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Status of *Logania imbricata* (Guillaumin) Steenis & Leenh. (Loganiaceae)

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Abstract

Molecular systematics has clarified the taxonomic status of *Logania imbricata* (Guillaumin) Steenis & Leenh. as being a species of the genus *Geniostoma* J.R.Forst. & G.Forst., with the new combination ***Geniostoma imbricatum*** (Guillaumin) C.S.P.Foster & B.J.Conn made here.

Introduction

Guillaumin (1953) incorrectly assigned his New Caledonian species *Nautophylla imbricata* Guillaumin to the family Epacridaceae. Leenhouts and van Steenis (1962) correctly transferred this taxon to the Loganiaceae. These authors concluded that this taxon was best placed within *Logania* because of the papillose internodes and shortly ciliate calyx lobes, all morphological features commonly found within the latter genus. However, these features also occur in *Geniostoma*.

A recent systematic treatment of the intergeneric relationships within the tribe Loganieae (Loganiaceae) by Gibbons *et al.* (2012) was unable to support the monophyly of *Logania*, even though both *L.* section *Logania* and *L.* section *Stomandra* were resolved as monophyletic. As part of a study to test the monophyly of *Logania* and to develop a species phylogeny, an increased number of *Logania* taxa and additional molecular markers are being investigated. With the exception of two species, *Logania* is currently considered to be confined to Australia (Conn 1994; 1995). The status of the New Zealand species, *L. depressa* Hook.f., is uncertain, with the type and protologue inadequate for detailed assessment. This taxon is regarded as extinct (Anonymous 2003+). The status of the other non-Australian species, *L. imbricata* (Guillaumin) Steenis & Leenh. from New Caledonia, had already been queried by Conn (1995) and its phylogenetic placement is reevaluated here.

Materials, Methods and Data Analysis

Nucleotide sequences for the chloroplast *pet*D gene region of *Geniostoma, Logania, Mitrasacme, Mitreola, Phyllangium, Schizacme* and several outgroup taxa (*Neuburgia, Spigelia,* and *Strychnos*) were downloaded from GenBank (see Gibbons *et al.* 2012). A specimen of *Logania imbricata* (*G. McPherson 19383 et al.*; NSW905713, full details below) was used for DNA extraction (GenBank Accession Identifier: KC537758).

To determine the placement of *Logania imbricata* within the Loganieae phylogeny, genomic DNA was extracted and the *pet*D gene region was amplified using the polymerase chain reaction (PCR). PCR was carried out using the PIpetB1365F and PIpetD738R primers and thermal cycling conditions of Lohne and Borsch (2005), which amplify the *pet*B-*pet*D intergenic spacer, *pet*D 5′exon (coding for the cytochrome b6/f complex subunit IV) and *pet*D group II intron. Reactions were carried out in a total volume of 25 µL using 12.5 µL of EconoTaq PLUS GREEN 2X Master Mix (Lucigen), 1.25 µL of each primer (final concentration of 1 µM in solution), 2-5 µL of template genomic DNA, and 5-8 µL of molecular grade water. PCR products were visualised using 1.5% agarose gel electrophoresis and cleaned using Exonuclease I and Antarctic phosphatase according to the manufacturer's protocol, before being sequenced under BigDye terminator cycling conditions by Macrogen (Seoul, South Korea).

The forward and reverse sequences for the *pet*D region of *L. imbricata* were assembled into a contiguous sequence using SEQUENCHER version 4.5 (Gene Codes Corporation, Ann Arbor, MI) and aligned with the sequences from GenBank using MUSCLE (Edgar 2004), followed by manual adjustments when the automatic alignments resulted in minor inconsistencies. To allow subsequent phylogenetic analysis, the appropriate nucleotide substitution model for the data was determined in ModelGenerator version 0.85 (Keane *et al.* 2006) using the Bayesian information criterion (BIC). The model that best fitted the *pet*D region was shown to be the transversion model with gamma-distributed rate variation among sites (TVM+Γ), the next best being the general time-reversal model with gamma-distributed rate variation among sites (GTR+ Γ). The data were analysed using maximum likelihood in MEGA version 5 (Tamura *et al.* 2011). As the TVM+Γ model cannot be implemented in MEGA, the GTR+Γ model was used. Support for clades was provided by non-parametric bootstrap (BS) analysis (Felsenstein 1985) with 1000 pseudoreplicates. For the purposes of discussion, nodes with BS values of 85–90 were defined as moderately supported and those ≥90 as strongly supported.

Bayesian phylogenetic analyses were carried out in BEAST version 1.7.4 (Drummond and Rambaut 2007) with support values provided by estimation of posterior probabilities. Posterior probabilities (PP) ≥0.95 were considered to provide support. The analysis was carried out with the TVM+Γ model implemented and run for 10,000,000 generations, with samples taken every 1000 generations. This was confirmed in Tracer version 1.5 (Rambaut and Drummond 2009) to be an adequate number of generations, with effective sample size values for all parameters well over the recommended minimum of 200. The first 10% of trees (1000 trees) was discarded as burn-in.

Results and Discussion

Logania imbricata is placed within a strongly supported clade (PP=1.0; BS=96%) comprising members of the genus *Geniostoma* (Fig. 1). Research into resolving the status of the subgeneric classification of *Logania* is ongoing, but these results unequivocally demonstrate that *L. imbricata* belongs in *Geniostoma.*

The inclusion of *L. imbricata* in *Geniostoma* is also supported by the following morphological features: (1) corolla yellow-green (in New Caledonia, the corolla of *Geniostoma* is often greenish; *Logania* – white or yellow); (2) corolla lobes ± erect, frequent in species of *Geniostoma* from New Caledonia (*Logania* – tending to be usually more spreading, hence corolla often ± campanulate); (3) capsules septifragal in *Genisotoma* (*Logania* – septicidal); (4) seeds appear to be embedded in fleshy placenta, as in *Geniostoma* (*Logania* – fleshy placenta absent) (for detailed circumscription of these two genera see Conn 1980; 1994; 1995).

Nomenclature

Geniostoma imbricatum (Guillaumin) C.S.P.Foster & B.J.Conn, ***comb. nov.***

Basionym: Nautophylla imbricata Guillaumin (1953) *Mémoires du Muséum National d'Histoire Naturelle, Paris, Série B, Botanique* 4: 44, fig. 13.

Synonym: Logania imbricata (Guillaumin) Steenis & Leenh. (1962) *Bulletin du Jardin Botanique de l'État à Bruxelles* 32: 440.

Type: New Caledonia: Province Sud: Arête meridionale du Mt Humboldt: *Virot 432*, décembre 1940 (holo.: P; iso: P).

Description: for a detailed description, see Guillaumin (1953).

Selected specimens examined: New Caledonia: Province Sud: Mt Humboldt, *H.S. McKee 5417*, 10 Oct 1956 (K, NSW823136); Contrefort Sud du Humboldt, *H.S. MacKee 27914*, 8 Dec 1973 (NSW823135, P); Mont Kouakoué, *H.S. MacKee 32437*, 9 Dec 1976 (NSW840989, P); Slopes of Mont Humboldt, *G.D. McPherson*

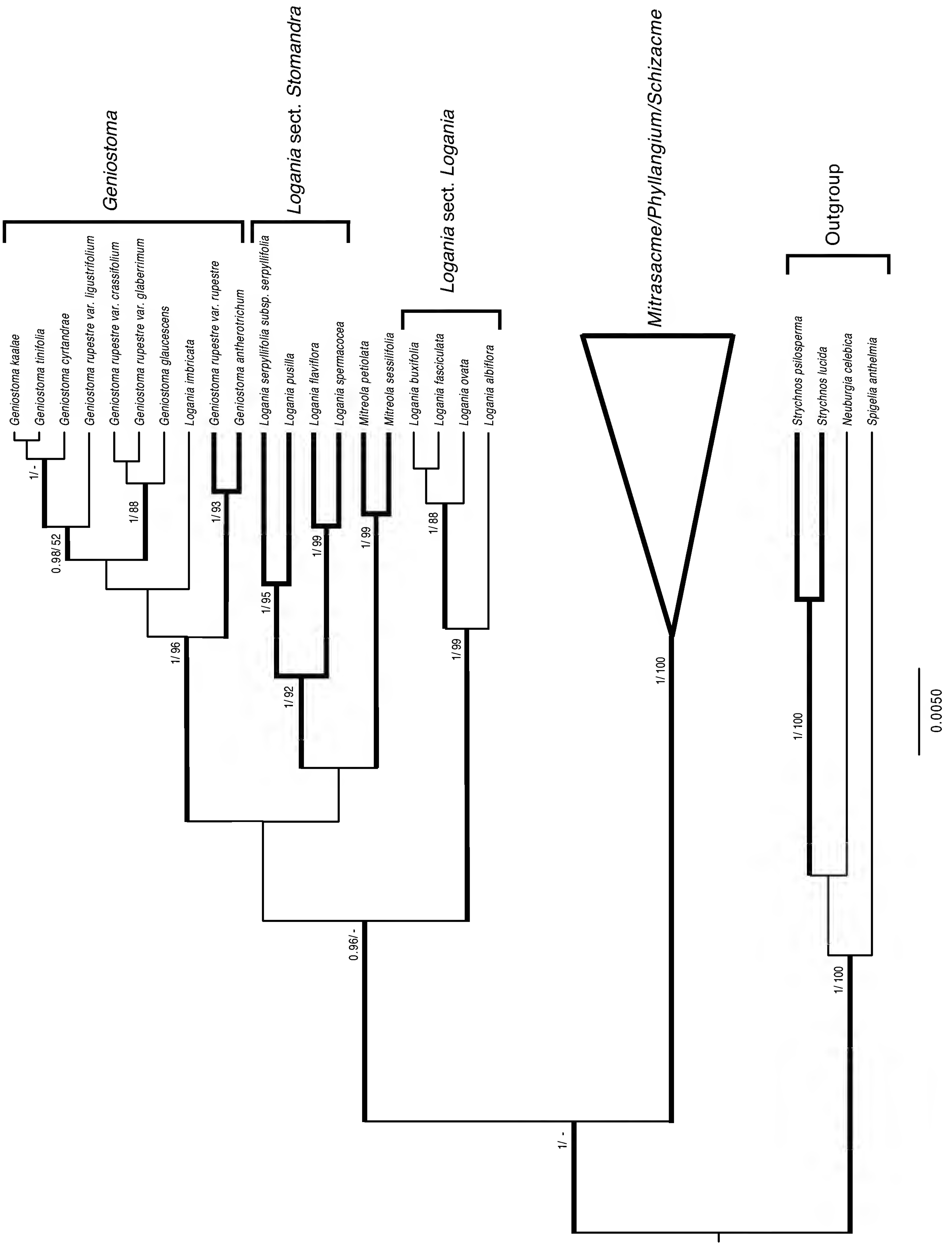

Fig. 1. Bayesian inference tree showing the phylogenetic relationships between *Logania imbricata* and other taxa within Loganieae. Posterior probabilities and bootstrap values are given above the branches (PP/BS); branches with support ≥ 0.95 PP are shown in bold; support values of PP<0.95 and BS<70% are not shown. Scale is in estimated substitutions per site. The data for this analysis were largely based on those of Gibbons et al. (2012).

3457, 20 Dec 1980 (MO, NSW244451); SE of summit of Mont Kouakoué, *G.D. McPherson 19383, Y. Pillon, E.A. Brown & M. Gaudeul*, 26 Apr 2006 (MO, NSW905713).

Affinities: the phylogeny of species of *Geniostoma* is still poorly known because insufficient taxa have been investigated. This species has a glabrous pistil and branchlets with enlarged nodes similar to those of *G. novae-caledoniae* Vieill. ex Baill., but lacks the undulate 'wings' on the internodes of that species and the tapering corolla buds are somewhat reminiscent of those of *G. balansaeanum* Baill. However, there is no evidence to suggest that *G. imbricatum* is likely to be closely related to either of these species.

Note: in the 'Selected specimens examined', the two names H.S. McKee and H.S. MacKee refer to the same plant collector. Hugh S. McKee changed the spelling of his family name to MacKee so that it would be easier for French-speakers to pronounce his name (K.L. Wilson, pers. comm., 30 Jan 2013).

Conclusions

Morphological and molecular data support the reassignment of *Logania imbricata* to *Geniostoma,* as *G. imbricatum*. Furthermore, the transfer of this taxon to *Geniostoma*, together with the above-mentioned extinction of the New Zealand *L. depressa*, results in the genus *Logania* being regarded as endemic to Australia.

Acknowledgments

We thank Jérôme Munzinger (IRD) and L'Institut de recherche pour le développement, Nouvelle-Calédonie (IRD) for providing silica gel dried samples of *Logania imbricata* for the DNA analysis used in this study.

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A new combination in *Ackama* (Cunoniaceae)

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Abstract

Taxonomic revisions of the genera *Ackama* and *Caldcluvia* have left one taxon without a current validly published name under the *International Code of Nomenclature for algae, fungi and plants* (ICN, McNeill et al. 2012), and the new combination ***Ackama paniculosa*** is made.

Introduction

Caldcluvia paniculosa (F.Muell.) Hoogland is a pioneer tree of eastern Australian rainforest with soft, pale, cork-like bark. There is currently a lack of consensus amongst Australian herbaria and floras as to the correct generic placement and name of this taxon, which has been referred to either *Ackama* or *Caldcluvia*. The Australian Plant Census (2012) recognises this species as a *Caldcluvia* and this is followed by some local Floras (eg, Harden 1990, Pellow et al. 2009) but a recent field guide (Harden et al. 2006) treats it as *Ackama*.

The genus *Caldcluvia* was erected in 1830 by David Don for the Chilean taxon originally described by Cavanilles in 1797 as *Weinmannia paniculata* Cav. The genus *Ackama* was established in 1839 by Allan Cunningham for the New Zealand taxon, *A. rosifolia* A.Cunn. A number of names were published in *Ackama* over the next century or so, but Hoogland (1979) subsumed *Ackama* under a broadly defined *Caldcluvia* that also included the genera *Betchea*, *Opocunonia, Spiraeopsis* and *Stollaea.*

Molecular phylogenetic studies of relationships in Cunoniaceae (Bradford & Barnes, 2001; Sweeney et al., 2004; Heslewood, unpublished analysis), corroborated by morphological differences (Bradford & Barnes 2001, Bradford et al. 2004, Godley 1983, Webb & Simpson 1991) indicate that species from Australia and New Zealand, assigned to *Caldcluvia* by Hoogland (1979), should again be referred to *Ackama*. In the course of a phylogenetic study of Australian Cunoniaceae (Heslewood, unpublished data), it became apparent that the taxon currently known as *Caldcluvia paniculosa* has no valid combination in the genus *Ackama*.

Under the revised view of the Caldcluvieae (Bradford & Barnes, 2001), there are currently four taxa that would be assigned to *Ackama*: the type, *A. rosifolia* A.Cunn. plus a second, recently described, New Zealand taxon, *A. nubicola* de Lange (de Lange et al. 2002) and two Australian species, *A. australiensis* (Schltr.) C.T.White and a species variously known as *A. paniculata* Engl. (Harden et al. 2006) or *A. paniculosa* Beuzev. & C.T.White (Sweeney et al., 2004). The origin of the last two names lies in the publication of the name *Weinmannia paniculata* by Mueller (1860), a name that is an illegitimate homonym due to the earlier publication of the same binomial by Cavanilles in 1797. Mueller soon realised this and published the replacement name, *Weinmannia paniculosa*, the following year (Mueller 1861).

When later botanists adopted the generic concept *Ackama*, they introduced the replacement names *Ackama muelleri* Benth. (1864) and *A. paniculata* Engl. (1891) rather than make a new combination based on Mueller's *Weinmannia paniculosa*. It should be noted that Engler's name is incorrectly cited as *Ackama paniculosa* Engl. on Tropicos (http://www.tropicos.org accessed 19 October 2012).

As the latest research supports moving the Australian and New Zealand species assigned to *Caldcluvia* by Hoogland back to *Ackama*, it is now necessary to address the validity of the name *Ackama paniculosa* Beuzev. & C.T.White that has been in limited use (Sweeney et al., 2004). This name appeared in comments under the description of a new species of *Longetia* (now *Austrobuxus*, Picrodendraceae) and was mentioned, only peripherally, by those authors and without stating a basionym or place of publication. Even though it is clear that this name is based on *Weinmannia paniculosa* F.Muell., the name does not satisfy the requirements for valid publication under the ICN and is therefore *nom. nud.* and *nom. inval.*, as indicated in the Australian Plant Name Index. Accordingly, if this taxon is considered a member of the genus *Ackama*, it has no validly published combination based on the earliest legitimate name, *Weinmannia paniculosa* F. Muell. Herein this oversight is corrected and the new combination made.

Ackama paniculosa *(*F.Muell.) Heslew., **comb. nov.**

Weinmannia paniculata F.Muell., *Fragmenta* 2(13): 83 (1860) *nom. illeg.*, non Cav. (1797).

Type citation: "Ad amnes fluvii Clarence River, e.g. ad torrentem Cloud's Creek. Dr. Beckler."

Type: Clouds Creek (Holo MEL 532193, photo!).

Weinmannia paniculosa F.Muell., *Fragmenta* 2(15): 126, 175 (1861) nom. nov. pro *Weinmannia paniculata* F. Muell., nom. illeg., non Cav.

Ackama muelleri Benth., *Flora Australiensis* 2: 444 (1864)

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A new species of *Saurauia* (Actinidiaceae) from Papua New Guinea

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Abstract

Saurauia rufescens B.J.Conn & Damas (Actinidiaceae) is here described as a new species from the West Sepik region of Papua New Guinea.

Introduction

The systematics of the genus *Saurauia* (Actinidiaceae) in Papuasia is inadequately known, being based largely on the early publications of Lauterbach (1912), Diels (1922), Gilg and Werdermann (1925) and Smith (1941). The delimitation of many species is challenging because the amount of morphological variation within most species is undetermined. Hence, the delimitation of species and the recognition of undescribed taxa are problematic. As a result of this, herbaria frequently have as many unidentified specimens of *Saurauia* as identified ones. Diels (1922) classified the species that he recognised into ten series based on types of leaf vestiture, inflorescence arrangement and floral features. Gilg and Werdermann (1925) treated Diels' Old World series *Calyptratae*, *Ramiflorae* and *Uniflorae* as sections and described Section *Pleianthae* as new. They included the remaining series of Diels in the latter section. Gilg and Werdermann (1925) recognised five separate sections for Central and South American species without discussing the relationships between the sections of these two regions. The most recent comprehensive account of the genus deals with the American species (Soejarto 1980) and proposes a new infrageneric classification based on the series classification of Buscalioni (Buscalioni and Muscatello 1912; 1913a; b; 1915; 1916; 1917; 1918; 1919; 1920; 1921; 1922; 1923; 1927), without reference to Gilg and Werdermann (1925). Burtt (1936) regarded both the infrageneric classifications of Diels, and Gilg and Werdermannn as artificial. Therefore, the taxonomic usefulness of all of these classifications is, as yet, to be fully evaluated (Briggs 2011; Takeuchi 2008). The most complete, recent review of the New Guinean species (Royen 1982) deals with those occurring at elevations above 3000 m. He documented nine species of *Saurauia*, all in section *Pleianthae.*

The Papuasian region is here used as first defined in 'Beiträge zur flora von Papuasien' (Lauterbach 1913) and later illustrated by Womersley (1978). It includes the island of New Guinea (Indonesian Papua and the main island provinces of Papua New Guinea), plus the Bismarck Archipelago (New Britain, New Ireland and Manus) and the Solomon Islands (excluding Santa Cruz). Approximately 100 *Saurauia* names have been published for Papuasia (Briggs 2011). However, the number of accepted taxa is unknown. Although several undescribed species are yet to be formally recognised, it is expected that many currently recognised taxa will be reduced to synonymy. We estimate that there are approximately 50–75 species within Papuasia.

