** ECUADOR. Azuay: between Cruz Pamba and Loma de Canela, in region of Río Sadracay, tributary of Río Mehuir, north of Molleturo, in Cinchona forest, 2315–2500 m, 12 June 1943 (fl, fr), *J.A.Steyermark 52965* (holotype: VEN! [119697]; isotypes: CORD! [00006739], F! [1276519]).

***Deprea sagasteguii* (S.Leiva, Quip. & N.W.Sawyer) Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145428-1

Basionym: *Larnax sagasteguii* S.Leiva, Quip. & N.W.Sawyer, *Arnaldoa* 5 (1): 86–89. 1998.

**Type.** PERU. Piura: Ayabaca, Cerro Aypate, 2800–2880 m, 4°42.94'S, 79°34.25'W, 23 May 1996 (fl, fr), *V.Quipuscoa* S., *O.Angulo* Z. & *R.Yahuana* 601 (lectotype designated in Deanna et al. 2014a, pg. 30: HUT! [031934]).

***Deprea sawyeriana* (S.Leiva, E.Rodr. & J.Campos) S. Leiva, comb. nov.**

urn:lsid:ipni.org:names:77145446-1

Basionym: *Larnax sawyeriana* S.Leiva, E.Rodr. & J.Campos, *Arnaldoa* 5 (2): 203. 1998.

**Type.** PERU. Cajamarca: San Ignacio, Caserío La Bermeja, bosques de neblina La Bermeja, Dist. Tabaconas, 1830 m, 4 Jan 1998 (fl, fr), *S.Leiva*, *J.Campos* & *E.Rodríguez* 2097 (lectotype, designated in Deanna et al. 2014a, pg. 31: HUT! [031884]; isolectotypes: CONN! [00055668], CORD! [00004051], F! [2198659], MO! [04906480]).

***Deprea schjellerupiae* (S.Leiva & Quip.) Barboza & Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145447-1

Basionym: *Larnax schjellerupiae* S.Leiva & Quip., *Arnaldoa* 9 (1): 32. 2002 [2003].

**Type.** PERU. San Martin: Huallaga, La Fila, entre Añazco Pueblo y Leguía, 2000 m, 10 Sep 2000 (fr), *S.Leiva* & *V.Quipuscoa* 2479 (lectotype, designated in Deanna et al. 2014a, pg. 31: HUT! [40030]).

***Deprea steyermarkii* (Hunz.) S.Leiva & Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145448-1

Basionym: *Larnax steyermarkii* Hunz., *Kurtziana* 10: 11. 1977.

**Type.** ECUADOR. Zamora: Arenillas, at junction of río Santa Bárbara and río Tintas, between Ca mpanas and Arenillas, southeast of El Pan, 2195 m, 13 July 1943 (fl, fr), *J.A.Steyermark* 53535 (holotype: VEN! [119698]; isotypes: CORD!, F! [1276523, 1739588]).

***Deprea toledoana* (Barboza & S.Leiva) Barboza, comb. nov.**

urn:lsid:ipni.org:names:77145429-1

Basionym: *Larnax toledoana* Barboza & S.Leiva, *Phytotaxa* 167 (1): 16. 2014.

**Type.** ECUADOR. Zamora-Chinchipe: [Cerro Toledo], rumbo a Valladolid desde Yanganá, al costado de la ruta, 2690 m, 79°08'52.7"W, 04°26'30.7"S, 16 Nov 2011 (fl, fr), *C.I.Orozco, G.E.Barboza, A.Orejuela & S.Leiva 3936* (holotype: QCA!; isotypes: CORD! [00006769, 00006770, 00006771], COLI, HAO!).

***Deprea vasquezii* (S.Leiva, E.Rodr. & J.Campos) Deanna, comb. nov.**

urn:lsid:ipni.org:names:77145449-1

Basionym: *Larnax vasquezii* S.Leiva, E.Rodr. & J.Campos, *Arnaldoa* 5 (2): 206. 1998.

**Type.** PERU. Cajamarca: San Ignacio, Dist. San José de Lourdes, Estrella del Oriente, 1600 m, 04°50'S, 78°55'W, 8 Jan 1998 (fl, fr), *S.Leiva, J.Campos & E.Rodríguez 2109* (lectotype, designated in Deanna et al. 2014a, pg. 31: US! [00623565]; isolectotypes: CONN! [00055674], CORD! [00004050], F! [2198657], M! [M-0171574], MO! [04908632], NY! [00328793], US! [00623565], USM! [000902]).

After these new combinations, the genus *Deprea* includes the following 45 currently accepted species:

1. *Deprea abra-patriciae* (S.Leiva & Barboza) S.Leiva & Deanna
2. *Deprea altomayoensis* (S.Leiva & Quip.) Barboza & Deanna
3. *Deprea andersonii* (N.W.Sawyer) Deanna & S.Leiva
4. *Deprea bitteriana* (Werderm.) N.W.Sawyer & Benítez
5. *Deprea bongaraensis* (S.Leiva) Deanna & Barboza
6. *Deprea cardenasiana* Hunz.
7. *Deprea chotanae* (S.Leiva, Pereyra & Barboza) S.Leiva
8. *Deprea cuyacensis* (N.W.Sawyer & S.Leiva) S.Leiva & Lezama
9. *Deprea cyanocarpa* J.Garzon & C.I.Orozco
10. *Deprea darcyana* (N.W.Sawyer) Barboza & S.Leiva
11. *Deprea dilloniana* (S.Leiva, Quip. & N.W.Sawyer) Barboza
12. *Deprea ecuatoriana* Hunz. & Barboza
13. *Deprea glabra* (Standl.) Hunz.
14. *Deprea grandiflora* (N.W.Sawyer & S.Leiva) Deanna & Barboza
15. *Deprea harlingiana* (Hunz. & Barboza) S.Leiva & Deanna
16. *Deprea hawkesii* (Hunz.) Deanna
17. *Deprea kann-rasmussenii* (S.Leiva & Quip.) S.Leiva & Barboza