Taxonomy

Saurauia rufescens B.J.Conn & Damas ***sp. nov.***

Diagnosis: *Saurauia rufescens* differs from *S. excurrens* by its red-brown indumentum, branchlets with indistinct lenticels, leaf margin indistinctly crenulated, and flowers occurring amongst foliage.

Holotype: Papua New Guinea: West Sepik: Itomi, Amanab Block 3-4, c. 100 km (direct) S of Vanimo, *K. Damas, O. Paul, T. Magun & D. Damas LAE79589,* 4 Nov 2011 (LAE); isotypes: K, L, NSW.

Shrub 1 m high; branchlets terete, densely hairy, with hairs red-brown, retrorse, spreading to more frequently antrorse, 2–5 mm long, usually distinctly swollen at base; lenticels sparse, white. Leaves simple, alternate, exstipulate; petiole terete, 10–12 mm long, densely hairy (as per branchlets); lamina narrowly elliptic, (65–) 135–160 mm long, (10–)12–16 mm wide, length to width ratio (6.5–)10–11.3; base narrowly acute; margin indistinctly crenulate, with a hair-like trichome on each crenulation, hair 1–2.5 mm long, directed towards apex of lamina; apex gradually tapering acuminate into a fine, blunt point; abaxial surface green with red-brown coloration (indumentum), moderately hairy (as per branchlets), particularly on venation (including primary, secondary and tertiary veins); adaxial surface green, sparsely hairy (hairs as per branchlets), with hairs tending to be restricted to mid-vein and margin; mid-vein slightly raised on both surfaces; secondary veins moderately distinct on abaxial surface, numerous, aligned at an angle of 75–80 degrees to mid-vein; intramarginal vein faint to indistinct, often not well-developed on abaxial surface, not visible on adaxial surfaces, inserted 0.5–1.5mm from margin. Inflorescence axillary, with 1 or 2 flowers per axil; bracts rounded, 1.5–2 mm long; pedicels 10–12 mm long (rarely shorter), red-brown (indumentum), moderately hairy (as per branchlets). Sepals 5, green, ovate to oblong, equal in length, 5–6 mm long, (1.5–)2.5–3 mm wide, glabrous; margin entire, slightly incurved; apex obtuse. Petals 5, spreading, membranous, ± oblong, 5–6 mm long, c. 2.5 mm wide, white; margin entire; apex rounded, somewhat irregular to slightly emarginate. Stamens c. 30–40, in 2 series; filaments distally free, laterally flattened, 5–6 mm long, connate basally for c. 2–2.5 mm; anthers dorsifixed, oblong, c. 1.5 mm long, distally divided into 2 tapering lobes (lobes c. 0.5 mm long), subapically poricidal. Ovary 3-locular, superior, globular, c. 2 mm diam.; styles terete, 3.5–4 mm long; stigma oblique. Immature fruits globular, 4–5 mm diam., green; mature fruits unknown. Figs 1a & b.

Etymology: the specific epithet *rufescens* refers to the red-brown hairs on branchlets, leaves, pedicels and sepals.

Locality: only known from the type collection from near Vanimo, in the West Sepik region.

Habitat: occurring in disturbed lowland forest dominated by *Pometia pinnata* J.R.Forst & G.Forst., *Vitex cofassus* Reinw. ex Blume and *Intsia bijuga* (Colebr.) Kuntze. Other common trees in this forest include species of *Chisocheton*, *Dysoxylon* and *Maniltoa*. The area was logged in the last 2–3 years.

Notes: there are several morphological features that distinguish *Saurauia rufescens* from *S. excurrens*. The former species has red-brown indumentum (Figs 1a & b; compared to *S. excurrens* which is glabrous – Fig. 1d); branchlets are sparsely covered with indistinct lenticels (*S. excurrens* is densely covered with distinct lenticels – Fig. 1d); leaf margin is indistinctly crenulated with a single trichome terminating each crenulation (*S. excurrens* with margin serrate with teeth c. 1 mm long); and flowers occur amongst the foliage (Fig. 1b, compared to *S. excurrens* with flowers appearing ramiflorous after leaves fallen – Figs 1c & d).

Leaves of *Saurauia rufescens* and *S. longifolia* Oliv. are similar in shape and both are densely hairy; however the laminae of the latter species are longer (250–350 mm long) and broader (25–40 mm wide) than *S. rufescens* (mostly 135–160 × 12–16 mm). Although there is considerable variation in flower size, the sepals of *S. longifolia* appear to be longer (c. 10 mm long) than those of *S. rufescens* (5–6 mm long).

According to the infrageneric classification of Diels (1922), *S. rufescens* is a member of series *Squamulosae* (Section *Pleianthae sensu* Gilg and Werdermann 1925). Although *S. excurrens* A.C.Sm. technically would be classified as a member of series *Ramiflorae* (Diels 1922), based on the flowers being crowded along leafless branches, we agree with Smith (1941) that it is probably morphologically more similar to species of series *Squamulosae*, and hence to this new species.

Fig. 1. *Saurauia rufescens* **a,** habit showing hairy branches, reddish juvenile leaves and mature leaves; **b,** detail of branches, leaves and flowers, showing hairiness of branches, leaves, pedicels and calyces. Corolla, androecium and gynoecium are also visible. *Saurauia excurrens* **c,** showing pendulous habit with leaves tending to be clustered towards distal end of branches. Flowers occurring in small clusters on older, leaf-less part of branches; **d,** details of inflorescence showing corolla, androecium, style and stigma (a, b from *Damas et al. LAE79589*, photographs KQ Damas; c, d from *Conn 5761*, photographs BJ Conn).

Acknowledgments

The taxonomic status of *S. rufescens* was clarified during several field studies of other species of *Saurauia*. Different forest communities were visited while undertaking research into trees species of Papua New Guinea (Conn and Damas 2006; 2006+). We gratefully thank *Mundango Abroad*, the *European Union African Caribbean Pacific FORENET program*, and *National Science Foundation* for generously funding different aspects of the*PNGtrees* project. We thank Miguel Garcia (NSW) for locating some of the more obscure references used in this study. We acknowledge the traditional Papua New Guinean landowners who provided access for us to collect from forests under their care. Oliver Paul, Thomas Magun and Dubi Damas (all LAE) provided expert field assistance on many occasions and are joint collectors of the type material.

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A review of the genus *Stenochlaena* (Blechnaceae, subfamily Stenochlaenoideae)

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Abstract

Stenochlaena is a small but widespread genus confined to the tropics and subtropics of the Old World. A key to the species, updated descriptions, distribution-maps, and detailed drawings are provided. Also included is a key to assist in separating several genera that are most often confused with *Stenochlaena*. There is morphological evidence suggesting that hybrids may exist between several species in Malesia. Although primarily a rainforest genus, the distribution patterns of the various species of *Stenochlaena* appear closely related to ecological requirements; the hemiepiphytic members of the genus are most frequently present along forest margins in relatively high light conditions with access to a moist soil or an aquatic environment but not necessarily to perpetually humid atmospheric conditions.

Introduction

Stenochlaena J.Sm. is a small genus of six (or possibly seven) species confined to the old-world tropics and sub-tropics. No species have been recorded from the Americas, including associated islands and the Caribbean; claims for the presence of *Stenochlaena* in these regions all appear to be based on earlier and broader generic concepts that included species of *Lomariopsis* Fée.

In the early literature there was much confusion over the generic limits of *Stenochlaena*, especially in relation to the genera *Lomariopsis* and *Teratophyllum* Mett. ex Kuhn. However, it was the contribution by Holttum (1932) that defined the currently accepted boundaries of the three genera. Holttum (1966) extended this work to include the definition of *Lomagramma* J.Sm. in his consideration of the Pacific and Malesian occurrences of *Lomariopsis* and *Teratophyllum*. Holttum added to his treatment of *Teratophyllum* in the *Flora of Malaysia* (1968) and the neotropical species of *Lomariopsis* have recently been revised and monographed by Moran (2000).

Holttum (1971) described an additional species, *Stenochlaena cumingii*, briefly summarising the information then available for the genus and providing a key to the species.

The present study on *Stenochlaena* is an extension and update largely based on additional collections considered together with those used in Holttum's pioneering studies of the genus.

In herbarium collections there continues to be confusion of members of the genus *Stenochlaena* (Blechnaceae) with genera in the family Lomariopsidaceae, *Lomagramma, Lomariopsis,* and *Teratophyllum.* All four genera are mostly hemiepiphytic occurring in rainforest habitats, with mature plants usually producing pinnate sterile fronds spaced along a climbing rhizome; most species have fertile laminae that are once pinnate and the fertile pinnae are exindusiate but otherwise appearing lomarioid in external morphology. The following key is provided to assist in distinguishing *Stenochlaena* from the above three genera of the Lomariopsidaceae.

Key

1a. Pinnae of adult fronds with a closed network of areolae that lack free veins in the islets; rhizomes with deciduous clathrate scales .... ***Lomagramma***

1b. Areolae, if present, give rise to the lateral veins; rhizome scales not clathrate 2

2a. Lateral veins of the sterile pinnae arising from a closely parallel series of areolae on both sides of the costa; rhizome anatomy radially symmetrical; spores with a very thin and closely appressed perispore .... ***Stenochlaena***

2b. Veins free with lateral veins of the sterile pinnae arising directly from the costa; areolae not present; rhizome anatomy dorsiventral; spores with a conspicuous perispore 3

3a. Rhizome of adult plant slender, cylindrical, sometimes spiny; pinnae including the terminal pinna articulated; juvenile fronds with the lamina variably but finely dissected, forming bathyphylls .... ***Teratophyllum***

3b. Rhizome of adult plant robust, flattened and conspicuously covered in scales especially at the apex but not bearing spines; lateral pinnae articulated on the rhachis, but terminal pinna not articulated; juvenile fronds with lamina simply pinnate, bathyphylls absent .... ***Lomariopsis***

Taxonomic position of *Stenochlaena*

Holttum (1932), having demonstrated that the anatomy of *Stenochlaena* is distinctive and emphasizing the significance of the absence of an indusium, suggested that this genus be placed with or near to the acrostichoid ferns, a view he maintained throughout later studies (Holttum 1949, 1966, 1971).

Copeland (1947) abandoned his earlier view that *Stenochlaena* be placed with the asplenioid ferns (Copeland 1905), and concluded from venation, spore morphology and other characters that it was more logically placed in the Blechnaceae. This view contrasts with that of Ching (1978) who placed *Stenochlaena* in a new family 'incertae sedis', the Stenochlaenaceae Ching, independent from the pteridioid and blechnoid ferns but, like Holttum, he favoured a position near the acrostichicoid genera.

Based on a detailed developmental study, Stokey & Atkinson (1952) reported that the gametophyte of *Stenochlaena,* especially in the early stages of development, is morphologically very similar to that of several species of *Blechnum* and very different from *Acrostichum.*

Pichi-Sermolli (1977) considered *Stenochlaena,* in some of its features, to be more closely related to *Blechnum* than to *Brainea* and he concluded that '*Stenochlaena* represents a phyletic line, probably rather old, independent from both those of *Blechnum* and *Brainea*, but derived from the same ancestral source.' The stomatal structure (Van Cotthem 1970), venation, and the existence of some climbing species in the genus *Blechnum* gives some support to placing *Stenochlaena* closer to the genus *Blechnum.*

The significance of the lack of an indusium in *Stenochlaena*, a character shared with the genus *Brainea* may have been overemphasized by both Holttum and Ching in their separating *Stenochlaena* from the blechnoid ferns. While the venation pattern in *Stenochlaena* is essentially blechnoid, the stand-alone characters in *Stenochlaena* (if placed in the Blechnaceae) include its rhizome with a complex polycyclic dictyostele, a very complex multi-stele arrangement in the stipe and rhachis, the nature of the rhizome scales, and the characteristic spore ornamentation with the very thin and closely adhering perispore. Additionally, for some species there is the presence of a gland (sometimes two glands) at the bases of the lateral pinnae. These various distinctive features appear to justify a separate monogeneric subfamily, the Stenochlaenoideae (Kramer et al., in Kramer & Green 1990; Roux 2001) within the Blechnaceae, a view supported in the present study.

Stevenson & Loconte (1996), in their study of ordinal and familial relationships of pteridophyte genera based on a cladistic analysis of 116 characters, concluded that the genera *Stenochlaena* and *Brainea* could be resolved as early branches of the Blechnaceae; *Stenochlaena* they interpreted as a sister group to *Pteridoblechnum.* Molecular work using *rbc*L (Hasebe et al. 1995) is also consistent with this view, with the genera of the Blechnaceae (*Blechnum*, *Doodia*, *Sadleria*, and *Stenochlaena*) forming a well-supported clade with *Stenochlaena* sister to the other genera.

Cranfill & Kato (2003) in a recent study of the woodwardioid ferns, *Woodwardia* Sm., *Anchista* C.Presl and *Lorinseria* C.Presl, based on 22 morphological characters and a range of molecular markers, (*rbc*L, *rps4*, and *rps4–trnS* spacer) have clearly demonstrated that both *Stenochlaena* and *Blechnum* are consistently sister to the woodwardioid genera, clearly within a monophyletic Blechnaceae. In a more recent study, Smith et al (2006), in considering a classification of extant ferns, conclude that the family Blechnaceae consists of nine genera (including *Stenochlaena*) that nest within *Blechnum* s.l., but that acceptance is dependent upon a recircumscription of *Blechnum* s.l. Schuettpelz & Pryer (2008) also conclude that *Blechnum* is not monophyletic and that it requires further research.

Morphology and Terminology

In most members of the genus, *Stenochlaena* the rhizome is scandent, usually round in cross-section, 1–2.5 cm diameter and very long, often reaching the crowns of tall rainforest trees, but it maintains a connection with the ground (the one exception is *Stenochlaena areolaris*, a plant that grows epiphytically in natural water tanks usually in the crowns of palms etc.). As the plant climbs over rocks and forest debris and sometimes spreads as a floating mat over water surfaces, it gives rise to a succession of spaced fronds. No members form a woody caudex or trunk and none produces a true radial crown of fronds. Holttum (1932) described and illustrated the internal anatomy of the rhizomes of two species, *S. palustris* and *S. laurifolia* C. Presl (now *S. cumingii*), demonstrating that the stele has radial symmetry with 3 or 4 large bundles surrounded by numerous smaller bundles in two approximately concentric circles. The rhizome is capable of giving rise to roots and fronds from all sides but in most specimens, roots emerge only from areas coming into contact with the substratum and fronds arise from the opposite side, resulting in a false dorsiventral external morphology. The apical region of the rhizome is covered by scales, most of which are shed as the rhizome grows. Scales vary from peltate to acuminate but mostly with a peltate attachment and often are closely appressed to the rhizome surface.

The stipe may possess hairs and scales when young, but is glabrous or almost so at maturity; is grooved on the adaxial face and possesses two lateral lines of spaced glands, which are more easily observed in fresh material. Sterile lamina once pinnate in all taxa; however most species may on rare occasions produce aberrant bipinnate fronds. *Stenochlaena tenuifolia* is the only species regularly producing bipinnate fertile fronds. Most species have both sterile and fertile pinnae that are very shortly stalked and more or less articulate to the rhachis, but these are variable features both within and between taxa. Most species have a gland on the acropetal margin at the base of the lateral pinnae (or most of the lateral pinnae); more rarely there is also a gland on the basal margin. These glands possibly only function in the young stages of a frond's development, and on the mature sterile frond are small, dry, brown structures. A more detailed description can be found in Troll (1932). One of the morphological characteristics of *Stenochlaena* is that the lateral veins of the pinnae arise from a series of areolae sometimes close to the *costa*; when very closely parallel to the costa they may prove difficult to detect. The lateral veins arising from the areolar vein are either single or once bifurcate (less commonly twice) and each terminates within the pinna margin. Fertile fronds have the same basic pattern but the areolar vein pattern tends to be more complex; fertile pinnae in all species are very much more slender than the pinnae of the sterile fronds and the sori are linear on either side of the costa; although there is no protective indusium, some taxa have a narrow region of sterile tissue between the sorus and the pinna margin. During the maturation of the sporangia, the margins of the pinnae reflex, resulting in the soral surface appearing to completely cover the abaxial face of the pinna and further enhancing the acrostichoid appearance.

Spores of *Stenochlaena* are pale yellow or yellow-brown to hyaline, ellipsoidal, and monolete; the exospore has coarse, prominent tubercles with varying arrangements for each of the taxa. The perispore is very thin, difficult to detect unless sectioned, relatively smooth, and closely envelops the exospore. The distinctive structure of the spores of three species, as seen by light microscopy, were described and illustrated by Holttum (1932). They appeared to lack a perispore. However from a survey using both whole spores observed by scanning electron microscopy, and some wall details in sectioned material viewed by transmission electron microscopy, Tryon & Lugardon (1990) illustrated images of several species of *Stenochlaena* which all appear to have a thin, closely enveloping perispore.

Stenochlaena J.Sm.

Stenochlaena J.Sm., J. Bot. (Hooker) 3: 401 (1841), 4: 149 (1842).

Type: *Stenochlaena scandens* J.Sm. (= *Polypodium palustre* Burm.f., 1768; *Stenochlaena palustris* (Burm.f.) Bedd., 1876). Lectotype technically designated by Pfeiffer, Nom. bot. 2:1274 (1874).

Etymology: the genus *Stenochlaena* from Greek 'stenos' = slender, presumably referring to the pinnae of the very large fronds and 'chlaina' = cloak or mantle, referring to the climbing plants together with their very large sterile fronds cloaking the trunk and canopy of a rainforest host tree.

Rhizome creeping and scandent, maintaining connection with the ground, hence hemiepiphytes except for a single species which is essentially a crown aquatic epiphyte with no direct connection with the soil; rhizome internal anatomy a complex perforated dictyostele with radial symmetry which in cross-section has a few large central steles and two more peripheral rings with numerous small vascular bundles; young rhizome green, with sparse small, usually appressed, brown peltate and/or linear-acuminate brown *scales*, sometimes clathrate and with fine marginal outgrowths; as rhizome matures most of the scales are shed leaving a few that are scattered and closely appressed; roots, rootlets and fronds arising at any point on the rhizome but roots mainly in clusters where rhizome touches a supporting surface; *sterile fronds* distant on the rhizome and not forming a crown; *stipes* at maturity glabrous or slightly hairy on the adaxial surface, which has one or more grooves; a line of small glands extend on either side of the stipe to the rhizome (often difficult to detect on dried specimens); in cross section the vascular system is complex with ±40 bundles derived from all 3 rings of bundles in the rhizome (Holttum 1968); *sterile lamina* ovate to oblong-lanceolate, pinnate, glabrous and coriaceous; *pinnae* oblong-ovate to lanceolate, acuminate to attenuate and often alternate, sessile to shortly stalked and in some taxa ± articulate at the rhachis; terminal pinna rarely articulate; *pinna margins* finely cartilaginous and serrulate to sharply and sometimes irregularly dentate, usually not green; *veins* arise from the *costa* as a single series of *areolae* sometimes very close to the costa; *lateral veins* arise from the *areolar veins* and free, simple or once- or more rarely twice-furcate, ending near to or at the sclerotic margin; a single marginal gland is usually present on the acroscopic margin close to the pinna base; occasionally two glands are present, one acroscopic and one basiscopic; *fertile fronds* usually with a longer stipe than in the sterile fronds; *fertile lamina* pinnate (bipinnate in *S. tenuifolia*); *fertile pinnae* usually longer than the sterile, ± articulate, slender, (2–10 mm broad), entire to finely toothed, and with narrow, sterile margins either enveloping the sporangia (interpreted here as a false indusium) or spreading, abaxial surface with a sorus on either side of the costa, lacking a true indusium; *sporangia* in linear sori, extending for the length of the pinna or pinnule, the venation with a commissural (areolar) vein and a supplementary system of veins supplying the sori (more easily visible when sporangia are removed). *Spores* (Fig. 1) bilateral, ellipsoid, somewhat hyaline, colourless to pale yellow, papillose with distant tubercles tending to be in parallel rows and with an exceptionally thin, closely adhering perispore.

Cytology: Mehra & Bir (1958) reported the distinct chromosome number of n = 73 for *Stenochlaena* and concluded, on the basis of investigation of a number of morphological characters of *Stenochlaena palustris*, that a phylogenetic relationship exists between *Stenochlaena* and the members of the family Blechnaceae.This report of n = 73 (or 74) is further supported by Tindale & Roy (2002) with 2n = c.146 for material collected from Iron Range in North Queensland, Australia, and by the earlier report of x = 37; 4n = 148 by Manton & Sledge (1954).

Notes: 1. The pioneering study by Underwood (1906) segregated three of the species now recognised as Malesian taxa of *Stenochlaena* into section '*Eustenochlaena*' and the African taxon *S. tenuifolia* into section *Cafraria* (C. Presl) Underw. He also treated the species now segregated into the genera *Lomariopsis* and *Teratophyllum* as sections of his broadly circumscribed *Stenochlaena*. The majority of species, in which both the sterile and fertile fronds are once pinnate, were placed in the section '*Eustenochlaena*' and section *Cafraria* was reserved for the one species with pinnate sterile fronds but bipinnate fertile fronds. However, morphologically, all species share many characters and in some of the once-pinnate taxa occasional mutants will produce a partly bipinnate fertile frond and, less frequently, bipinnate sterile fronds have also been recorded. It is concluded on the basis of comparative morphology, but admittedly in the absence of detailed cytological and molecular analyses, that the separation of section *Cafraria* is not justified.

2. Of the six species accepted as belonging to the genus, only *Stenochlaena areolaris* is a true epiphyte having a relatively specialized and restricted growth habit in the crowns of palms and other plants providing a water reservoir. The other species are hemiepiphytes climbing high on tree trunks but maintaining connection to the soil. All species of *Stenochlaena* appear to require moderately high light conditions in order to produce fertile fronds. All species also require perpetual access to moisture. Based on limited field observations, together with notes accompanying herbarium specimens, those from rainforest environments usually only produce fertile fronds when climbing on trees at the forest margin or on river banks, or when the climbing fern within the forest has reached the canopy.

3. Based on general morphology, it would appear that the loss of an indusium in Blechnaceae probably occurred independently in the genera *Stenochlaena* and *Brainea* and that the two genera arose very early from distinct ancestral elements within this family. This view is supported by the spore morphology which is distinctive in each of these genera. The analyses of Cranfill & Kato (2003), which included both morphological and molecular data (although with only limited sampling of these two genera), provide further support for this hypothesis.

4. There is evidence suggesting that hybrids may occur between several species. *Stenochlaena palustris*, the most widespread and variable taxon, appears to form hybrids with *S. milnei*. It is possible that *S. milnei* is itself of hybrid origin, a view tentatively put forward by Holttum (1971) when he reported that *S. milnei* possessed some characters "almost exactly intermediate" between *S. cumingii* and *S. palustris*.

Biogeography of the genus *Stenochlaena*

The distribution pattern of *Stenochlaena* has parallels in a number of other plant taxa confined to the Old World tropics and sub-tropics. Most species of *Stenochlaena* are present in the Malesian region. *Stenochlaena palustris*, the most widely distributed, best known, abundant, and variable species, occurs throughout Malesia, extending northwest to India, north to other south-east Asian countries, south to northern Australia and east to the Bismarck Archipelago of Papua New Guinea and the south-west Pacific region.

Citations for localities in Papuasia are based on Womersley's (1978) map of "Geographical Regions of Papuasia" Three of the four species in the Malesian region are, from the available evidence, of limited distribution. *Stenochlaena areolaris* appears to be confined to the Philippines and New Guinea, a pattern repeated in a number of ferns and seed plants. *Stenochlaena milnei* is restricted in its distribution to New Guinea, the Philippines, and the Solomon Islands. For *S. cumingii* there are very few collections, these coming from New Guinea, the Philippines, and within Indonesia from the Moluccas. It seems probable that, with further collecting, the distribution may be considerably extended. A recently described additional taxon, *S. hainanensis*, reported from Hainan (Ching & Chiu 1964), although lacking fertile material, is provisionally treated here as a variant within the range of variability accepted for *S. palustris*.

On the Indian Ocean islands, including Madagascar, and in East Africa, the ecological niches occupied by *Stenochlaena palustris* elsewhere are often taken by the tropical and subtropical east African species *S. tenuifolia* (Rakotondrainibe 2002), a taxon with similar ecological requirements but morphologically characterized by having distinctive bipinnate fertile fronds. Cranfill & Kato (2003) mentions that *S. tenuifolia* has been recorded as a garden escape in Florida, U.S.A. in the 1930's. In tropical West Africa, (possibly including Cameroon) and extending south into northern Angola and east into Uganda, *S. mildbraedii* occupies comparable ecological niches. This exceptionally robust and least known species has once pinnate fertile fronds and possesses the largest and most robust sterile fronds reported for the genus. Whether *S. mildbraedii* is really present in Cameroon cannot at this stage be confirmed; I suspect, despite records noting its presence (Tardieu-Blot 1953), that the *Stenochlaena* reported from there may be an additional, as yet undescribed, species. The Cameroon specimens that I have studied are unsatisfactory and it is not possible to be certain that they merit a separate taxon.

Key to the species of *Stenochlaena*

1a. Sterile and fertile fronds once pinnate 2

1b. Sterile fronds pinnate; fertile fronds almost invariably bipinnate .... **5. *S. tenuifolia***

2a. Aquatic epiphyte; lamina with few sterile pinnae (usually about 7 pairs); fertile pinnae with thin, reflexed sterile margins, 1 mm wide; areolae, created by the veins parallel to the costa, conspicuous .... **4. *S. areolaris***

2b. Hemiepiphytes; lamina usually with 15 or more pairs of sterile pinnae; fertile pinnae with a very slender sterile margin; conspicuous areolae lacking 3

3a. Apical rhizome-scales elongate, entire, slender, acuminate and mostly deciduous 4

3b. Apical rhizome scales entire and slender and some almost circular, and appressed 5

4a. Pinnae coriaceous, margins sharply and irregularly antrorsely toothed .... **6. *S. mildbraedii***

4b. Pinnae chartaceous, margins regularly serrate to finely dentate .... **7. *S.* sp. 'Cameroon'**

5a. Bases of sterile pinnae cuneate; pinnae of fertile fronds 2–3 mm wide; basal sterile pinnae usually articulated .... **1. *S. palustris***

5b. Bases of sterile pinnae broadly rounded to cordate; pinnae of fertile fronds at least 5 mm wide; pinnae often not distinctly articulate 6

6a. Sterile pinnae rounded at base, some partly articulate; fertile pinnae c. 5 mm wide; spores with prominent tuberculae, partially aligned in rows .... **3. *S. milnei***

6b. Sterile pinnae cordate at base, not articulate; fertile pinnae 7–10 mm wide; spores with continuous or broken ridges and occasional scattered tuberculae .... **2. *S. cumingii***

Southern India, Indochina, Malesia, Papuasia, Northern Australia and Southwestern Pacific Taxa

1. ***Stenochlaena palustris*** (Burm.f.) Bedd., Ferns Brit. Ind. Suppl. 26 (1876); Handb. Ferns Brit. Ind., 421 (1883).

Polypodium palustre Burm.f., *Fl. Indica* 234 (1768); *Lomariopsis palustris* Kuhn, Ann. Mus. Bot. Lugduno-Batavi., 4: 294 (1869); *Chrysodium palustre* (Burm.f.) Luerss., Fil. Graeff., 73 (1871); *Acrostichum palustre* (Burm.f.) Clarke, Trans. Linn. Soc. Bot., 577 (1880).

Type citation: "Habitat in Indiis". **Type:** 'Ceylon' [=Burman, Thes. Zeyl. 100, t. 46] (lecto, see Underwood 1906: 38).

Onoclea scandens Sw., Syn. Fil. 112 (1806) nom. illeg.; *Lomaria scandens* Willd. Sp. Pl. 5, 293 (1810).

Stenochlaena scandens J.Sm., Hook. J. Bot. 3: 401 (1841); *Olfersia scandens* (J.Sm.) Presl, Tent. Pterid. 235 (1836); *Acrostichum scandens* (J.Sm.) Hook. Sp. Fil. 269 (1866) nom illeg., non Raddi.

Pteris scandens Roxb., Hort Bengal. 75 (1814); Calcutta J. Nat. Hist. 4: 505 (1844) **Type:** Rheede, Hort. Ind. Malab. 12: t.35 (see Morton 1974: 375).

Stenochlaena blumeana C. Presl, Epim. Bot. 163 (1851). **Type citation: "**Habitat in sylvis Indiae orientalis ad Tranquebar (Rottler), Javae occidentalis (Blume), Moluccarum (Rumphius)." (Synonymy *fide* Index Filicum, see Holttum, 1969).

Lomaria ? juglandifolia C. Presl, Rel. Haenk. 1: 52 (1825); *Stenochlaena juglandifolia* (C. Presl) C. Presl, Epim. Bot. 164 (1851). **Type:** [Luzon,] *Haenke s.n.* (PR, n.v.).

Stenochlaena fraxinifolia Presl, Epim. Bot. 164 (1851); *Stenochlaena scandens* var., J.Sm., Hook. J. Bot. 3: 401 (1841). **Type:** Philippines, Negros, *Cuming 347* (PR, n.v.).

Stenochlaena laurifolia C. Presl, Epim. Bot.164 (1851). **Type:** Philippines, Luzon, *Cuming 226* (PR, n.v.; excl. dupl. BM, K).

Etymology: from the Latin, 'paluster' referring to the swampy places from which the original collections were made.

Published illustrations: Hooker, Gen. Fil. pl. 105B (1842) (as *S. scandens*); Beddome, Ferns of Southern India, pl. 201 (as *S. scandens*) (1863); Tardieu-Blot, Aspléniacées Tonkin, pl. 47, f. 1 (as *S. palustris*) (1932); Nayar & Devi, fig. 52 (spore as *S. palustris*) (1964); Holttum, Rev. Fl. Malaya, 2: f. 241 (1968); Zamora P.M. & Co L, Guide Philip. Flora & Fauna 2: 52, f. 44 (1986); A.G.Piggott & C.J.Piggott, Ferns of Malaysia in Colour, 410 (as *S. palustris*) (1988); S.B. Andrews, Ferns of Queensland, 87, f. 7.1c (1990) (*as S. palustris*); Kramer & Green, fig. 25 A–E (1990); Chambers & Farrant, Fl. Australia 48, fig 123 A, B. (1998).

Rhizome extensive, indeterminate, smooth, scrambling and climbing (sometimes floating when growing over river and lake banks), stramineous to brown, 0.5–0.7 cm diameter, with peltate ± entire, mostly round persistent scales and green to red-brown acuminate scales that are closely appressed to the surface and mostly caducous except for areas giving rise to roots, clusters of rootlets and dimorphic fronds. *Sterile fronds* variable in size, mostly 25–85 (–175) cm × 9–30 cm wide; s*tipes* 10–30 cm or more, stramineous to brown, glabrous or with a few persistent peltate scales; *lamina* ovate or oblong-ovate in larger specimens; *pinnae* 4–15 pairs, usually widely spaced, all or some articulated to the rhachis, sessile to shortly stalked, ovate to lanceolate, acuminate to frequently attenuate, entire to finely toothed or apex more markedly toothed if attenuate; base almost entire, a single *gland* (rarely 2) usually present either at the base of the pinna margin or on the short pinna stalk; lateral veins simple or once-furcate, arising from areolar veins closely parallel on either side of the costa; *terminal pinna* usually larger than the sub-terminal pairs, in most specimens lacking a gland and not articulated to the rhachis. *Fertile fronds* about as long as sterile fronds but with stipe longer; *pinnae* 8–25 cm, up to twice the length of those of the sterile lamina, 2–3 mm broad; approaching maturity the margins of the *fertile pinnae* appear to slightly envelop the linear sori but at maturity the lamina reflexes and the sori appear acrostichoid. Fig. 2.

Spores bilateral, and ornamented with short round projections more or less in rows and almost colourless but in masses have a pale lemon yellow tinge; *perispore* very thin, closely enveloping, difficult to differentiate from the spore wall. Fig. 1d.

Chromosome number: x = 74 (base number may be 37; Kramer & Green (1990), a number occasionally also reported for *Blechnum*). Mehra & Bir (1958) illustrate a spore mother cell at meiosis with 73 bivalents, while Manton (1954) and Manton & Sledge (1954) have suggested that $n = 70–80$ and most probably $n = 74$ and $2n =$ c. 148.

Distribution and habitat: extending from India through Myanmar (Burma), south and south-east Yunnan in China, Thailand, Laos, Vietnam through Malesia east to the Solomon Islands and south to northern Australia, and in the Pacific southeast as far as the islands of Fiji, (recorded by Brownlie (1977) on three islands: Viti Levu, Vanua Levu and Taveuni) (Fig. 3). This species is also reported present on Samoa and Tonga (Holttum 1971). *Stenochlaena palustris* is a very adaptable species colonising margins of hot springs and mangroves in coastal environments; in some areas forming extensive floating mats on fresh water at forest edges. This species is found growing in permanently damp open places in tropical and subtropical lowland areas especially on forest margins on the ground and climbing high up a wide range of trees and palms and also abundant in secondary forest. It has also been reported as a weed in rubber and oil palm plantations and in abandoned gardens.

Selected specimens examined: THAILAND: Bangkok, Straits of Malacca, Pulau Labang, *Smith 995* (SING). **MALAYSIA:** Penang: Penang Waterfall Gardens, *Holttum s.n.* (SING); Pahang: TeKah, *Holttum 24678* (SING); near Tamerloh, *Holttum*

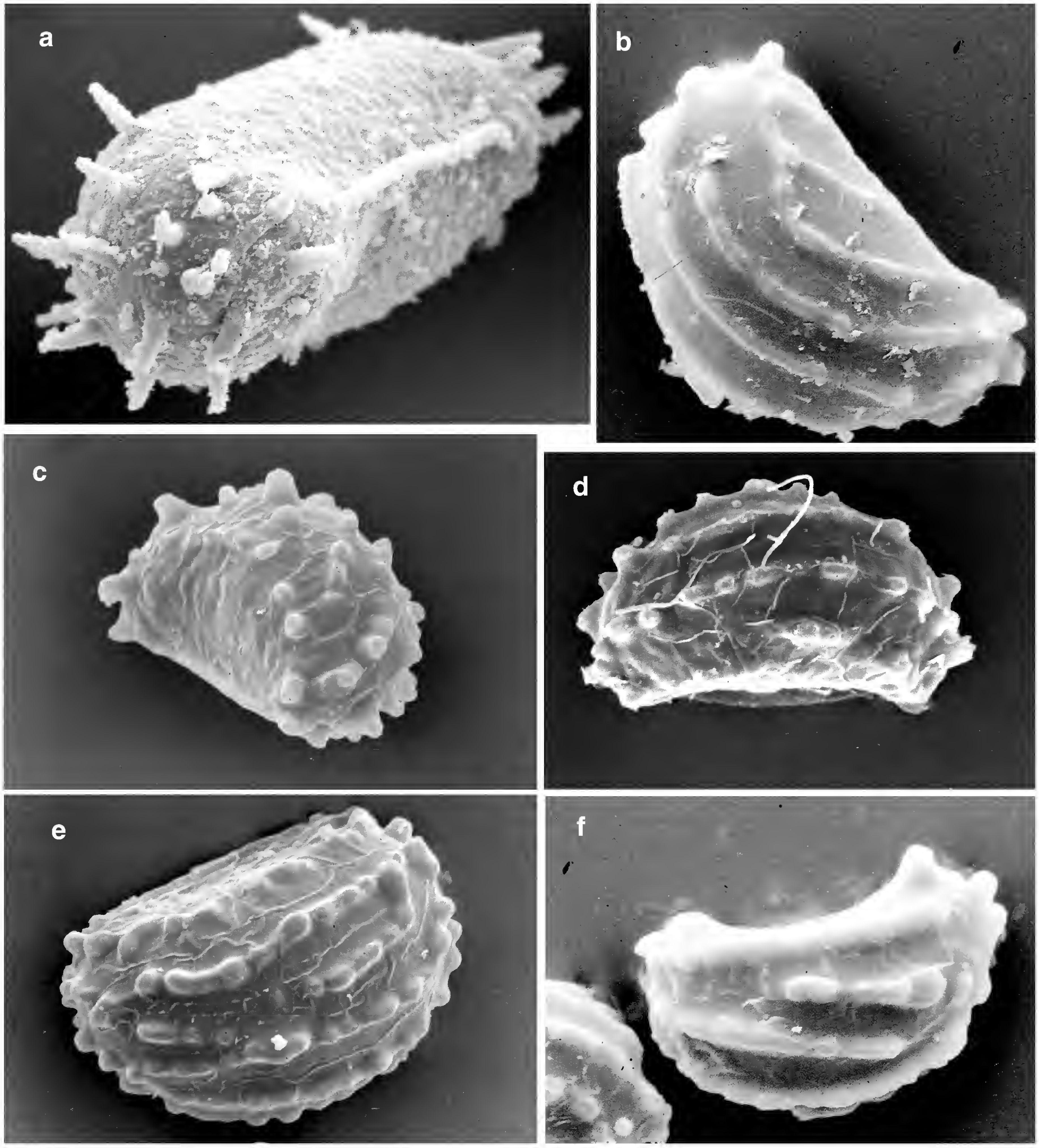

Fig. 1. Scanning electron micrographs of *Stenochlaena* spores. **a,** *S. areolaris*; **b,** *S. cumingii*; **c,** *S. milnei*; **d,** *S. palustris*; **e,** *S. tenuifolia*; **f,** *S. mildbraedei.*