18. *Deprea longipedunculata* (S.Leiva, E.Rodr. & J.Campos) Barboza
19. *Deprea lutea* (S.Leiva) Deanna
20. *Deprea macasiana* (Deanna, S.Leiva & Barboza) Barboza
21. *Deprea maculatifolia* (E.Rodr. & S.Leiva) S.Leiva
22. *Deprea nieva* (S.Leiva & N.W.Sawyer) Barboza & Deanna
23. *Deprea nubicola* N.W.Sawyer
24. *Deprea orinocensis* (Kunth) Raf.
25. *Deprea oxapampensis* M.Cueva & I.Treviño
26. *Deprea paneroi* Benítez & M.Martínez
27. *Deprea parviflora* (N.W.Sawyer & S.Leiva) S.Leiva
28. *Deprea pedrazae* (S.Leiva & Barboza) Deanna & S.Leiva
29. *Deprea peruviana* (Zahlbr.) S.Leiva & Barboza
30. *Deprea pilosa* (S.Leiva, E.Rodr. & J.Campos) Deanna
31. *Deprea pomacochaensis* (S.Leiva) Barboza
32. *Deprea psilophyta* (N.W.Sawyer) S.Leiva & Deanna
33. *Deprea pumila* (S.Leiva, Barboza & Deanna) S.Leiva
34. *Deprea purpurea* (S.Leiva) Barboza & S.Leiva
35. *Deprea purpureocarpa* (S.Leiva, Deanna & Barboza) Deanna
36. *Deprea sachapapa* (Hunz.) S.Leiva & Deanna
37. *Deprea sagasteguii* (S.Leiva, Quip. & N.W.Sawyer) Barboza
38. *Deprea sawyeriana* (S.Leiva, E.Rodr. & J.Campos) S. Leiva
39. *Deprea schjellerupiae* (S.Leiva & Quip.) Barboza & Deanna
40. *Deprea steyermarkii* (Hunz.) S.Leiva & Barboza
41. *Deprea subtriflora* (Ruiz & Pav.) D'Arcy
- 42a. *Deprea sylvorum* (Standl. & C.V.Morton) Hunz. subsp. *sylvorum*
- 42b. *Deprea sylvorum* (Standl. & C.V.Morton) Hunz. subsp. *novogranatensis*  
N.W.Sawyer
43. *Deprea toledoana* (Barboza & S.Leiva) Barboza
44. *Deprea vasquezii* (S.Leiva, E.Rodr. & J.Campos) Deanna
45. *Deprea zamorae* Barboza & S.Leiva

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# Dataset of Phenology of Mediterranean high-mountain meadows flora (Sierra Nevada, Spain)

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## Abstract

Sierra Nevada mountain range (southern Spain) hosts a high number of endemic plant species, being one of the most important biodiversity hotspots in the Mediterranean basin. The high-mountain meadow ecosystems (*borreguiles*) harbour a large number of endemic and threatened plant species. In this data paper, we describe a dataset of the flora inhabiting this threatened ecosystem in this Mediterranean mountain. The dataset includes occurrence data for flora collected in those ecosystems in two periods: 1988–1990 and 2009–2013. A total of 11002 records of occurrences belonging to 19 orders, 28 families 52 genera were collected. 73 taxa were recorded with 29 threatened taxa. We also included data of cover-abundance and phenology attributes for the records. The dataset is included in the Sierra Nevada Global-Change Observatory (OBSNEV), a long-term research project designed to compile socio-ecological information on the major ecosystem types in order to identify the impacts of global change in this area.

**Keywords**

Wet high-mountain meadows, abundance, phenology, Sierra Nevada (Spain), long-term research, global change monitoring, occurrence, observation

**Project details****Project title**

Sierra Nevada Global-Change Observatory (OBSNEV)

**Personnel**

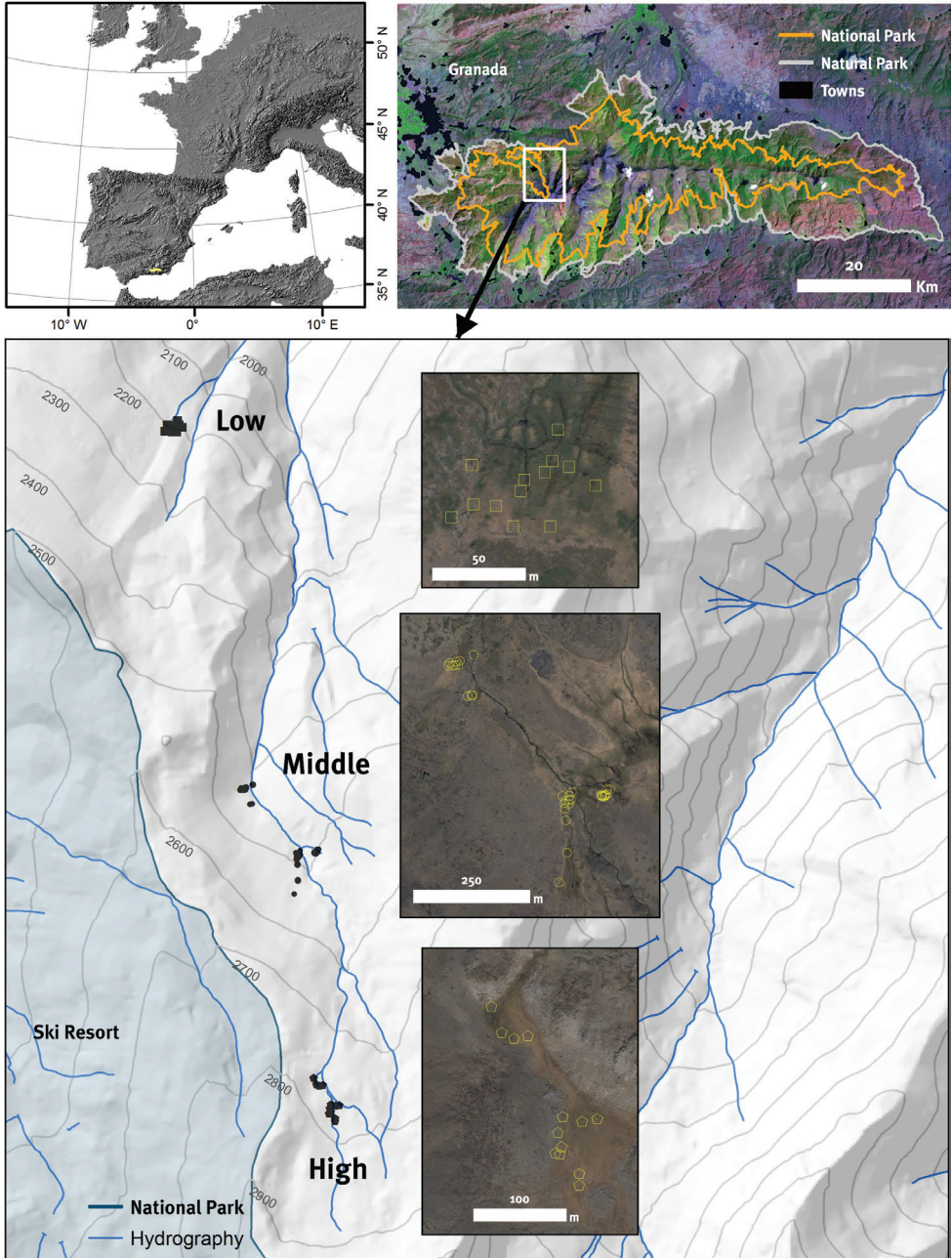
Regino Jesús Zamora Rodríguez (Scientific Coordinator, Principal Investigator, University of Granada); Francisco Javier Sánchez Gutiérrez (Director of the Sierra Nevada National Park and Natural Park).