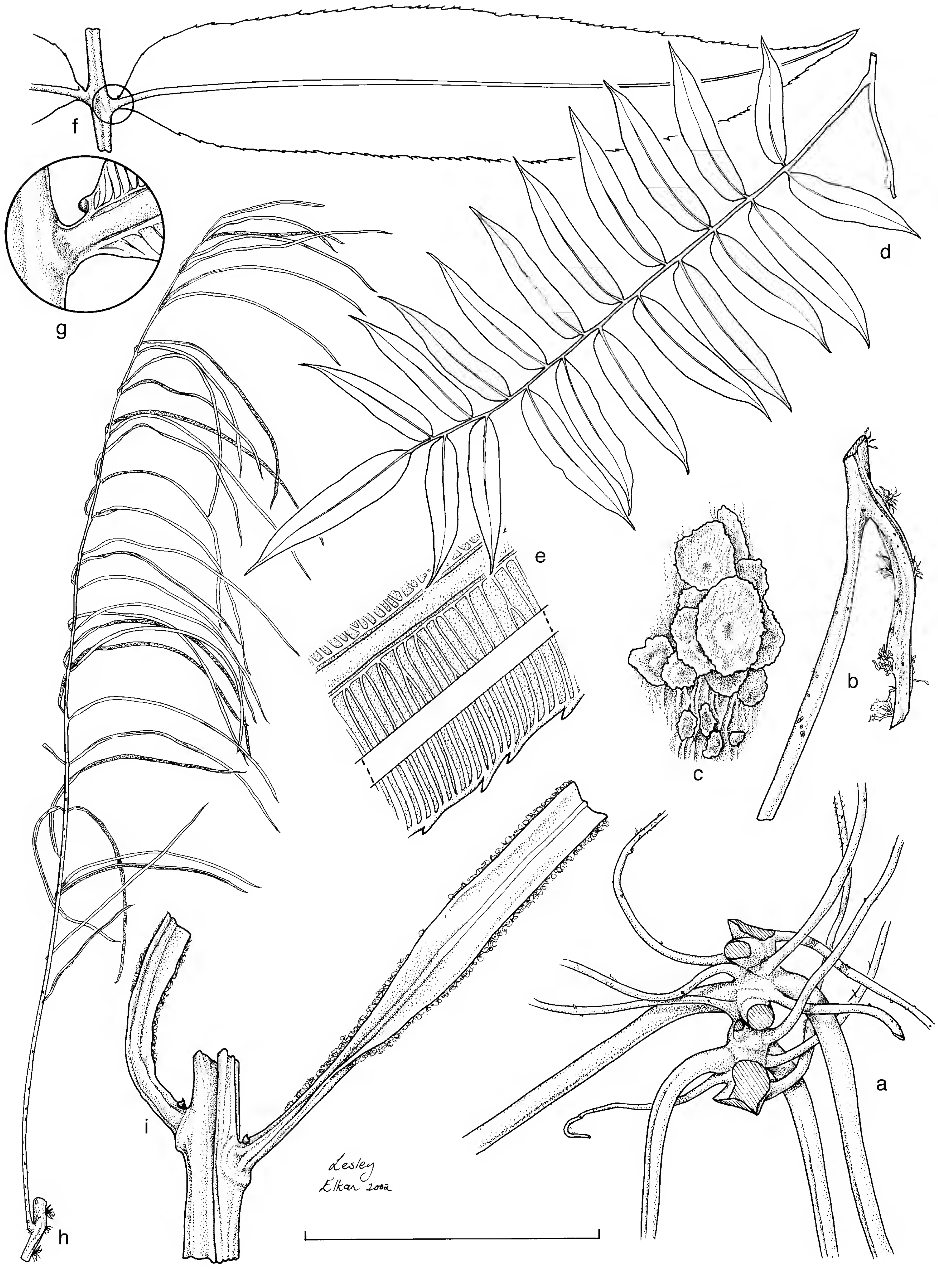

Fig. 2. *Stenochlaena palustris* (Burm.f.) Bedd. **a,** mature rhizome showing roots and stipes; **b,** rhizome showing characteristic branching and clusters of rootlets; **c,** peltate scales on the rhizome; **d,** sterile frond; **e,** detail of abaxial surface of a sterile pinna showing serrate margin and the lateral veins arising from the areolar vein closely parallel to the costa; **f,** rhachis and sterile pinna; **g,** abaxial view showing detail of articulation of pinna at the rhachis and the gland at the base of a pinna; **h,** fertile frond; **i,** adaxial view showing detail of base of fertile pinna, articulation at the rhachis and the gland. Scale bar: a, b = 7.5 cm; c = 0.4 cm; d, h = 20 cm; f = 5 cm; e, g, i = 1.2 cm. Specimens: a, *M. Raciborski s.n.* (L 0440437); b, h, i, *L.J. Brass 6441* (L 0441454, 55); c–g, *L.J. Brass 7648* (L).

24590 (SING); Selangor: Pulau Angsa, Kuala Selangor, *Wyatt Smith 71140* (SING); Klang Road, *Strugell, 13995*bis (L); **SINGAPORE:** Singapore Botanic Gardens, *Holttum s.n.* (SING); Kuala Trengganu *Hume* (SING). **PHILIPPINES:** Luzon: Labo, *Price 360* (L, NSW); Leyte: *Ramos 15311* (L, NSW). **INDONESIA:** Sumatera Utara: *Iwasuki et al 4532* (L, SING); Lampung: Enggano *Lutjeharms 4060* (L, SING); Java, *M. Raciborski s.n.* (L); Jawa Barat: *Holstrooyd 742* (L, SING); Bali: *van Steenis 7570* (SING). **PAPUA NEW GUINEA:** East Sepik: 'Nungrum', *Leach 34243* (L, NSW); Amba, *King s.n.* (NSW); Daru I. *Brass 6441* (L); Lake Davimbu, Middle Fly River, *Brass 7648* (L). **AUSTRALIA:** Northern Territory: Darwin and Gulf: Alligator River, *Bishop 827* (L, NSW, SING); 15 km SE of Darwin *Chippendale 6194,* (L, NSW, SING); Gove, *Croat 52473* (L, MO, NSW, SING); Howard Springs, *Beauglehole 10964* (L, NSW, SING); Arnhem Land, *Specht 1126* (L, NSW); Kakaku National Park, *Tindale 10002 & Nunns* (L, NSW); Bickerton I.,Gulf of Carpentaria, *Specht 452* (L, NSW); Cobourg Peninsula, *Letts 8316* (L, NSW); Melville I., *Briggs 8096* (L, NT, NSW). Western Australia: Gardner: South of Cockburn Range, Kimberleys, *Beauglehole 47133* (NSW, SING). Queensland: Cook: Daintree, *Jacobs 6183* (L, NSW).

Nomenclature and Typification: 1. Underwood (1906) was the first person to use this binomial and to cite *Polypodium palustre* Burm.f. as a synonym. Morton (1974) suggested that Beddome (1876) did not validly publish the combination and attributed it to Underwood, but it is clear that Beddome did make the combination, despite the vague, indirect reference to the basionym. Underwood was also the first to indicate a type for *Polypodium palustre*. His designation 'Type from Ceylon' can only be interpreted as a reference to the plate in Burman's *Thesaurus Zeylanicus* cited above.

2. Underwood (1906) was also the first to point out that Swartz was responsible for a "Change of Burmann's specific name without warrant." Swartz cited *Polypodium palustre* as a synonym, thus rendering his binomial illegitimate. Swartz has often been cited as parenthetic author for the binomial *Stenochlaena scandens* but John Smith did not cite Swartz, rather he cites 'Acrostichum scandens *Linn.*' as a synonym although Linnaeus apparently never published this name. The type of *Stenochlaena scandens* J.Sm. is difficult to determine. Smith's mention of Linnaeus might be taken as an indirect reference to p. 200 of his pre-starting point *Flora zeylanica* and to his citation of 'Burm. zeyl. 100. t. 46.' there, under the first entry on the page; otherwise, one of the three Cuming collections he cites would have to be chosen as lectotype. The first option is preferable.

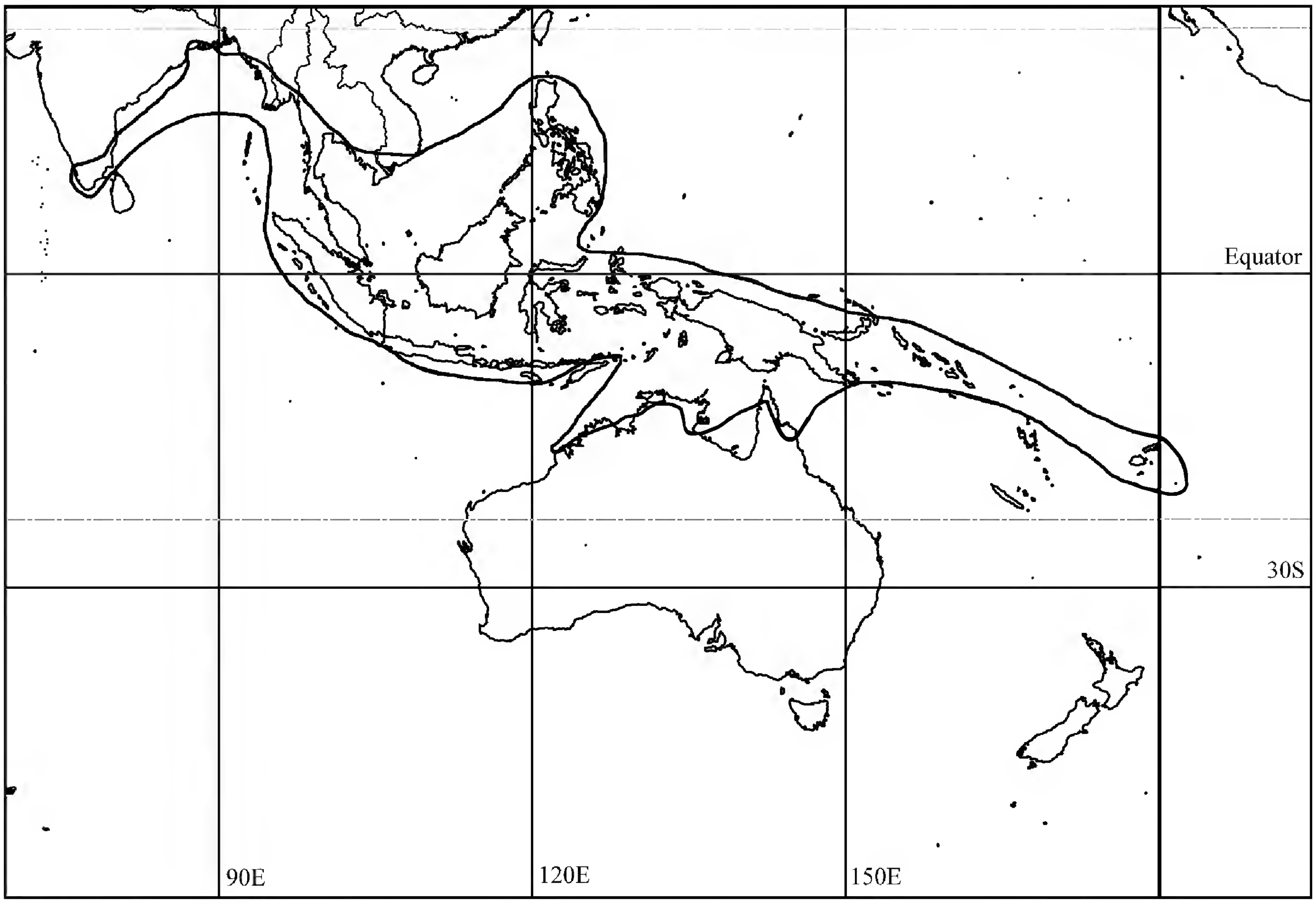

Fig. 3. Distribution map for *Stenochlaena palustris* (Burm.f.) Bedd.

3. Holttum (1932, 1939) adopted Presl's name *Stenochlaena laurifolia* following Hooker's concept (1864), accepting it as a distinct species. Later he was able to examine Presl's types and found that the Prague specimens of the type, *Cuming 226*, were "within the normal limits of variation" of *Stenochlaena palustris* (see Holttum 1969: 51, 52) and, therefore, not conspecific with specimens at BM and K, bearing the same number. Rather, these specimens were in agreement with Hooker's application of the name. Holttum (1971) subsequently published a new name for the taxon, *Stenochlaena cumingii*, typified by the Kew specimen of *Cuming 226* (see further note below, under *S. cumingii*).

Notes: 1. The sterile pinnae are variable in shape and size. At least some of this variation is a response to the position of a frond on the extensive rhizome of this liana. Unfortunately, the information on the position on a plant from which herbarium material has been collected is rarely given. I have not found any collection that gives a full representation of the variation in morphology to be found in the various zones inhabited by a single plant.

2. Two specimens collected by *van Daalen 460a* (L 0441508, L 04415090) are labelled *Stenochlaena palustris* f. *subintegerrima* Ros. (det. by Rosenstock, presumably unpublished) and annotated 'Vide Enumerationem Revisionis Filic. Palaeotrop. ex bibliotheca Ludg. Ba. No 13,679'. The sterile pinnae have margins tending to be entire at least in their basal half. This is a commonly observed phenomenon and is not worthy of formal recognition.

3. Another herbarium specimen (L 0441506) is labelled *Stenochlaena palustris* v. *pubescens* Ros., (det. by Rosenstock, 1922; probably also ined.) and is annotated 'Vide Enumerationem Revisionis Filic. palaeotrop. in Bibliotheca Herb. Lugd. Bat: No. 19191.' It has the abaxial surfaces of the stipe, rhachis, costae and pinnae surface densely pilose with very fine short, unicellular hairs less than 0.4 mm in length; on the pinna surface these arise from the lateral veins as well as from the areas between the veins. This appears to be a distinct variety but I have only seen this single, incomplete specimen.

4. A further specimen (L 0441504) is glabrous and labelled *Stenochleana palustris* var. *inermis* Ros. (det. by Rosenstock, 1922; probably also ined.) and is annotated 'Vide Enumerationem Revisionis Filic. palaeotrop. ex bibliotheca Herb. Lugd. Bat. No.18155.'

5. Occasional specimens produce bipinnate or at least partly bipinnate sterile fronds (see, for example, *Hennipman s.n.* [L 0441491] ex cult. Leiden), the pinnules of which are slender. However these pinnules always show, on careful examination, the areolae very close to parallel to their costae.

6. Holttum (1968) reports that the characteristic 'pinna gland' on the rudimentary basal pinnae are active secretory organs when the frond is very young and become blackened and shrivelled on older fronds (Troll 1932).

7. Locally known as *hagnáya* at Taytay, Palawan, in Manila as *diliman*. The tough climbing stems are brought to Manila in large quantities, and because of their durability in salt water, are extensively used by the local people for tying together the parts of bamboo fish traps'. Zamora & Co (1986) also list the local name '*lanas*' but without mentioning a particular region.

2. *Stenochlaena cumingii* Holttum, Amer. Fern J. 61: 122 (1971).

Type: Luzon, *Cuming 226* (holo: K; iso: BM; excl. dupl. PR, see note under *S. palustris*); see further note below.

Stenochlaena scandens var. β, J.Sm., J. Bot. (Hooker) 3: 401. 1841. **Type:** Philippines, Luzon, *Cuming 133* (K, L).

Stenochlaena laurifolia C.Presl, *sensu* Holttum, Gard. Bull. Str. Settl. 5: (1932) see note below.

Literature: Holttum, Gard. Bull. Str. Settl. 9: 140 (1937); Copeland, Fern Fl. Philippines, 428, (1960).

Published illustrations: Holttum (1932) as *S. laurifolia*, plate 18, fig.18.

Etymology: honours Hugh Cuming (1791–1865), who collected the type material from the Philippines on his third voyage to the Pacific region in his yacht *Discover*.

Rhizome robust, to 30 m, up to 2 cm diameter, with several large central vascular bundles and c. 2 outer whorls of numerous small bundles, (essentially similar in arrangement to those of *Stenochlaena palustris*), scales not observed; *stipes* robust, vascular tissue very complex with over 100 vascular bundles; *sterile lamina* oblong-ovate; *sterile pinnae* 2.5–3.2 cm wide, 12–25 cm or more long, broadest near their bases which are distinctly rounded to slightly cordate, not articulated, acuminate, margins strongly toothed, apex shortly attenuate, coriaceous, *costal areolar veins* giving rise to single or once furcate lateral veins; lowermost pinnae robust and usually serrate to almost dentate, almost sessile and rounded to sub-cordate and spaced on the rhachis,

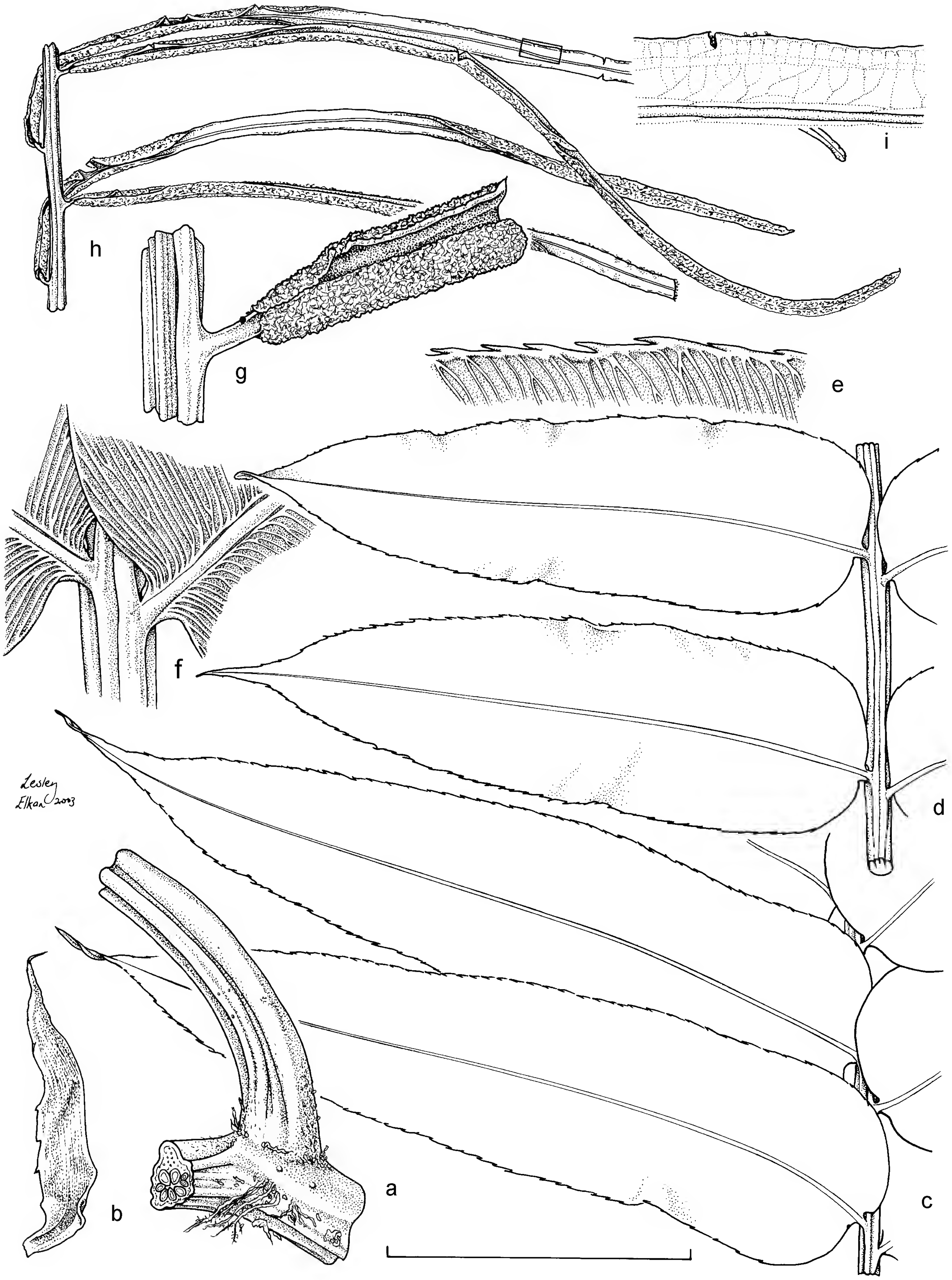

Fig. 4. *Stenochlaena cumingii* Holttum **a,** rhizome section and junction with base of stipe; **b,** rhizome scale; **c,** basal sterile pinnae; **d,** mid-region sterile pinnae; **e,** detail sterile pinna margin; **f,** adaxial view sterile pinna attachment to rhachis, lateral veins arising from areolae closely parallel to the costa; **g,** fertile pinna arising from rhachis, showing rolling of the lamina; **h,** fertile pinnae from mid-frond region **i,** venation abaxial surface of fertile pinna showing the network of lateral veins originating from the commissural vein parallel to and close to the costa. Scale bar: a, c, d = 6 cm; b = 0.6 cm; e, i =1.5 cm; f, g = 2 cm; h = 10 cm. Specimens: a, b, *Beguin 1170* (L 0440287); c–f, *Cuming 133* (L 0440273); g–i, *J.R.Croft 1703* (L 0441486).

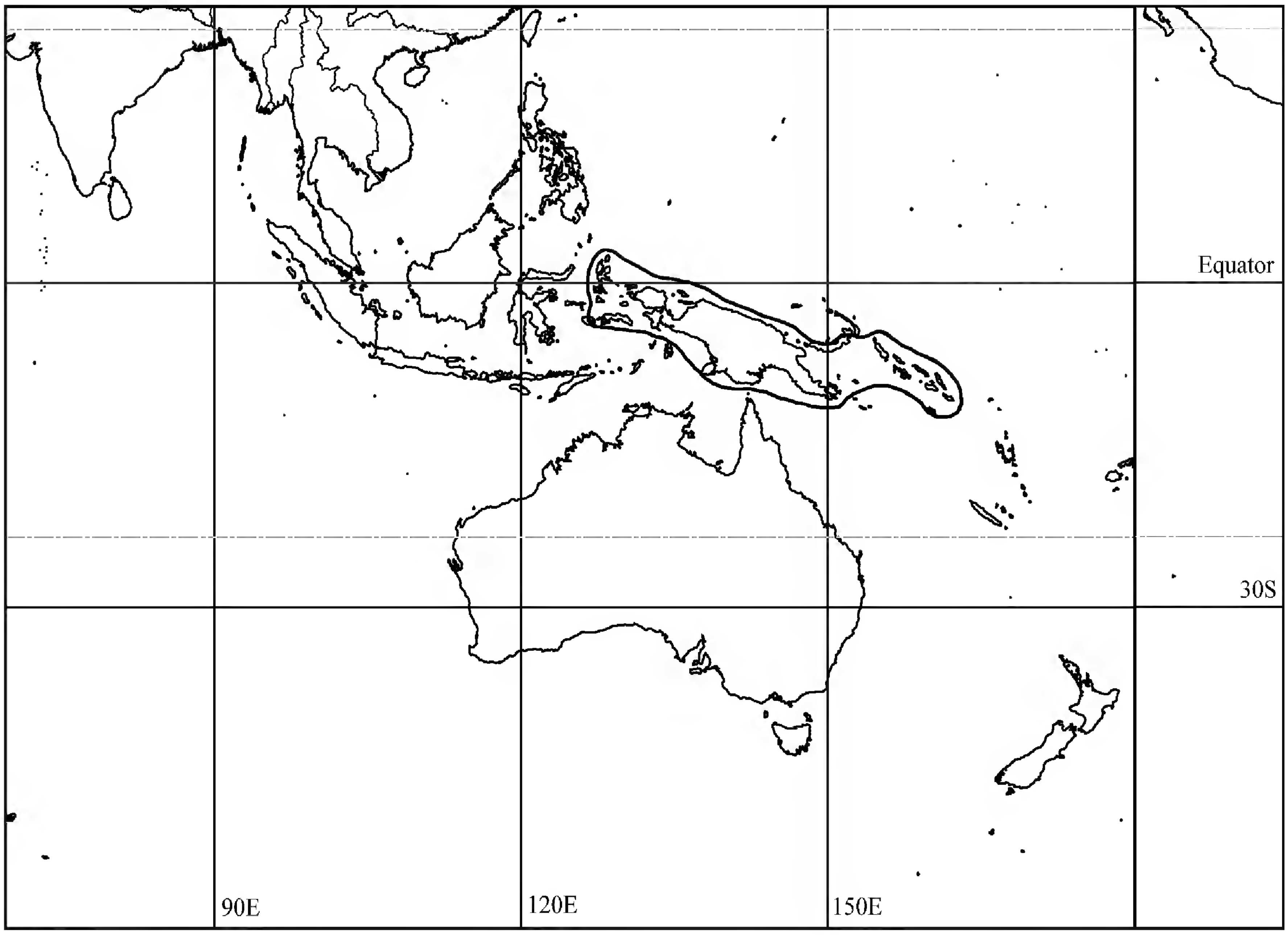

Fig. 5. Distribution map for *Stenochlaena cumingii* Holttum.

towards the lamina apex the pinnae decrease in length, become shortly stalked and increasingly imbricate and cuneate at their bases and less serrate than lower pinnae; a *gland* is present on the acropetal margin at the base of the lateral pinnae (but sometimes difficult to detect), *terminal pinna* usually lacking a gland. *Fertile fronds* with *fertile pinnae* mostly shortly stalked, up to at least 30 cm long, 7–10 mm wide, with a network of sub-costal areoles and anastomosing veins not extending to the sometimes finely toothed margins which are reflexed at maturity; veins can be observed on the adaxial surface showing numerous anastomoses. Fig. 4.

Spores pale yellow, with numerous blunt spiny projections along elongate parallel ridges. Fig. 1b.

Distribution and habitat: extending from the Philippines, through Maluku to Papua New Guinea (Holltum 1971), possibly occurring in the Solomon Islands, especially on the edges of forest habitats. Fig. 5.

Specimens examined: PHILIPPINES: Luzon: *Cuming 226* (K, BM); Cuming 133 (L 0440273). **INDONESIA:** Maluku: Ternate, *Beguin1170* (L 0440287).

Note: 1. Hooker (1864) accepted *Stenochlaena laurifolia* C. Presl as distinct. Holttum (1932, 1939) followed Hooker in this, but later discovered that Presl's type, *Cuming 226*, was not conspecific with specimens bearing the same collector's number at K and BM (see Holttum 1969: 51, 52). Holttum attempted to address this by publishing the nom. nov., *S. cumingii*, but Morton (1970: 123) pointed out that this did not constitute valid publication of the name, which would require a Latin description and designation of a type. Holttum (1971) remedied this and designated the Kew specimen of *Cuming 226* as holotype.

2. Very few specimens were available for study and a number of characters were poorly preserved or missing, e.g. rhizome scales. The species has been reported from Papua New Guinea but no specimens were located.

3. *Stenochlaena milnei* Underw., Bull. Torrey Bot. Club 33: 38 (1906).

Type: Solomon Islands., *Milne 518* holotype: K; paratypes: *Milne 590*; New Guinea, *Honkmann* s.n. K; Admiralty Is., *Moseley s.n.* (K).

Stenochlaena juglandifolia sensu Holttum, Gard.Bull.Str. Settl. 9: 139 (1937).

Literature: Copeland, Fern Fl. Philippines 428 (1960) as *S. juglandifolia*; *non* C. Presl, Epimel. 164 (1849).

Etymology: honors William Grant Milne, a Scottish botanist and horticulturist who collected the original specimens of this taxon on the voyage in the 18th century of the sailing ship 'HMS Herald'.

Rhizome climbing and similar to that of *S. palustris,* symmetry radial; scales peltate to linear-acuminate, 4–5 mm long, 1 mm wide at base, entire to irregularly toothed and with a peltate attachment. S*terile fronds* large, with glabrous stipes, vascular bundles numerous (usually more in number than in *S. palustris*); *sterile lamina* oblong acuminate to oblong-ovate, ± 10 pairs pinnae; *sterile pinnae* large and robust, in the mid-lamina region 15–25 cm long, 2.5–3 (–3.5) cm wide, oblong and attenuate, mostly not distinctly articulate to the rhachis, broadly rounded and entire at their bases but remaining margins cartilaginous and conspicuously toothed; terminal pinna not much larger than the subtermina. *Fertile fronds* with both *stipe* and *fertile lamina* of about the same dimensions and outline as for the sterile frond; *fertile pinnae* as long as or longer than sterile pinnae, at least 5 mm wide. Fig. 6.

Spores with tubercles emerging from irregular discontinuous ridges. Fig. 1c. Holttum (1971) and Tryon & Lugardon (1990) illustrated a spore from a New Guinea specimen (*Clemens 3125*), indicating fewer tubercles (than in Fig 1c) that are randomly distributed on irregular discontinuous ridges.

Distribution and Habitat: occurs in closed forest in humid habitats. It is less frequent in collections, probably indicating it is less common in occurrence. It is reliably recorded from the Philippines, Indonesia (Maluku), Papua New Guinea and Solomon Islands. Fig. 7.

Specimens examined: PHILIPPINES: Luzon: Mt. Makiling, Laguna, 420 m, *Price 476* (L); Luzon, *Elmer 16253* (L); *Cuming 133A* (L). **INDONESIA:** Maluku: Ceram, *de Vriese,.Teijsmann s.n.* (L 0440288, 0440289); Hunitetu, Kairatu, 350-400 m, *Kato et al c-2184* (L, BO.); Trail to Mt Totaniwel, Kecamatan District, Kairatu,120 m, *Kato et al C-13290* (L, BO), N of Piroe *Rutten 1914* (L); Hunitetu, *Kato et al c-2194* (L); Ternate, Sasa-ketjil, *.Beguin 1170* (L); Tehoru, *Kato et al c-13760* (L, BO); Trail from Wae River to Tehoru, *Kato et al c-11742* (L, BO); West New Guinea,Vogelkop: (probably) Forest Reserve Tafelberg, *Versteegh & Vink BW 8398* (L). **PAPUA NEW GUINEA:** West Sepik: N. slope of Bewani Mts. *Croft 1703B* (NSW) & 1703 (one sheet of two at L, A, CHR); Papuan Islands: Salamo, Fergusson I. *Streimann & Lelean LAE52572* (L).

Notes: 1. Holttum (1937) pointed out that *Stenochlaena milnei* (as *S. juglandifolia*) is intermediate in a number of characters between *S. palustris* and *S. cumingii* (*S. laurifolia*) including shape of base of sterile pinnae, articulation of the pinnae, width of fertile pinnae, number of vascular bundles in the stipe and the distribution of tubercles on the spores.

2. Holttum (1971) confirmed that *Stenochlaena milnei* is 'almost an exact intermediate between *S. palustris* and *S. cumingii*' indicating that *S. milnei* may be of hybrid origin.

3. *Stenochlaena milnei* is a very robust fern, sometimes confused with large specimens of *S. palustris.* However in *Stenochlaena milnei* the rhachis ridges are more complex and support much larger and more consistently oblong pinnae and more conspicuously toothed pinna margins the teeth closer together especially towards the pinna apices; pinnae are often with attenuate apices sometimes with the appearance of drip tips. Fertile pinnae of *S. milnei* at maturity are very much more robust than those of *S. palustris.*

4. Some specimens that are intermediate in their morphological characters between *Stenochlaena milnei* and *S. palustris* are probably backcrosses to the parental species. e.g. *McKee 1643* (NSW) from Betivatu, British Solomon Is. (Guadalcanal) and *Gideon LAE78512* (L, NSW) collected from Mt Bagana, Torokina, North Solomons Province (Bougainville) and *Hennipman 5689* from Sulawesi Tengah (L) are specimens that would appear to be either the result of dominance of *S. milnei* characters or the product of further backcrossing to *S. milnei*. A specimen from Sirinumu (Central, Papua New Guinea), *R. Schodde 2986* (L) is intermediate in a number of characters and is also possibly a hybrid with *S. palustris.*

5. Holttum (1971) reported that *S. milnei* is the common species in the vicinity of Lae (Morobe), Papua New Guinea whereas *S. palustris* is not common.

6. Underwood's original description (1906: 38) was based on fragmentary specimens at K. Although additional material available for the present study has made a more complete description possible, the specimens available lack some details. Pinna variation indicates a wide range in the degree of stalk development and this may, with more carefully documented collecting, be indicative of a response to the position of a sterile frond on the plant; this is possibly an important detail not noted on any of the specimens examined.

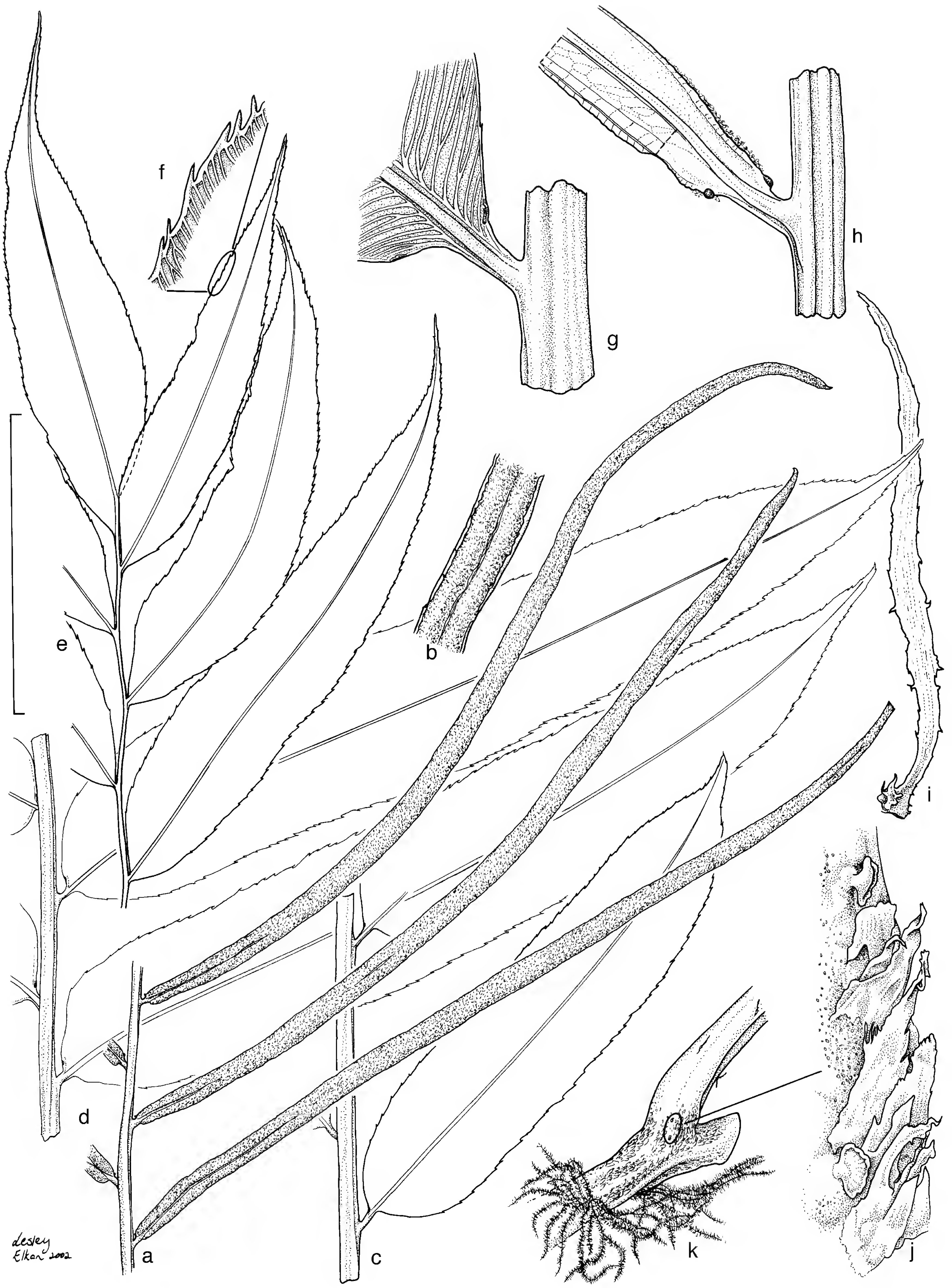

Fig. 6. *Stenochlaena milnei* Underw. **a,** mid-region of fertile lamina, abaxial surface; **b,** abaxial detail of pinna from base of fertile lamina; **c,** sterile pinnae from basal region; **d,** sterile pinnae from mid-region; **e,** sterile pinnae from apex of lamina; **f,** slightly irregular serration detail of sterile pinna margin; **g,** detail of sterile pinna base; **h,** fertile pinna bases showing glands venation in dissected region; **i,** detail rhizome scale; **j,** rhizome scales in situ; **k,** detail of rhizome and typical clustering of roots. Scale bar: a, b, c, d, e & k = 8 cm; f, g, h =2 cm; i, j = 0.6 cm. Specimens: a–c, f, g, *J.R. Croft LAE 373938*, L 0440309; d, e, *J.R. Croft 68280* L 0440308; f, g, *J.R. Croft* L 0440309; h–k *L.J. Brass 27581* L 0440311.