**Funding**

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**Study area descriptions/descriptor**

Sierra Nevada (Andalusia, SE Spain), a mountainous region with an altitudinal range between 860 m and 3482 m a.s.l., covers more than 2000 km<sup>2</sup> (Figure 1a, b). The climate is Mediterranean, characterized by cold winters and hot summers, with pronounced summer droughts (July–August). The annual average temperature decreases in altitude from 12–16 °C below 1500 m to 0 °C above 3000 m a.s.l., and the annual average precipitation is approximately 600 mm. Additionally, the complex orography of the mountains causes strong climatic contrasts between the sunny, dry south-facing slopes and the shaded, wetter north-facing slopes. Annual precipitation ranges from less than 250 mm in the lowest parts of the mountain range to more than 700 mm in the summit areas. Winter precipitation is mainly in the form of snow above 2000 m of altitude. The Sierra Nevada mountain range hosts a high number of endemic plant species (ca. 80; Lorite et al. 2007) for a total of 2100 species of vascular plants (25% and 20% of Spanish and European flora, respectively). This mountain area comprises 27 habitat types from the habitat directive. It contains 31 animal species (20 birds, 5 mammals, 4 invertebrates, 2 amphibians and reptiles) and 20 plant species listed in



**Figure 1.** Location of Sierra Nevada (southern Spain) and boundaries of the National and Natural Parks (top panels). The bottom panel shows the location of the borreguiles in the San Juan river basin with the sampling plots along an altitudinal gradient.

the Annex I and II of habitat and bird directives. It is thus considered one of the most important biodiversity hotspots in the Mediterranean region (Blanca 1996, Blanca et al. 1998, Cañadas et al. 2014).

This mountain range has several types of legal protection: Biosphere Reserve MAB Committee UNESCO; Special Protection Area and Site of Community Importance (Natura 2000 network); and National Park. The area includes 61 municipalities with more than 90000 inhabitants. The main economic activities are agriculture, tourism, cattle raising, beekeeping, mining, and skiing (Bonet et al. 2010).

## Design description

Sierra Nevada Global Change Observatory (OBSNEV) (Bonet et al. 2011) is a long-term research project which is being undertaken at Sierra Nevada Biosphere Reserve (SE Spain). It is intended to compile the information necessary for identifying as early as possible the impacts of global change, in order to design management mechanisms to minimize these impacts and adapt the system to new scenarios (Aspizua et al. 2010, Bonet et al. 2010). The general objectives are to:

- Evaluate the functioning of ecosystems in the Sierra Nevada Nature Reserve, their natural processes and dynamics on a medium-term time scale.
- Identify population dynamics, phenological changes, and conservation issues regarding key species that could be considered indicators of ecological processes.
- Identify the impact of global change on monitored species, ecosystems, and natural resources, providing an overview of trends of change that could help bolster ecosystem resilience.
- Design mechanisms to assess the effectiveness and efficiency of management activities performed in the Sierra Nevada in order to implement an adaptive management framework.
- Help to disseminate information of general interest concerning the values and importance of Sierra Nevada.

The Sierra Nevada Global-Change Observatory has four cornerstones:

- 1 A monitoring program with 40 methodologies that collect information on ecosystem functioning (Aspizua et al. 2012, 2014).
- 2 An information system to store and manage all the information gathered (<http://obsnev.es/linaria.html> – Pérez-Pérez et al. 2012; Free access upon registration).
- 3 A plan to promote adaptive management of natural resources using the data amassed through the monitoring programme.
- 4 An outreach programme to disseminate all the available information to potential users (see News Portal of the project at <http://obsnev.es> and the wiki of the project at <http://wiki.obsnev.es>, Pérez-Luque et al. 2012)

The Sierra Nevada Global Change Observatory is linked to other national (Zamora and Bonet 2011) and international monitoring networks: GLOCHAMORE (Global Change in Mountain Regions) (Bjørnsen 2005), GLOCHAMOST (Global Change in Mountain Sites) (Schaaf 2009), LTER-Spain (Long-Term Ecological Research). This Observatory is also involved in several European projects like MS-MONINA (FP7 project, [www.ms-monina.eu](http://www.ms-monina.eu)) or EU BON (Hoffmann et al. 2014)

In addition to monitoring the ecosystems of this mountain range (i.e. collection of recent data from biotic and abiotic variables) the Sierra Nevada Global-Change Observatory is incorporating historical information of biodiversity into its information system and some historical experiments and studies are being revisited to detect potential changes due to global change. The dataset described here is a good example of this idea: a singular ecosystem was revisited and resampled 30 years after its inception to check whether the phenology of its flora community had undergone changes.