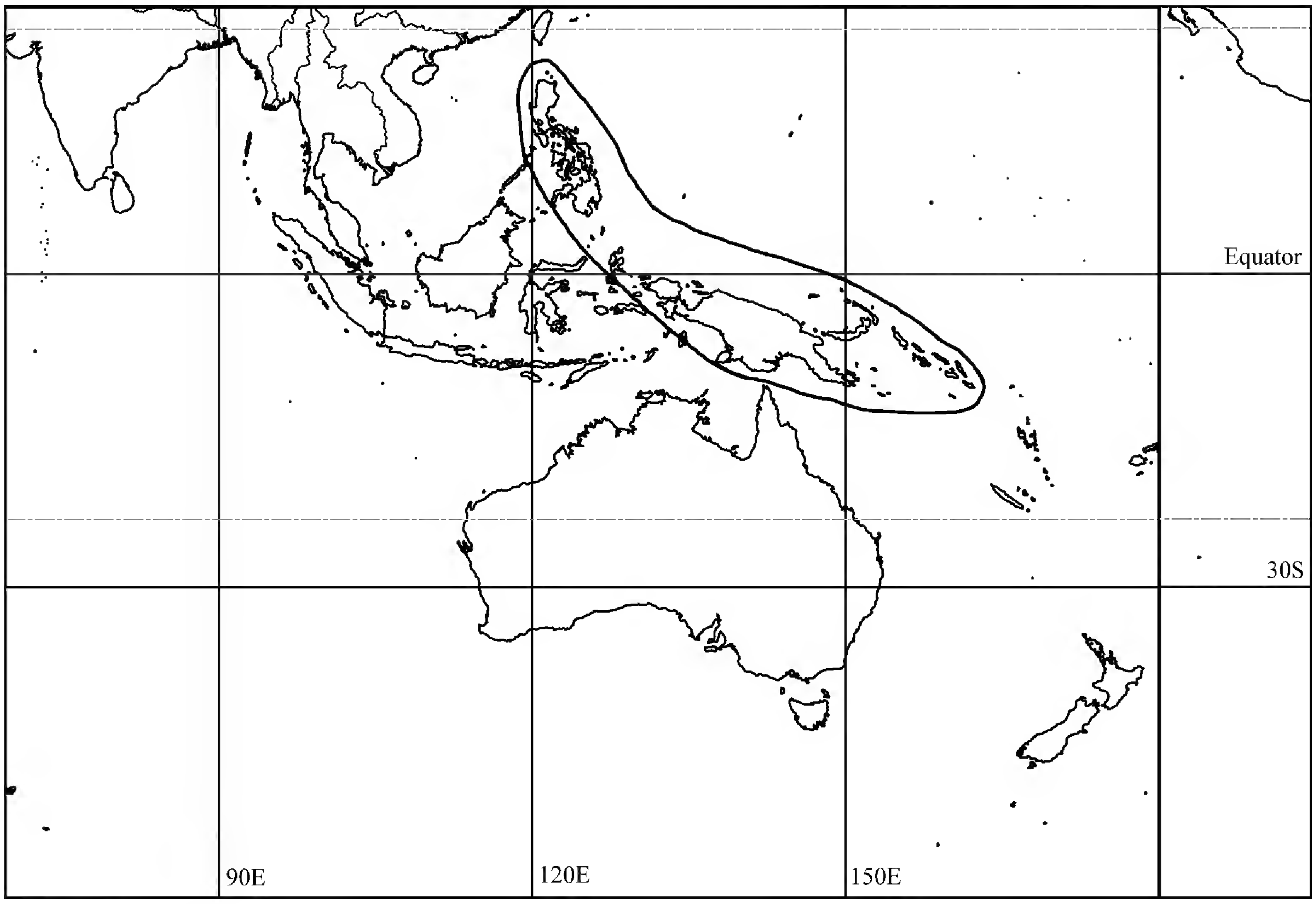

Fig. 7. Distribution map for *Stenochlaena milnei* Underw.

4. ***Stenochlaena areolaris*** (Harr.) Copel. Philipp. J. Sci. 2C, 406 (1908); Fern Fl. Philippines 427(1960).

Lomaria areolaris Harr., J. Linn. Soc. Bot. 16: 28 (1877); *Spicanta areolaris* (Harr.) Kuntze Rev.Gen. Pl. 822 (1891); *Blechnum areolare* (Harr.) C. Chr. Ind., 150 (1905.

Type: PHILIPPINES: Luzon: Mount Mahayhay, *Steere*, 'Growing among the leaves of a *Pandanus*' (holo: MICH?, n.v.).

Published illustrations: Holttum (1932: 252, fig. 3) drawing of spore.

Etymology: from the Latin 'areola' which describes the often conspicuous spaces defined by the vein pattern on the sterile pinnae, especially the shapes created by the commissural veins parallel on either side of the costa (Fig. 8 d, i).

Crown epiphyte with *rhizome* to about 30(– 90) cm long, smooth, buff-coloured, relatively slender 1–2.5 mm diameter often twisted, and giving rise to slender branches (0.5–1 mm diameter), each terminated by a tuft of minute, linear-acuminate, red-brown almost entire, and somewhat clathrate scales 2 mm long, 0.5 mm wide. *Sterile fronds* with *stipes* smooth, glabrous, stramineous and up to 25 cm; *sterile lamina* to 30 cm, ovate to oblong-lanceolate, coriaceous. *Sterile pinnae* few, typically up to 7 pairs spaced, ovate, acuminate, finely serrate, sessile to sub-sessile (up to 10 cm long, 2.2–3 cm wide on mature specimens); *lateral veins* single or once furcate, arising from *areolae* less than 1/6 width of a pinna and usually more distinct on adaxial surface; *sterile pinnae* with bases rounded to sub-cordate; *terminal pinna* as large or larger than sub-terminal pinna; usually on any one plant there are also smaller fronds with fewer pinnae, 2.5 cm long, 0.8 cm wide. *Fertile fronds* with *stipes* 50 cm long or more, significantly longer than the stipes of sterile fronds; *fertile pinnae* 7–9 pairs, to 100 mm long, 3–4 (– 6) mm wide with margin thin, 1mm wide, forming a false indusium during early development of sporangia and becoming reflexed at maturity when sporangia appear to cover the abaxial surface. Fig. 8.

Spores relatively elongate, tubercles or spines are slender and longer than in other members of the genus and are usually more densely clustered at the polar ends which tend to be flattened. Fig. 1a.

Fig. 8. *Stenochlaena areolaris* (Harr.) Copel. **a,** habit; **b,** detail of base of sterile pinna showing glands; **c,** sterile pinna base showing the articulated junction at the rhachis; **d,** sterile pinna showing areolae parallel to the costa giving rise to the lateral veins; **e,** base of fertile pinnae abaxial surface showing the gland; **f,** fertile pinnae adaxial view; **g,** fertile lamina abaxial surface; **h,** roots arising from rhizome; **i,** juvenile plant showing rhizome, roots and juvenile frond with three pinnae with conspicuous areolar veins. Scale bar: a = 12 cm; b = 2 cm; c = 1 cm; d = 4 cm; e, f = 1 cm; g, h = 6 cm; i = 4 cm. Specimens: a, b, *M.G. Price 285* (NSW); c, d, i, *M.G. Price 578* (L); e–g, *J. Croft* 1110 (NSW); h, *A.D.E. Elmer 7961*(L L044026).

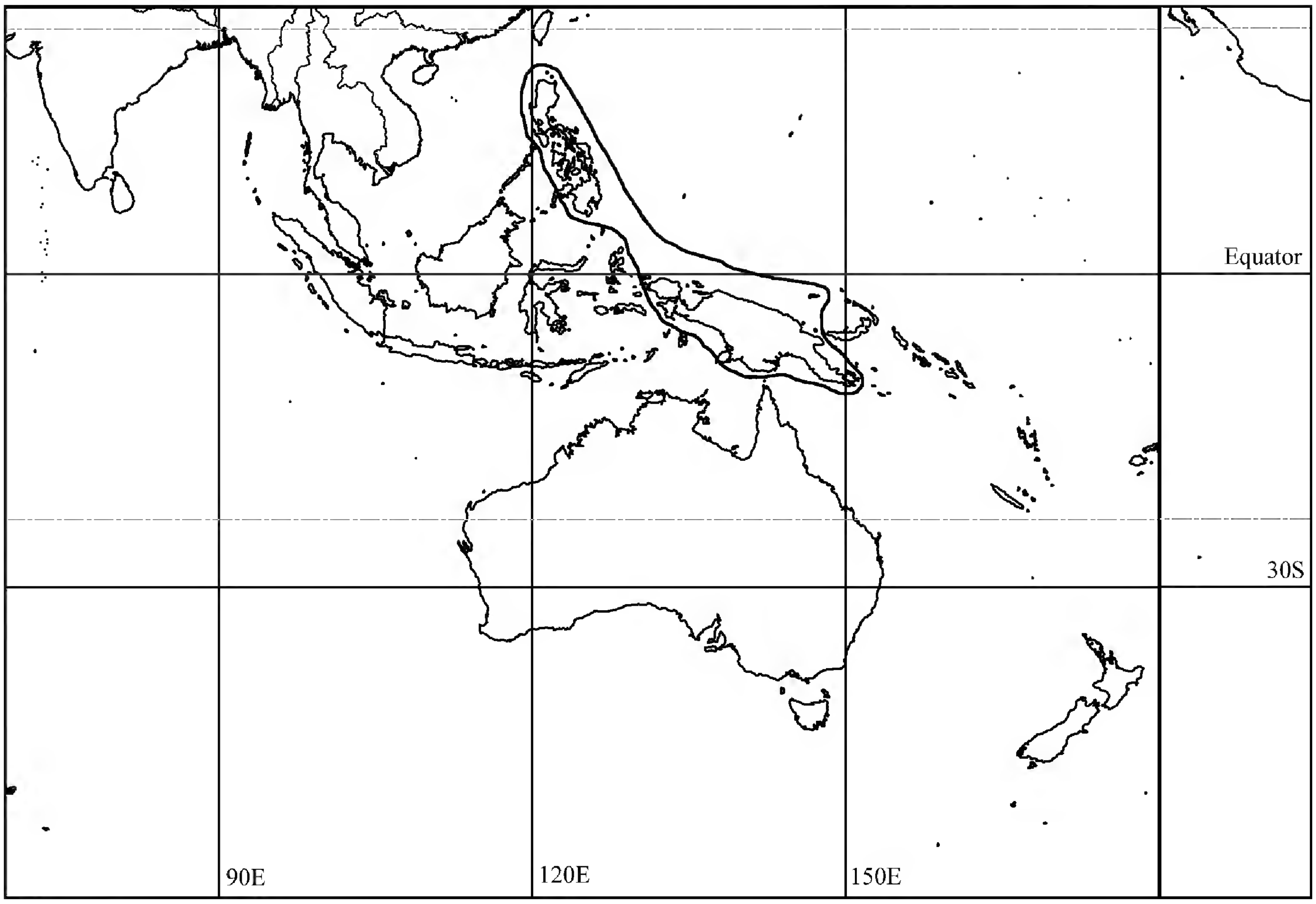

Fig. 9. Distribution map for *Stenochlaena areolaris* (Harr.) Copel.

Chromosomes: $2n = $ c. 73 (fide note on specimen L440260; collector: *Price 578*, Luzon, Philippines).

Distribution and habitat: occurs in the Philippines (from Luzon to Mindanao) and in Papua New Guinea. There are no confimed records from outside Malesia and Papuasia. Fig. 9. This is a tropical species extending from sea level to lower montane areas up to at least 1500 m. From field notes on herbarium specimens *S. areolaris* is an aquatic species, usually an epiphyte and more rarely an epilithic species growing over wet rocks adjacent to a nearby water supply or in stagnant pools. Most specimens examined have been noted as being collected from water pockets in the crowns and leaf bases of *Pandanus* spp. as well as the crowns of various genera of palms and there is nothing to indicate the rhizomes connect to the ground. Some records indicate that *S. areolaris* survives on palms in more open habitats, probably in secondary vegetation. Frequently overlooked by collectors, possibly because it is inconspicuous in the crowns of tall trees.

Notes: 1. Harrington (1877) originally regarded this taxon as a species of *Lomaria*, incorrectly interpreting the presence of a narrow marginal thickening as an indusium which he stated 'is readily overlooked, except in young plants'

2. Collectors have reported that the natural 'tanks' in which this taxon grows are often packed with a tangled mass of rhizomes and roots of *S. areolaris*, sometimes with branches of the rhizomes extending to many water-filled axillary pockets.

Selected specimens examined: PHILIPPINES: Luzon: Laguna, between Cavinte and Luisiana. In water pockets of leaf-bases of *Pandanus simplex*, voucher for $2n = $ c. 73, *Price 578* (L, NSW, BM, GE, K, MEL, PUH, TAI, U, US); Laguna, between Luisiana and Lucban, *Price 285* (L, NSW, K, MEL, OSAK, PNH, US; Tayabas Prov. Lucban, *Elmer 7961* (L). **INDONESIA:** West New Guinea: Jayapura: Idenburg River, 850m, wedged between leaves of tall *Pandanus*, *Brass 13417* (A, L); Rouffaer River, 175 m, *van Leeuwen 9909* (B, L); "nova Guinea neerlandica meridionalis", *Versteeg 1102* (L, BO). **PAPUA NEW GUINEA:** West Sepik: Meinet floodplain, N. slopes Bewani Mts, *Croft 1709* (CANB, K, L, NSW); Star Mountains, Busilmin northern foothills 1500m, rhizome entwined in crown of *Pandanus*, *Croft LAE65705* (L, K, BM). Manus: Manus I., fronds reported to be eaten by villagers, *Croft 1110* (NSW); Morobe: E. of Mongi River, Huon Penin. 700m ridge forest, *Croft 453* (L); Wagau, Numeng Sub-District, epiphytic on *Pandanus* in grassland habitat, 4000 ft (1200m), *Streimann & Kairo NGF35819* (L, LAE); Papuan Islands: Sudest I., Mt Riu, *Croft 774* (NSW).

African and African Island Taxa

5. *Stenochlaena tenuifolia* (Desv.) Moore, Gard. Chron. 1856: 193 (1856).

Basionym: *Lomaria tenuifolia* Desv., Mag. Ges. Naturf. Fr. Berlin Mag. 5: 326 (1811); Synonyms: *Lomariobotrys tenuifolia* (Desv.) Fée, Mém. Fam. Foug. 5: 46 (1852); *Polybotrya tenuifolia* (Desv.) Kuhn, Fil. Afr. 52 (1868); *Acrostichum tenuifolium* (Desv.) Bak. Syn. Fil. 412 (1868); *Lomariopsis tenuifolia* (Desv.) Christ, Farnkr. 42 (1897).

Type: Madagascar, *Commerson* (holo: P n.v.; see Schelpe & Anthony 1986).

Lomaria meyeriana Kunze, Linnaea 10: 509 (1836); *Stenochlaena meyerana* (Kunze) C.Presl, Epim. Bot.166 (1851); *Polybotrya meyeriana* (Kunze) Mett. Fil. Bot. Lips.24, t.1 figs 4 & 7 (1856); *Acrostichum meyeranum* (Kunze) Hook.Gdn Ferns, t.16 (1862); Sp. Fil. 5: 249 (1864). **Type:** South Africa: "In palude sylvatica inter a Omtendo et Omsamculo, 70 m.", *Drège s.n.*, Mar 1832 (lecto: B, isolecto BM, n.v.; designated by Roux 1986: 357).

Literature: Tardieu-Blot, Fl. Madag. Fam. 5, 1: 110, f. 16, 1-3 (1958); Morton, Amer. Fern J. 51: 165 (1965); Schelpe, Fl. Zamb. Pterid. 240, t. 69 (1970); Holttum, Amer. Fern J. 61: 120 (1971); Jacobs, Ferns of Southern Afr. 471, t. 22, 353 (1983); Schelpe & Antony, Fl. Southern Afr., Pterid. 277-8 f.96 (1986); Roux, Pterid. 211 (2008).

Published illustrations: Hooker, (1862) Garden Ferns, pl 16 as *Acrostichum meyerianum*; Jacobsen (1983) f. 353a, b; Burrows (1990) pl. 56.3, illust.82 p.337; Schelpe (1970) t. 69, figs 1, 2. For spores see Tryon & Lugardon 1990 figs 211.4 & 5; Tardieu-Blot, Fl. Madagascar et des Camores (1960) Pl.16, fig. 1, 2, 3 (drawings sterile pinna, fertile frond and spore).

Etymology: in reference to the relatively slender sterile pinnae and to the very slender fertile pinnae and pinnules.

Rhizome extensive, usually at least 20 m long, weakly dorsiventral, but radially symmetrical in cross section, creeping and climbing (and always connected to the ground), 1–2 cm diameter, green to purple-black in fresh material, scaly in young stages becoming ± glabrous except for a few persistent scales; scales dark-brown, small, linear triangular acuminate, often with minute marginal outgrowths 1–5 mm long; *sterile fronds* large, up to 3 m long; *stipes* stramineous, glabrous, reported to be up to 2 cm diameter towards the base and up to about one third the length of the frond; *sterile lamina*, ovate to oblong, 0.5–2 m long and 2–70 (– 75) cm wide, chartaceous to coriaceous. *Sterile pinnae* about 20 pairs, oblong-ovate to linear-lanceolate, tending to be cuneate at the rhachis, 15–35 cm long x 2–3.8 cm wide near the base; pinnae glabrous on both surfaces, glossy green adaxially, dull green abaxially and sometimes with a conspicuous gland at the base on the anterior margin; *margins* finely serrulate to serrate, usually tapering evenly to an acuminate apex which is sometimes shortly attenuate; base of pinna rounded to shortly (and sometimes unequally) cuneate, shortly stalked, not articulate; *terminal pinna* about the same dimensions as the sub-terminal lateral pinnae, occasionally very much longer. *Fertile lamina* bipinnate, occasionally pinnate distally, usually shorter than sterile lamina, typically 0.5–1.5 m long; *fertile pinnae* 25–30 pairs, 8–25 cm or more long and very slender, 1.5–3 mm wide, alternate and sometimes decurrent, adnate to shortly stalked with the gland on the stalk. Fig. 10.

Spores pale yellow-brown to almost colourless, with the tubercles mostly on the irregular ridges, sometimes somewhat coalescent in parallel bands. Fig. 1e.

Chromosomes $n = 72–74$ (Manton & Sledge 1954).

Distribution and habitat: *Stenochlaena tenuifolia* is a widespread species (Fig. 11) extending in favourable habitats from tropical east Africa south through Mozambique to eastern South Africa, including Zululand, Natal, and Transkei, mainly in coastal forests and with isolated populations in the inland Barberton district of Transvaal at over 500 m and also inland at comparable high elevations in Mozambique, Zululand and Natal. The species is a vigorous liana climbing a wide range of tree species and usually is found in humid areas, often on stream margins in swampy places where soil moisture is present even in dry periods.

This species is also present in Zanzibar and the Seychelles and Grande Comoro Island, and also a number of localities in Madagascar (Christensen 1931, Tardieu-Blot 1958). Lorence (1978) reports that *S. tenuifolia* has been recorded but not recently seen in the wild in Mauritius, probably due to the clearing for agriculture of much of the forested areas. I have not seen any records for this taxon from the other islands of the Mascarenes, i.e., Réunion and Rodrigues.

Selected specimens examined: SOUTH AFRICA: Natal: North Coast, 5 m., *de Joncheere SAC 338* (L). **MOZAMBIQUE:** E. of Haroni/Lusitu River confluence, 700 m Manica E. Sofala, *Goldsmith 36/72* (L, SRGH).

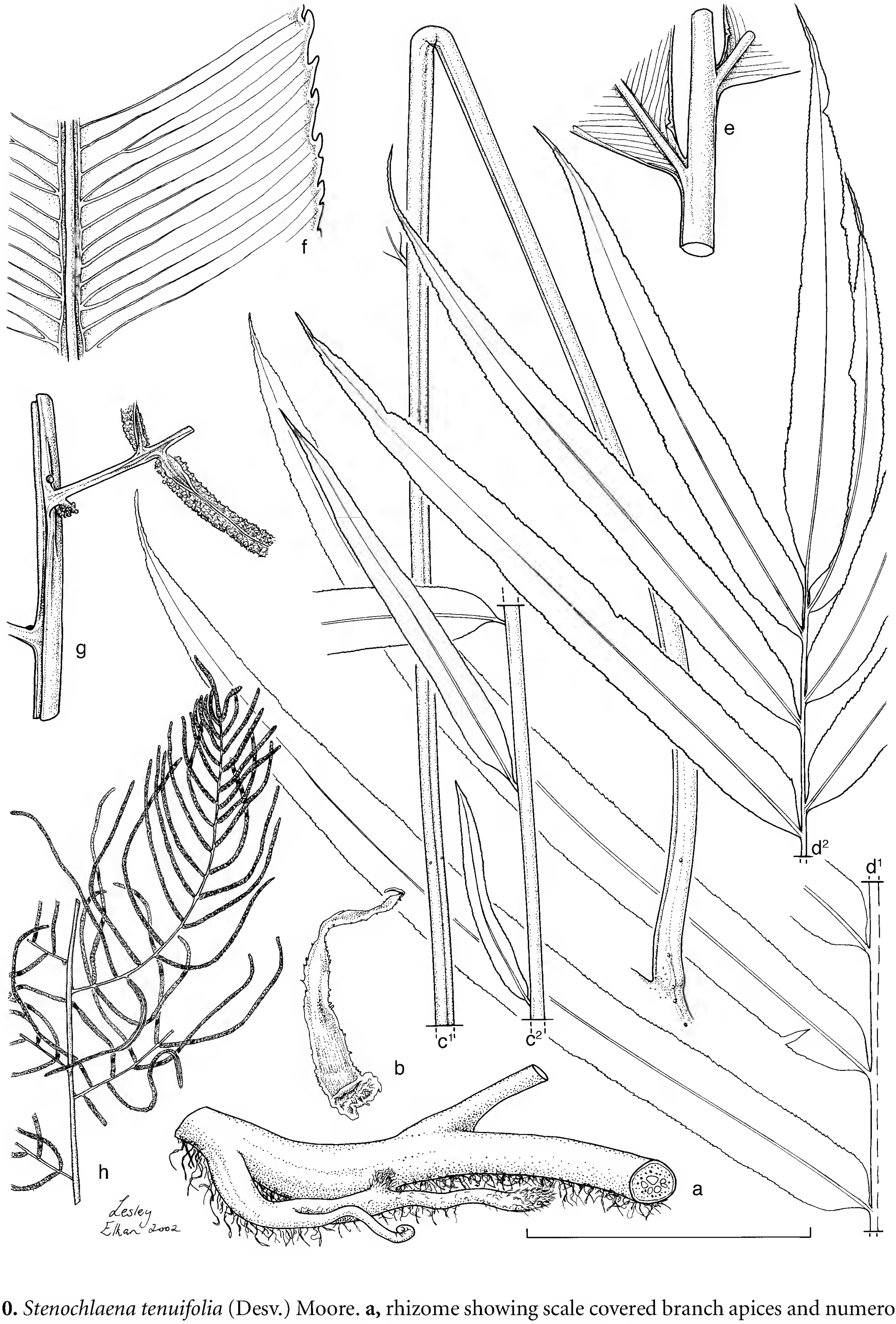

Fig. 10. *Stenochlaena tenuifolia* (Desv.) Moore. **a,** rhizome showing scale covered branch apices and numerous roots and the main rhizome in cross-section; **b,** scale from apical region of the rhizome; **c, d** sterile frond showing full length of stipe (c1), lamina with basal pinnae (c2), pinnae of mid-region (d1) and terminal pinna and several sub-terminal pairs of pinnae (d2); **e,** sterile pinna-base showing the inconspicuous gland; **f,** mid region of sterile pinna showing lateral veins arising from areolar veins closely parallel to the costa; **g,** detail of fertile pinnae and rhachis, adaxial view; **h,** portion of fertile frond showing bipinnate habit, abaxial view. Scale bar: a & h = 10 cm; b = 0.4 cm; c, d = 10 cm; e = 2 cm; f = 1 cm; g = 2 cm. Specimens: a, b, *de Jonchere SAc.338* (L); c–f, *B. Goldsmith 36/72* (NSW); g, h, *J.C. Scheepers 2401* (NSW).

Notes: 1. Schelpe & Antony (1986) reported that the species only produces fertile fronds in areas of high light intensity; plants in closed forests only produce fertile fronds at canopy level.

2. Morton (1965) reported a variant in cultivation in the University California Botanical Garden, introduced from Zululand, South Africa, with extremely narrow pinnae. I have not seen any specimens of this form.

6. *Stenochlaena mildbraedii* Brause, in Brause & Hieron., Bot. Jahrb. Engler 53: 384 (1915).

Type: Fernando Poo, Central Africa: Bioco; Musola oberhalb San Carlos, 500 m (Westkűste), growing on the trunks of the palm, *Raphia*, *G.W.J. Milbraed 6995* (lecto [fide Tardieu-Blot 1964: 354] B20 0121855, photo). Residual syntypes: Cameroon: Südkameruner Waldgebiet: Bezirk Ebolowa, *Mildbraed 5554* (4 sheets, B); Cameroon: Molundu, 21 km Nördlich Molundo *Mildbraed 4192* (3 sheets, B).

Literature: Tardieu-Blot, Mém. L'Inst. Francais D'Afrique Noire 28: 86, 87 pl. 39 f. 5, 6 (p.198) (1953); Tardieu-Blot, Fl. Cameroun 3: 353–354, pl. 34, f.5, 6 (1964); Alston, Fl. W. Trop. Afr. ed. 2, Suppl. Pterid. p. 50 (1959); Holttum, Amer. Fern J. 61: 121 (1971); see discussion below and Schelpe, Conspectus Florae Angolensis, Pteridophyta, 185 (1977); Benl, Acta Bot. Barcinonesia 38: 63 (1967).

Etymology: honouring the German botanist and collector G.W.J. Mildbraed who made several expeditions to tropical West Africa and obtained the Type of this species.

Rhizomes indeterminate, very long, 1.5 cm or more in diameter, frequently branching, scrambling and climbing, adhering to supporting vegetation by means of clusters of short roots and giving rise to successsive spaced fronds, internally with 10 large central bundles in a ring surrounded by 2 rings of more numerous small bundles (approx 30 in each ring); the young growing apex densely clothed with scales; *scales* mid to dark-brown, concolorous, shiny, acuminate and entire or almost so, 6 mm long, 1–1.5 mm wide at base, mostly deciduous, sometimes minutely toothed, weakly bicolorous with a darker mid region and tending to be closely appressed and peltately attached from a raised darker area towards the base; when shed the older more persistent scales leave a small dark raised area on an otherwise glabrous rhizome surface; *sterile fronds* up to at least 3 m in length; *stipes* robust, up to 2 cm diameter at the base tapering to 1 cm diameter and to at least 1.5 m long, glabrous, deeply channelled on the adaxial surface, olive green in fresh material but stramineous to red-brown in dried specimens; *sterile lamina* with 15–50 pairs of pinnae, broad, oblong-lanceolate up to 2 m long, chartaceous to very coriaceous, glabrous. *Pinnae* up to 40 cm long, to 4 cm wide, apices attenuate; basal pairs more spaced, shortly stalked and abruptly shortened, towards the lamina base; pinnae decreasing in length with apical pairs sessile and more crowded, sometimes forming decurrent wings at the rhachis; lamina golden in dried specimens, margins thickened and irregularly sharply serrate to dentate, coriaceous; pinna base entire, rounded to cuneate, not articulate, with a gland near the base on the anterior margin; lateral veins very fine and close together, merging and terminating in the thickened margin; *terminal pinna* similar in dimensions to the lateral pinnae but lacking the gland. *Fertile frond* bipinnate but with same dimensions as sterile frond, the 15–25 (–50) pairs of pinnae the same length or shorter than the sterile and only 4–5 mm wide, widely spaced on the rhachis, subsessile or sometimes distinctly but shortly stalked; *sori* covering almost the whole abaxial surface. Fig. 12.

Spores verrucate, and pale, the tubercles are in several rows and some tubercles appear to coalesce. Fig. 1f.

Distribution and Habitat: native to Tropical West Africa, (possibly the Cameroons), Equatorial Guinea and the island of Fernando Póo (Benl 1988), south to Angola and east including Zaire (Belgian Congo) extending in rainforest habitats along the Congo River and some tributaries to Uganda in tropical east Africa, and usually reported in forest at low elevation, frequently as a climber on *Raphia* palms in swampy areas and along rivers and streams. Fig. 11.

Notes: 1. In the *Flore du Cameroun*, Tardieu-Blot (1964) cites one of the 3 syntypes as 'Type'; effectively lectotypifying the species (ICBN, Art. 9.8). In this work, she illustrates a plant (pl. 34, f.5, 6) with finely and regularly serrate sterile pinnae margins; this figure was taken from an earlier paper (Tardieu-Blot 1953) and does not match the lectotype of *S. mildbraedii* at B. This plant is possibly an undescribed species and is referred to below as sp. 'Cameroon'.

2. This species appears to be a scrambler and climber on a wide range of tree species. The holotype was reported as climbing on a *Raphia* palm and the species has also been recorded on other palms.

3. The external morphology and ecological preferences of *Stenochlaena mildbraedii* are similar to both *S. palustris* and the African *S. tenuifolia* but it usually has much larger fronds than in either of those species. Together with *S. tenuifolia, S. mildbraedii* lacks the characteristic articulation of the pinnae to the rhachis usually so characteristic of *S. palustris*. *Stenochlaena mildbraedii,* from the limited material available, appears to be a much more robust plant, and has a once pinnate fertile lamina clearly differentiating it from *S. tenuifolia*.

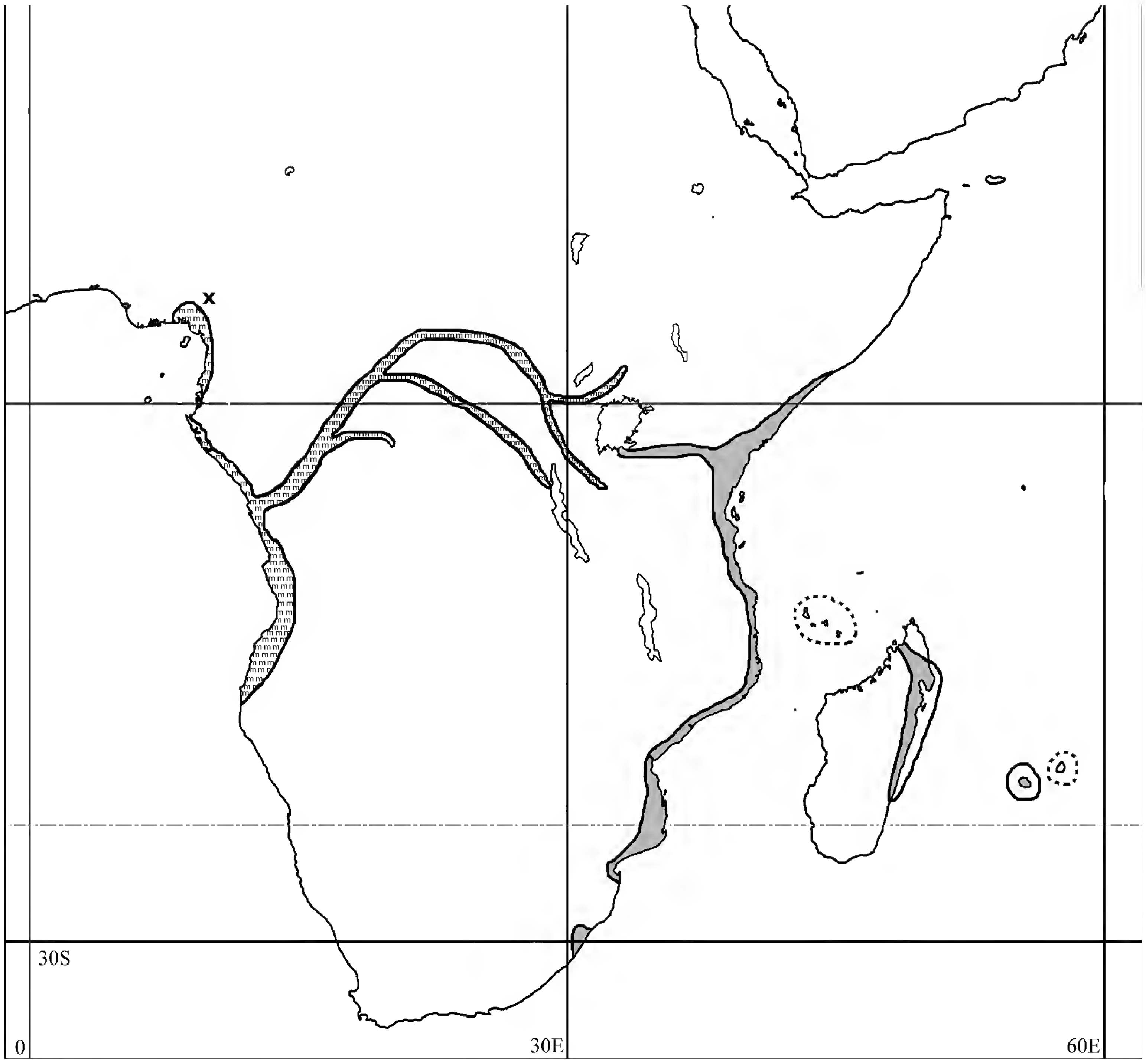

Fig. 11. Distribution map for *Stenochlaena tenuifolia* (Desv.) Moore (grey shading), *Stenochlaena mildbraedii* Brause (mmm) and *Stenochlaena* sp. 'Cameroon' (x).

Specimens examined: ANGOLA: Portuguese Maiomhe: Chiluango *Gossweiler 7953*, 1919, 3 sheets (K) Sheet 1 towards base sterile frond; sheet 2 mid-region sterile frond; sheet 3 several pieces of branching rhizome adhering to tree bark. **UGANDA:** Buddu county, District Masaka U4, 1km N. of Bukeri, 0° 26, 31° 46 E, 1140 m, *Lye* &. *Mani 3494,*12 Jul1969, *ex* Herb Makerere Univ.College (K, 2 sheets). **CAMEROON:** Mpoundou–Seglendom, *Letouzey 3028* (B, photo).

7. *Stenochlaena* sp. 'Cameroon'.

Stenochlaena mildbraedii sensu Tardieu-Blot, Fl. Cameroun (1964: 353–4), Les Pteridophytes de L'Afrique Intertropicale Francaise (1953: 86–87, pl. xxxix, pl. xxxiv).

A specimen at K (*Brunt 323*) from north-west Cameroon is described as a "creeper on tree to 60 ft [over 18 m]". This specimen has fronds that are chartaceous rather than coriaceous; all the sterile pinnae relatively slender, lanceolate, (all under 2 cm wide and up to 16cm long, apices attenuate, shortly stalked at the very slender rhachis, none are articulate and their margins are more regularly and finely dentate. This *Brunt* specimen appears to match the drawing labelled '*Stenochlaena mildbraedii*' in Tardieu-Blot (1964); the illustration of a sterile pinna shows a finely serrate margin and could be either from a sterile specimen of *S. tenuifolia* or possibly from the as yet undescribed taxon. In contrast, the limited material accepted as *S. mildbraedii* and examined in the present study has distinctly coriaceous sterile pinnae with the margins conspicuously sharply and irregularly dentately toothed. Further collections accompanied by careful field observations may indicate that the plant illustrated in Tardieu-Blot and the plant collected by Brunt (both from Cameroon) represent an undescribed taxon.

Specimen examined: CAMEROON: Indop [Ndop] Plain, 3800 ft [c. 1158 m], 5° 45' N, 10° 15' E (Ndop Plain is over 200 km NE of Mt Cameroon at 6°N 10° 35' E), *Brunt 323* (K).