### Data published through GBIF

<http://www.gbif.es:8080/ipt/resource.do?r=borreguiles>

### Taxonomic coverage

This dataset includes records of the phylum Magnoliophyta (10939 records, 99.43%) and marginally Pteridophyta (63 records, below 1% of total records). Most of the records included in this dataset belong to both the class Magnoliopsida (6057 records; 55.04%) and Liliopsida (4883 records; 44.37%). The class Psilotopsida is represented by 63 records. There are 19 orders represented in the dataset, Poales (44.25%) and Lamiales (12.52%) being the most important order from classes Liliopsida and Magnoliopsida, respectively (Figure 2). The class Psilotopsida is represented only by order Ophioglossales. In this collection, 28 families are represented, with Cyperaceae, Poaceae and Fabaceae being the families with highest number of records (Figure 3). The dataset contains 72 taxa belonging to 51 genera. *Carex*, *Nardus*, and *Scorzonerooides* are the most represented genera in the database. There are 29 threatened taxa (Table 1).

### Taxonomic ranks

**Kingdom:** Plantae

**Phylum:** Magnoliophyta, Pteridophyta

**Class:** Liliopsida (Monocotyledones), Magnoliopsida (Dicotyledones), Psilotopsida

**Order:** Apiales, Asterales, Asparagales, Boraginales, Brassicales, Caryophyllales, Celastrales, Ericales, Fabales, Gentianales, Lamiales, Liliales, Malpighiales, Myrtales, Ophioglossales, Poales, Ranunculales, Rosales, Saxifragales

Table 1. Threatened and/or endemic species of the dataset

Scientific name	Bern <sup>a</sup>	Habitat Directive <sup>b</sup>	Spanish Red List <sup>c</sup>	Andalusian Red List <sup>d</sup>	IUCN Global <sup>e</sup>	IUCN SN <sup>f</sup>	Endemic <sup>g</sup>
<i>Agrostis canina</i> L. subsp. <i>granatensis</i> Romero García, Blanca & C. Morales			VU	VU	VU	VU	SN
<i>Agrostis nevadensis</i> Boiss.							SN
<i>Arenaria tetraquetra</i> L.							SN
<i>Botrychium lunaria</i> (L.) Sw.				VU		VU	
<i>Carex capillaris</i> L.				DD			
<i>Carex nevadensis</i> Boiss. & Reut.				NT			
<i>Cerastium alpinum</i> L. subsp. <i>aquaticum</i> (Boiss.) Mart. Parras & Molero Mesa							SN
<i>Draba lutescens</i> Coss.				VU	LR-nt	VU	
<i>Eleocharis quinqueflora</i> (Hartmann) O. Schwarz				VU			
<i>Eryngium glaciale</i> Boiss.				NT			SN
<i>Euphrasia willkommii</i> Freyn				NT			
<i>Festuca frigida</i> Hack.			VU	VU	VU	VU	SN
<i>Galium nevadense</i> Boiss. & Reut.				NT			
<i>Gentiana alpina</i> Vill.				VU	VU	VU	
<i>Gentiana boryi</i> Boiss.			VU	VU	VU	VU	
<i>Gentiana pneumonanthe</i> L. subsp. <i>depressa</i> (Boiss.) Rivas Marr., A. Asensi, Molero Mesa & F.Valle			VU	VU	VU	VU	SN
<i>Gentiana sierrae</i> Briq.			VU	VU	VU	VU	SN
<i>Gentianella tenella</i> (Rottb.) Harry Sm.				DD			
<i>Herniaria boissieri</i> J.Gay				NT			SN
<i>Linaria aeruginea</i> (Gouan) Cav. subsp. <i>nevadensis</i> (Boiss.) Rivas Marr., A. Asensi, Molero Mesa & F.Valle							SN
<i>Lotus corniculatus</i> L. subsp. <i>glacialis</i> (Boiss.) Valdés				NT			
<i>Luzula spicata</i> (L.) DC. in Lam. & DC				NT			LR-lc
<i>Parnassia palustris</i> L.				NT			
<i>Phleum brachystachyum</i> (Salis) Gamsians, Romero García & C.Morales subsp. <i>abbreviatum</i> (Boiss.) Gamsians, Romero García & C.Morales			VU	VU	VU	VU	
<i>Pinguicula nevadensis</i> (H.Lindb.) Casper	Appendix I	Annex II	EN	VU	VU	VU	SN

Scientific name	Bern <sup>a</sup>	Habitat Directive <sup>b</sup>	Spanish Red List <sup>c</sup>	Andalusian Red List <sup>d</sup>	IUCN Global <sup>e</sup>	IUCN SN <sup>f</sup>	Endemic <sup>g</sup>
<i>Plantago nivalis</i> Jord.							SN
<i>Potentilla nevadensis</i> Boiss.				NT			SN
<i>Ranunculus acetosellifolius</i> Boiss.				NT			SN
<i>Ranunculus angustifolius</i> DC. subsp. <i>uniflorus</i> (Boiss.) Molero Mesa & Pérez Raya			VU	NT			SN
<i>Scorzonoides microcephala</i> J.Holub	Appendix I	Annex II	EN	VU	VU	VU	SN
<i>Scorzonoides nevadensis</i> (Lange) Greuter							SN
<i>Thlaspi nevadense</i> Boiss. & Reut.			VU	VU	VU	VU	SN
<i>Vaccinium uliginosum</i> subsp. <i>nanum</i> (Boiss.) Rivas Mart., A. Asensi, Molero Mesa & F. Valle							SN
<i>Veronica nevadensis</i> H.Lindb.				DD			SN
<i>Viola crassiuscula</i> Bory				NT			SN
<i>Viola palustris</i> L.				NT			

<sup>a</sup> Bern: Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention).

<sup>b</sup> Species included in the Habitat Directive Annex (EC 1992)

<sup>c</sup> 2010 Red List of Spanish vascular flora (Moreno 2010)

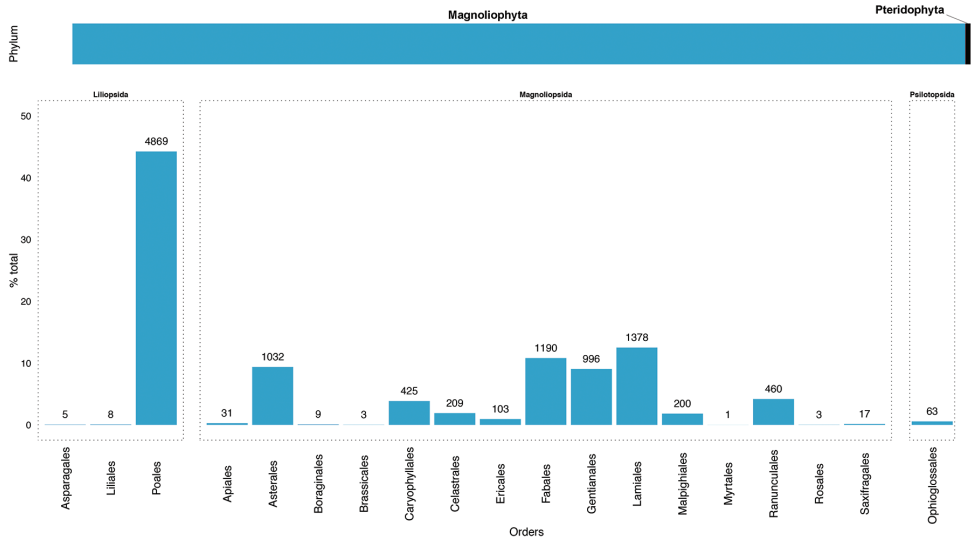
<sup>d</sup> 2005 Red List of vascular flora of Andalusia (Cabezudo et al. 2005)

<sup>e</sup> IUCN category in the distribution area (Blanca et al. 2001, Lorite et al. 2007)

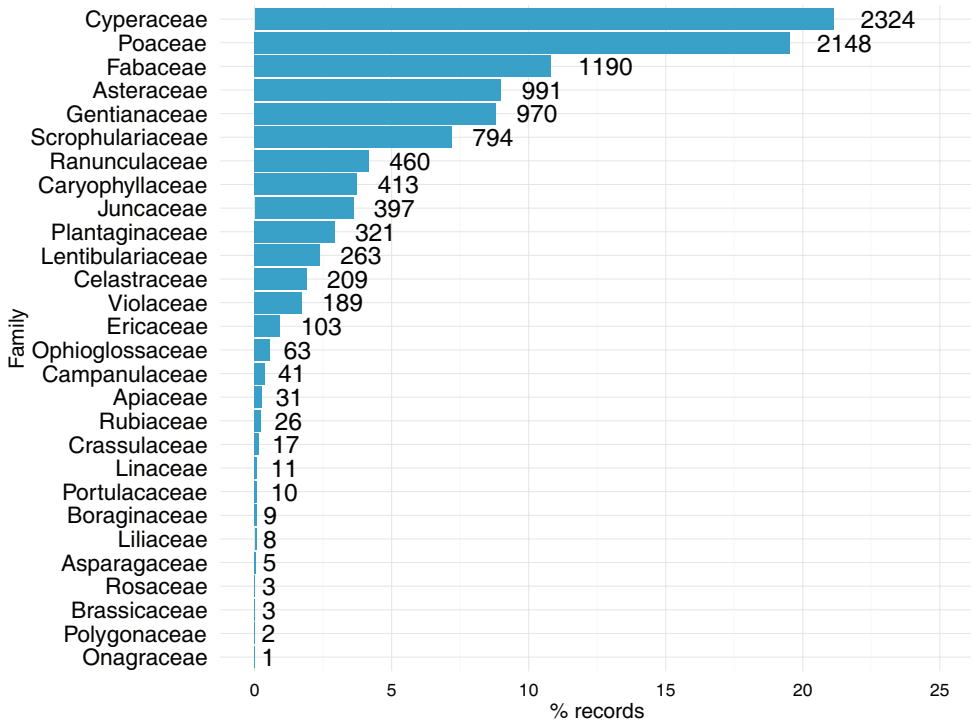
<sup>f</sup> IUCN category in Sierra Nevada (Blanca et al. 2001)

<sup>g</sup> Endemicity (Blanca et al. 2001)

EN: Endangered; VU: Vulnerable; NT: Near threatened; LR-nt: Lower Risk-Near Threatened; LR-cd: Lower Risk-Conservation Dependent; LR-lc: Lower Risk-Least Concern; DD: Data deficient; SN: Sierra Nevada



**Figure 2.** Taxonomic coverage. The upper bar shows the percentage of records of the dataset belonging to each phylum. The bottom bars show the percentage of total records in the dataset by order. The number of records is included above the bars. The order bars is aggregated by class.



**Figure 3.** Taxonomic coverage (families). Percentage of dataset records by families. The numbers indicate the records of each family.



**Family:** Apiaceae, Asparagaceae, Asteraceae, Boraginaceae, Brassicaceae, Campanulaceae, Caryophyllaceae, Celastraceae, Crassulaceae, Cyperaceae, Ericaceae, Fabaceae, Gentianaceae, Juncaceae, Lentibulariaceae, Liliaceae, Linaceae, Onagraceae, Ophioglossaceae, Plantaginaceae, Poaceae, Portulacaceae, Polygonaceae, Ranunculaceae, Rosaceae, Rubiaceae, Scrophulariaceae, Violaceae

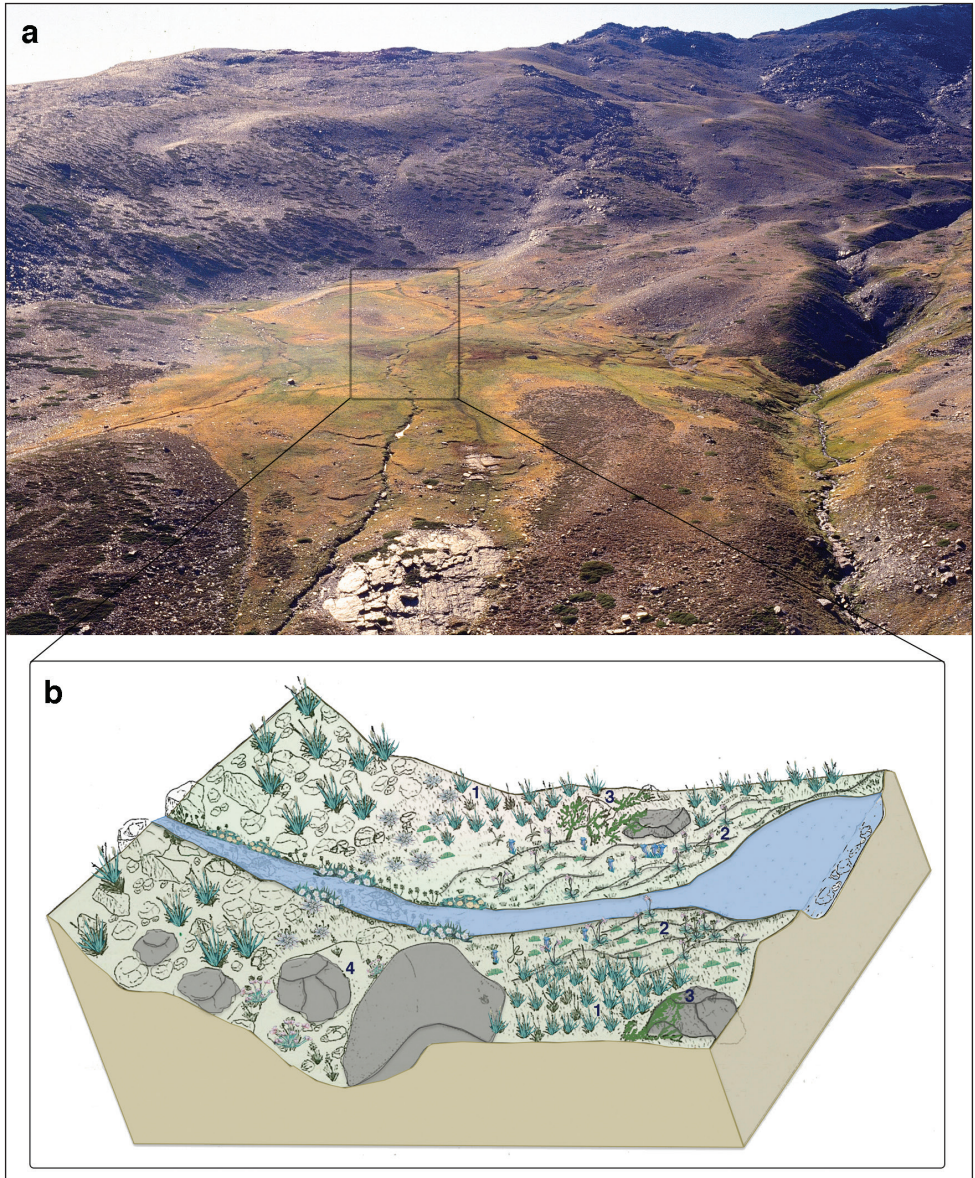
**Genus:** *Agrostis*, *Anthericum*, *Arenaria*, *Botrychium*, *Bromus*, *Campanula*, *Carex*, *Cerastium*, *Cirsium*, *Dactylis*, *Draba*, *Eleocharis*, *Epilobium*, *Erophila*, *Eryngium*, *Euphrasia*, *Festuca*, *Gagea*, *Galium*, *Gentiana*, *Gentianella*, *Herniaria*, *Juncus*, *Linaria*, *Lotus*, *Luzula*, *Meum*, *Montia*, *Myosotis*, *Nardus*, *Parnassia*, *Paronychia*, *Phleum*, *Pinguicula*, *Plantago*, *Poa*, *Potentilla*, *Radiola*, *Ranunculus*, *Rumex*, *Sagina*, *Scorzoneroides*, *Sedum*, *Silene*, *Spergularia*, *Stellaria*, *Thlaspi*, *Trifolium*, *Vaccinium*, *Veronica*, *Viola*

## Spatial coverage

### General spatial coverage

The present dataset covers the Mediterranean high-mountain meadows ecosystems (known locally as *borreguiles*), which is considered a singular ecosystem of the Sierra Nevada (Bonet et al. 2010) (for a description of Sierra Nevada see study area of the Project section). Borreguiles are conditioned by the snow dynamics and are potentially sensitive to changes in water availability and temperature (Martínez-Parras et al. 1987, Fernández-Casas 1974). This ecosystem occupies an altitudinal range between 2200 and 3000 m a.s.l. and its distribution is determined by accumulation of the meltwater (Fernández-Casas 1974). Although it represents only 1.4% of this mountain range (1125 ha), it has a high rate of plant endemism (Table 1) (Bonet et al. 2010, APMM 2013). The borreguiles are included in the Annex I of the Habitats Directive (EU habitat code 6230) (Bartolomé et al. 2005, Rigueiro et al. 2009). This ecosystem lies over hydromorphic soils that develop around mountain lakes, streams, depressions and glacial valleys. The overall appearance of borreguiles in summer is intense green, contrasting with the yellowish colour of the surrounding psychroxerophilic grasslands (Figure 4).

This ecosystem contains several plant communities arranged as parallel bands in relation to natural water courses (Molero-Mesa 1999, Lorite 2001, Lorite et al. 2003, Sánchez-Gutiérrez and Pino 2004) (Figure 4). The floristic composition of these communities depends on moisture content of the substrate. First, on some moist soil, as a transition from dry grasslands to the borreguiles themselves, there is a medium coverage grassland called *dry borreguil* (*Armerio-Agrostietum nevadensis*). It hosts species such *Agrostis nevadensis*, *Plantago nivalis*, *Ranunculus acetosellifolius*, *Thymus serpyllodes* or *Arenaria tetraquetra* subsp. *amabilis* (among others) (Losa-Quintana et al. 1986, Lorite 2001). Then *dense grassland* appears, located in areas with constant moisture throughout the summer and deep soils. As typical species of this community (*Nardo-Festucetum ibericae*)



**Figure 4.** (a) Panoramic view of the borreguil of San Juan valley. The particular zonation of this ecosystem depending on soil moisture is reflected in the different colours of the borreguil. (b) Schematic representation of the vegetal communities forming the borreguiles, including dry borreguil (**4** *Armerio-Agrostietum nevadensis*), dense grassland (**1** *Nardo-Festucetum ibericae*), incipient peat formations (**2** *Ranunculo-Caricetum intricatae*) and variants of borreguil in promontory areas (**3** *Ranunculo-Vaccinietum uliginosi*). Modified from Losa-Quintana et al. (1986). Picture: JM Martín-Martín.

include *Nardus stricta*, *Festuca iberica*, *Scorzoneroideis microcephala*, *Lotus corniculatus* subsp. *glacialis*, *Luzula spicata*, *Ranunculus demissus*, and *Campanula herminii*. Moreover, in the promontory areas appears a variation of the borreguil (*Ranunculo-Vaccinietum uliginosi*) enriched with the presence of *Vaccinium uliginosum* subsp. *nanum*. In places under constant flooding and still waters until fall, the optimum conditions of oxygen deprivation exist for *incipient peat formations*. These communities (*Ranunculo-Caricetum intricatae*) are characterized by the presence of species such as *Carex nigra*, *Eleocharis quinqueflora*, *C. echinata*, *C. nevadensis*, *Juncus articulatus*, *Ranunculus angustifolius*, *Pinguicula nevadensis* or *Festuca frigida*.

In addition to its high ecological value, this ecosystem plays an important role in transhumance livestock systems (Robles et al. 2009). These are pastures with a high nutritive value and with the greatest forage production of the Sierra Nevada ecosystems (Boza et al. 2007, González-Rebollar 2006, Robles et al. 2009, APMM 2013). This is important because they act as a trophic reserve for livestock in summer (Fernández-Casas 1974, Robles 2008). However, the abandonment of uses linked to this practice has tended to reduce the surface area of these ecosystems and consequent overloading of neighbouring areas (González-Rebollar 2006, Robles 2008).

### Coordinates

36°52'12"N and 37°21'36"N Latitude; 3°41'24"W and 2°33'36"W Longitude

### Temporal coverage

May 1988 – Oct 2013

### Parent collection identifier

NA

### Collection name

Dataset of phenology of Mediterranean high-mountain meadows flora (Sierra Nevada, Spain)

### Collection identifier

<http://www.gbif.es:8080/ipt/resource.do?r=borreguiles>

## Methods

### Study extent description

We selected one of the most representative borreguiles of Sierra Nevada (for more info about borreguiles ecosystems see “General spatial coverage” section), located at San Juan river basin (Guejar-Sierra; Granada, Spain) (Figure 1c). The catchment area is nearly 1325 ha. and the basin was formed by glacial erosion of the bedrock (mica schists) and presents a valley with U-shaped (Martín-Martín et al. 2010). This meadow, which originated about 2000 years ago (Esteban 1996), occupies an area of approximately 100 ha.

### Sampling description

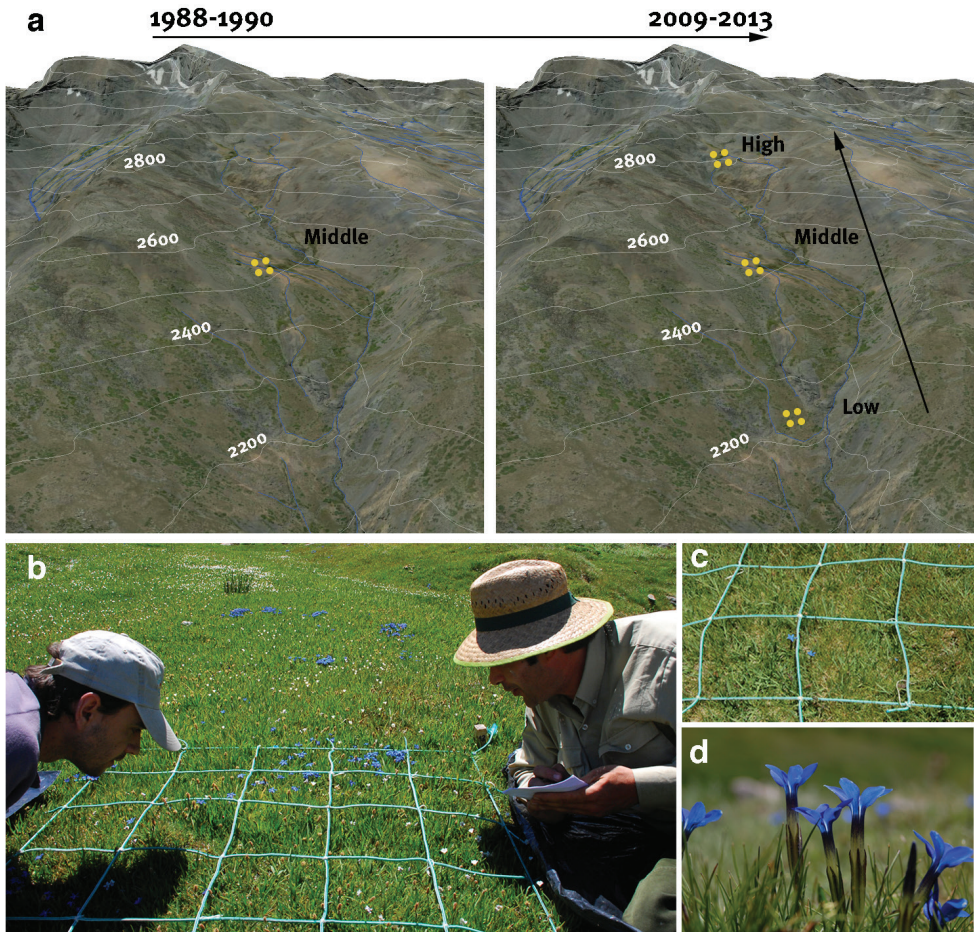
We sampled at three localities along an altitudinal gradient (Figure 5a): one at Prado de la Mojonera (Low Altitude; around 2200 m a.s.l.) and two at Hoya del Moro (middle and high altitude; 2430–2550 m a.s.l. and around 2775 m a.s.l., respectively). For each locality, the sampling was performed every 15 days during the free-snow period once a year from 1988–1990 and from 2009 to 2013. For the middle altitude locality, we have data from two periods: 1988–1990 and 2009–2013. For low- and high-altitude locations, we have data from 2009–2013 period.

At each locality, permanent plots of 1 × 1 m were distributed to cover the different types of borreguiles. In each plot, a floristic inventory was made. The presence/absence and an estimation of abundance-coverage using the Braun-Blanquet cover-abundance scale (Braun-Blanquet 1964) were recorded for each taxa (Figure 5b). We also counted the number of individuals belonging to the three main phenological phases (phenophase) established: vegetative phenophase, reproductive phenophase (flowering) and seed phenophase. The plots were divided into quadrats of 25 × 25 cm to facilitate counting (Figure 5c) (Sánchez-Rojas 2012).

### Method step description

All data were stored in a normalized database and incorporated into the Information System of Sierra Nevada Global-Change Observatory. Taxonomic and spatial validations were made on this database (see Quality-control description). A custom-made SQL view of the database was performed to gather occurrence data and other variables associated with some occurrence data, specifically:

- Flowering abundance: number of flowering individuals per square meter
- Fruit abundance: number of individuals in fruiting period per square meter
- Cover: the percentage of cover per taxon. The value represents a transformation of Braun-Blanquet cover-abundance scale (van der Maarel 1979, 2007)



**Figure 5.** Schema of the sampling design. **a** Different sampling plots were distributed along an altitudinal gradient. For the middle-altitude locality the plots were sampled in two periods: 1988–1990 and 2009–2013. View of a sampling plot of  $1 \times 1$  m (**b**) that was divided into quadrats of  $25 \times 25$  cm to facilitate counting (**c**) and to record the cover-abundance and the number of individuals in flowering (**d**) or in fruit phenophase.

The occurrence and measurement data were accommodated to fulfil the Darwin Core Standard (Wieczorek et al. 2009, 2012). We used Darwin Core Archive Validator tool (<http://tools.gbif.org/dwca-validator/>) to check whether the dataset meets Darwin Core specifications. The Integrated Publishing Toolkit (IPT v2.0.5) (Robertson et al. 2014) of the Spanish node of the Global Biodiversity Information Facility (GBIF) (<http://www.gbif.es:8080/ipt>) was used both to upload the Darwin Core Archive and to fill out the metadata.

The Darwin Core elements for the occurrence data included in the dataset are: occurrenceId, modified, language, basisOfRecord, institutionCode, collectionCode, datasetName, catalogNumber, scientificName, kingdom, phylum, class, order, family, genus,

specificEpithet, infraspecificEpithet, scientificNameAuthorship, continent, country, countryCode, stateProvince, county, locality, minimumElevationInMeters, maximumElevationInMeters, decimalLongitude, decimalLatitude, coordinateUncertaintyInMeters, geodeticDatum, recordedBy, DayCollected, MonthCollected, YearCollected, EventDate.

For the measurement data, the Darwin Core elements included are: id, measurementID, measurementType, measurementValue, measurementAccuracy, measurementUnit, measurementDeterminedDate, measurementDeterminedBy, measurementMethod, measurementRemarks.

## Quality control description

The sampling plots were georeferenced using a Garmin eTrex Legend GPS (ED1950 Datum) with an accuracy of  $\pm 5$  m. We also used colour digital orthophotographs provided by the Andalusian Cartography Institute and GIS (ArcGIS 9.2; ESRI, Redlands, California, USA) to verify that the geographical coordinates of each sampling plot were correct (Chapman and Wieczorek 2006).

The specimens were taxonomically identified using *Flora Iberica* (Castroviejo et al. 1986–2005, Castroviejo 2001) and others reference floras: *Flora de Andalucía Oriental* (Blanca et al. 2011), *Flora Vascular de Andalucía Oriental* (Valdés et al. 1987) and *Flora Europaea* (Tutin et al. 1964–1980). The scientific names were checked with databases of International Plant Names Index (IPNI 2013) and Catalogue of Life/Species 2000 (Roskov et al. 2013). We also used the R packages taxize (Chamberlian and Szocs 2013, Chamberlain et al. 2014) and Taxostand (Cayuela and Oksanen 2014) to verify the taxonomical classification.

We also performed validation procedures (Chapman 2005a, 2005b) (geographic coordinate format, coordinates within country/provincial boundaries, absence of ASCII anomalous characters in the dataset) with DARWIN\_TEST (v3.2) software (Ortega-Maqueda and Pando 2008).

## Dataset description

### Object name

Darwin Core Archive Phenology of Mediterranean high-mountain meadows flora (Sierra Nevada, Spain).

**Character encoding:** UTF-8

**Format name:** Darwin Core Archive format

**Format version:** 1.0

**Distribution:** <http://www.gbif.es:8080/ipt/resource.do?r=borreguiles>

**Publication date of data:** 2014-12-03

**Language:** English

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**Metadata language:** English

**Date of metadata creation:** 2014-11-18

**Hierarchy level:** Dataset

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