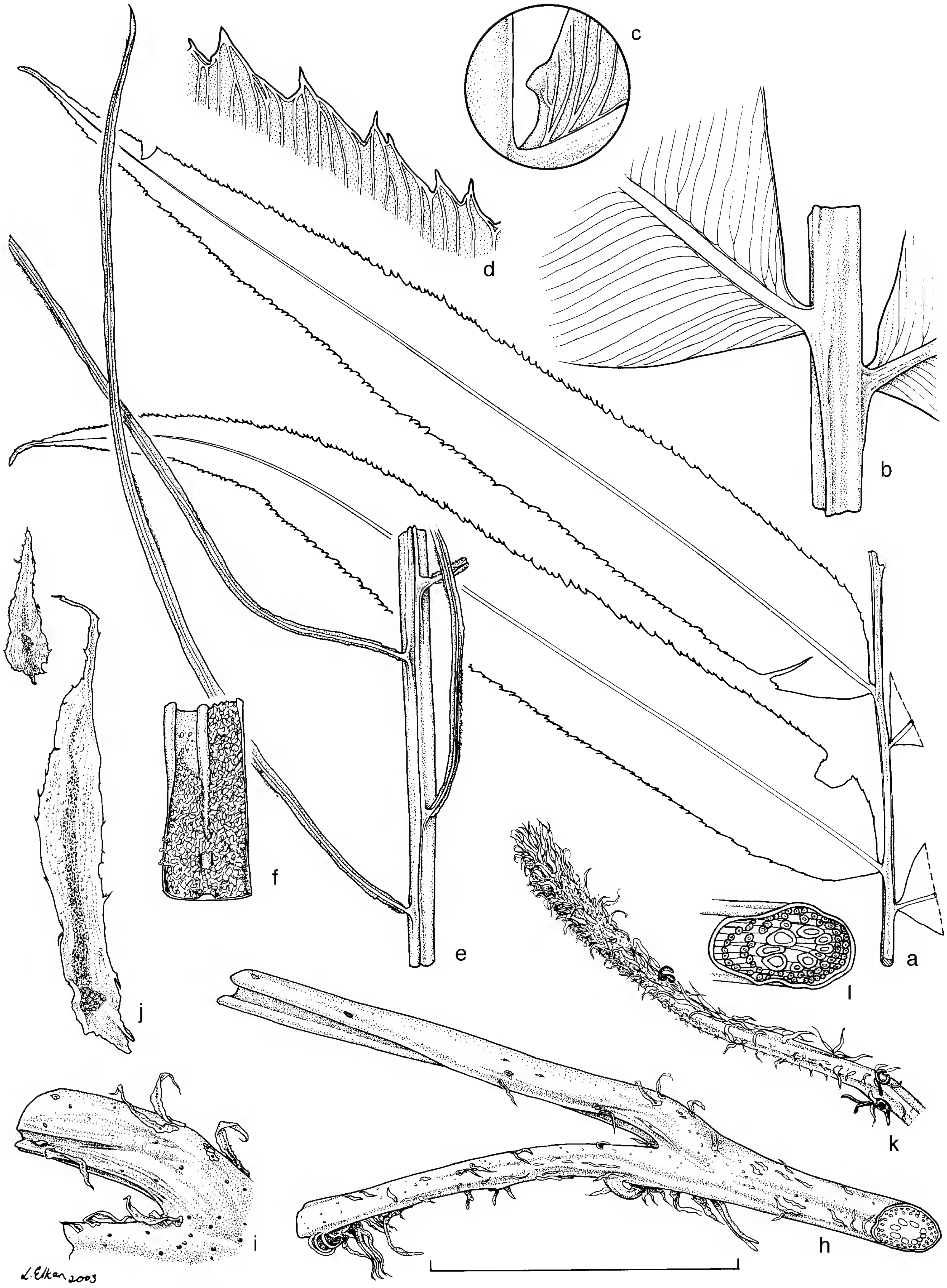

Fig. 12. *Stenochlaena mildbraedii* Brause. **a,** sterile pinnae; **b,** sterile pinnae attachment to rhachis and lateral veins arising from areolar vein close to costa, abaxial view; **c,** gland on sterile pinna; **d,** irregularly dentate margin detail, sterile pinna; **e,** fertile pinnae and rhachis abaxial view; **f,** abaxial detail of fertile pinna; **g,** apical region of rhizome with covering of scales; **h,** rhizome and roots including cross-section and base of stipe; **i,** detail of surface at base of stipe **j,** scales from young rhizome; **k,** young rhizome apex; **l,** rhizome cross section. Scale bar: a, e = 8 cm; b = 2 cm; c, f = 1 cm; d = 1.5 cm; g, h, k = 6 cm; i = 3 cm; j = 0.6 cm; l = 3 cm. Specimens: a–d, *J. Gossweiler 7953* (K); e, f, *K.A. Lye & K.V. Mani 3494* (K)

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Adelphacme (Loganiaceae), a new genus from south-western Australia

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Abstract

The new genus *Adelphacme* (Loganiaceae) is here described. *Adelphacme* is placed in Loganieae and is distinguished from all other genera in Loganiaceae by the following unique combination of characters: stipules reduced to a persistent, membranous, interfoliar sheath; 5-merous calyx, corolla and androecium; calyx with indistinct tube; corolla glabrous or papillose with valvate aestivation; ovary semi-inferior and capsule two-horned (mitre-shaped) with styles persistent and apically united. The new combination *Adelphacme minima* (B.J.Conn) K.L.Gibbons, B.J.Conn & M.J.Henwood is here made. A key to the seven genera of Loganieae, recognised here, is provided. The key is modified to include all Australian genera of the family Loganiaceae.

Introduction

Generic and infrageneric boundaries and phylogenetic relationships in Loganieae (Loganiaceae) have recently been evaluated using nucleotide sequence data (Gibbons et al. 2012). In that study, the south-western Australian endemic *Mitreola minima* B.J.Conn was not placed with other species of *Mitreola* L. Instead, *M. minima* was resolved as sister to *Mitrasacme* Labill., *Phyllangium* Dunlop and *Schizacme* Dunlop, thereby rendering *Mitreola* polyphyletic (Gibbons et al. 2012, Fig. 1). Morphological evidence supports this relationship and the recognition of the taxon '*Mitreola minima*' as a species of a new, monotypic genus.

In describing the new species *Mitreola minima*, Conn (1996) placed it in *Mitreola* based on its incompletely dichasial inflorescences, 5-merous calyx, corolla and androecium, slightly semi-inferior ovary and mitre-shaped capsules. *Mitreola* is largely distributed in the Americas, Asia and Madagascar, with one widespread species, *M. petiolata* (J.F.Gmel.) Torr. & A.Gray, also present in Africa, New Guinea and northern Australia. This new species, endemic to south-western Australia, was geographically isolated from the remainder of *Mitreola*, and its biogeographical history was puzzling. We are now able to evaluate the morphological characters used to support the generic placement of *M. minima* in a phylogenetic context (Gibbons et al. 2012). It appears that these morphological characters (listed above) are plesiomorphic or homoplastic within Loganieae, with incompletely dichasial inflorescences and 5-merous flowers also being widespread throughout the Loganiaceae. This paper formally establishes the new genus *Adelphacme* K.L.Gibbons, B.J.Conn & M.J.Henwood, with affinities to the Australasian genera *Mitrasacme*, *Phyllangium* and *Schizacme*.

Loganieae is one of four tribes remaining in Loganiaceae after re-circumscription of the family by Backlund et al. (2000). Following that study, Loganieae was expanded to include *Mitreola*, *Mitrasacme* and its segregates *Phyllangium* and *Schizacme*, previously placed in Spigelieae (Struwe 2004, Heywood et al. 2007). This classification, which placed these genera together with *Logania* R.Br. and *Geniostoma* J.R.Forst. & G.Forst. (including *Labordia* Gaudich.), has received further support in subsequent studies (Frasier 2008, Gibbons et al. 2012).

Loganieae is one of three tribes in Loganiaceae with dehiscent capsular fruits. Antonieae possess winged or spindle-shaped seeds and septicidal capsules (sometimes also splitting loculicidally for a short distance from the apex), and are further distinguished by aspects of their wood anatomy (Leeuwenberg & Leenhouts 1980, Mennega 1980, Backlund et al. 2000, Grant 2009). Spigelieae, now including only *Spigelia* L., is readily distinguished by its strongly bilobed capsules with persistent style bases (the upper portion of the style being deciduous) and generally cincinnate inflorescences (Leeuwenberg & Leenhouts 1980, Popovkin 2011). Capsule dehiscence in *Spigelia* is both loculicidal and septicidal, thus producing four deciduous valves from a bicarpelate gynoecium, with a distinctive basal cupula persisting within the calyx following shedding of the valves (Leeuwenberg & Leenhouts 1980). Strychneae are distinguished by their fleshy indehiscent fruits, although molecular evidence does not support the monophyly of the tribe as currently circumscribed (Backlund et al. 2000, Frasier 2008).

Finding morphological synapomorphies for an expanded Loganieae is somewhat more difficult, but they appear to lack the alkaloids and aluminium accumulation found in the rest of the family (Bisset 1980, Backlund et al. 2000). The tribe contains all genera of Loganiaceae with (variously) imbricate corolla aestivation, but also several genera or species with valvate corolla aestivation. *Mitrasacme* and *Mitreola* share mitre-shaped, semi-apocarpous capsules, and a close association between these genera has long been inferred (Bentham 1857, Leenhouts 1962, Leeuwenberg 1974). Backlund et al. (2000) suggested that early basipetal dehiscence found elsewhere in the tribe might be homologous with semi-apocarpy, which might then provide a morphological synapomorphy for the tribe. In the analysis of Gibbons et al. (2012), *Mitreola* was not placed sister to *Mitrasacme* and its segregates, but was instead sister to the remainder of Loganieae. It appears, then, that semi-apocarpy is not simply synapomorphic in these genera, but has either evolved in parallel, or has been secondarily lost several times within the tribe.

Taxonomic treatment

Adelphacme K.L.Gibbons, B.J.Conn & M.J.Henwood, ***gen. nov.***

Type species: *Adelphacme minima* (B.J.Conn) K.L.Gibbons, B.J.Conn & M.J.Henwood

Annual herb. *Leaves* decussate, rarely in whorls of 3, sessile; stipules persistent, membranous, reduced to interfoliar obtriangular sheath. *Inflorescence* terminal; uniflorescences incompletely dichasial. *Flowers* with calyx, corolla and androecium 5-merous; corolla lobes valvate; stamens epipetalous; ovary semi-inferior, 2-locular; placentation axile, hemispherical; styles 2, united apically at anthesis and in fruit. *Capsule* 2-horned.

Etymology: the name *Adelphacme* has been formed from the Greek άδελφή (*adelphe*), meaning sister, and although άκμη (*acme*) means highest point, the '*acme*' is here used in reference to the sister-relationship of *Adelphacme* with *Mitrasacme* and *Schizacme*.

Note: in the protologue of *Mitrasacme*, Labillardière (1804) equates άκμη with the Latin *flos* (flower), and states the etymology is in reference to the flower having the form of a mitre. The gynoecium of the type species, *Mitrasacme pilosa* Labill., is distinctly mitre-shaped and can be easily seen without dissection, the corolla being shallowly campanulate. Later authors have assumed the etymology of *Mitrasacme* refers to the shape of the capsule (Don 1837; Leeuwenberg & Leenhouts 1980; Dunlop 1996a, c). 'Highest point' and 'flower' are essentially variations of the same meaning of άκμη (which can also include prime and zenith), because the flower may be considered to be the 'highest point' in the lifecycle of the plant (Liddell & Scott 1940).

Adelphacme minima (B.J.Conn) K.L.Gibbons, B.J.Conn & M.J.Henwood, ***comb. nov.***

Basionym: *Mitreola minima* B.J.Conn *Kew Bulletin* 51: 169–173, Fig. 1 (1996)

Type: Western Australia: Darling (Warren): 1.8 km S along Middle Road from Boronia Road, headwaters of the Bow River, NE of Walpole, *T.D. Macfarlane 2297 & A.R. Annels*, 2 Nov 1994 (holo: PERTH4179323; iso: DNA, K, NSW366873).

Informal names: *Mitrasacme* sp. South West (*G.J. Keighery 343 n.v.*); *Mitreola* sp. Woolbernup Hill (*K.R. Newbey*

11066) (FloraBase 1998+)

Distribution: known from the Darling and Eyre regions of the South-West Botanical Province, Western Australia, from Bunbury in the north to Ravensthorpe in the east.

Conservation status: Department of Environment and Conservation (DEC) Conservation Codes for Western Australian Flora Priority Three: Poorly-known taxa.

Other specimens examined: Western Australia: Darling: 2.3 km S along Middle Road from Boronia Road, NE of Walpole, *Macfarlane 2298 & Annels*, 2 Nov 1994 (NSW, PERTH); 1.8 km S along Middle Road from Boronia Road, NE of Walpole, *Annels & Hearn s.n.*, 21 Nov 1994 (CANB, DNA, NSW366874, PERTH); W of South West Highway, *Bennett s.n.*, 9 Nov 2007 (PERTH07980922; photograph!); Eyre: Fitzgerald River National Park: 7 km NNE Woolbernup Hill, *Newby 11066*, 21 Nov 1985 (DNA, NSW, PERTH).

Key to the genera of Loganiaceae tribe Loganieae

Note: *Labordia* is not included in the following key. A recent molecular phylogenetic study (Gibbons et al. 2012) found that at least some species of *Labordia* should be reduced to synonymy of *Geniostoma*. Sampling was limited to three of the 17 species of *Labordia* and did not include the type species, *L. fagraeoidea* Gaud. A more complete phylogenetic evaluation of the status of all species of *Labordia* is required. Should the continued recognition of a reduced *Labordia* be warranted, the morphological characters separating *Labordia* and *Geniostoma* will require reassessment.

1. Herbs or subshrubs 2
1: Shrubs, trees or woody climbers 7

2. Capsule two-horned (horns occasionally adherent along almost their entire length, appearing continuous with base of styles) or bilobed 3
2: Capsule without horns, not bilobed; Australia (not Tasmania), doubtfully New Zealand (extinct) .... ***Logania***

3. Calyx, corolla and androecium 4-merous, or calyx absent 4
3: Calyx, corolla and androecium 5-merous 6

4. Calyx absent; corolla and capsule enclosed in a two-lobed foliaceous involucre; ovary semi-inferior; southern Australia (including Tasmania) .... ***Phyllangium***
4: Calyx present, involucre absent; ovary superior 5

5. Calyx tube indistinct, up to 1 mm long; calyx lobes generally unequal; capsule laterally compressed, appearing broadly cuneiform in lateral view; placenta elongate, seeds few; Australia (Tasmania and alpine Victoria) and New Zealand[1] .... ***Schizacme***
5: Calyx tube distinct; calyx lobes equal; capsule generally globular, ovoid or ellipsoid; placenta hemispherical, seeds many; northern and eastern Australia (including Tasmania), New Caledonia, New Guinea, Southeast and East Asia .... ***Mitrasacme***

6. Leaves <4 mm long; stipules a persistent membranous interfoliar sheath; corolla mouth glabrous or papillose; styles retained in fruit, connate at their apices (sometimes separating post-maturity); south-western Australia .... ***Adelphacme***
6: Leaves at least 10 mm long (except *M. sessilifolia* (J.F.Gmel.) G.Don ≥6 mm long and *M. petiolatoides* P.T.Li ≥5 mm long); stipules well-developed (mostly triangular) or reduced to a stipular line; corolla mouth with penicillate ring of hairs; styles not persisting in fruit or stigmas free, subsessile; Americas, Africa, Madagascar, Southeast and East Asia, New Guinea, northern Australia .... ***Mitreola***

7. Placenta fleshy, yellow to red, with seeds embedded; Mascarene Islands, Malesia, north-eastern Australia and Pacific .... ***Geniostoma***
7: Placenta dry, seeds not embedded; Australia (not Tasmania), doubtfully New Zealand (extinct) ... ***Logania***

[1] Species congeneric with *Schizacme* are currently recognised under the name *Mitrasacme* in New Zealand.

This key includes an optional modification to include the remaining Australian genus of Loganiaceae, *Strychnos* (Strychneae), by replacing couplet 7 with the following two couplets:

7. Fruit indehiscent, berry-like; leaves 3–7-plinerved .... ***Strychnos***

7: Fruit a two-valved capsule; leaves penninerved.. 8

8. Placenta fleshy, yellow to red, with seeds embedded; Mascarene Islands, Malesia, north-eastern Australia and Pacific .... ***Geniostoma***

8: Placenta dry, seeds not embedded; Australia (not Tasmania), doubtfully New Zealand (extinct).... ***Logania***

Discussion

Although we are, as yet, unable to identify a morphological synapomorphy for *Adelphacme*, the genus may be readily identified by a unique combination of morphological characters. In the molecular phylogeny of Gibbons et al. (2012), long branches separate *Mitrasacme*, *Schizacme*, *Phyllangium* and *Adelphacme minima*, further supporting their recognition as discrete genera, rather than as a more broadly defined *Mitrasacme*. Table 1 compares the morphological characteristics of *Adelphacme* with those of *Mitrasacme*, *Mitreola*, *Phyllangium* and *Schizacme*.

Adelphacme is distinguished from *Mitreola* by vegetative, floral and fruit characters. The stature and leaves of *Adelphacme* are much smaller than those of *Mitreola* and its stipules are reduced to a membranous, interfoliar sheath (*Mitreola* with stipules well-developed or reduced to a stipular line). These characters instead support the phylogenetic placement of *Adelphacme* sister to *Mitrasacme*, *Phyllangium* and *Schizacme*. The incompletely dichasial inflorescences of *Adelphacme* (refer Conn 1996; Fig. 1) are similar to those of *Mitreola* but do not extend into a long cincinnate distal portion, as is characteristic of most species of *Mitreola*. *Adelphacme* differs from *Mitreola* in its calyx without a distinct tube (*Mitreola* calyx lobes and tube ± equal). The corolla of *Adelphacme* is only slightly urceolate, with rounded lobes (*Mitreola* corolla distinctly urceolate, lobes generally subacute) and lacks the penicillate or pilose ring of hairs found in the corolla mouth of *Mitreola* (Leeuwenberg 1974). Corolla aestivation is valvate in *Adelphacme* but is generally quincuncial in *Mitreola*, with the exception of the Madagascan endemic *M. turgida* Jovet (Conn 1996). The stamens of *Adelphacme* are apiculate (by extension of the connective), as are those of *Schizacme* and of many species of *Mitrasacme* and *Phyllangium*. In *Mitreola petiolata* and *M. sessilifolia* the anthers appear apiculate but this character is uncertain in the remaining species of *Mitreola* because material was not available for examination. Leeuwenberg (1974, p. 4) states the anthers of *Mitreola* are "apiculate to retuse" but does not include this character in species descriptions. The gynoecium of *Adelphacme* is similar to that of *Mitreola*, except that the styles of *Mitreola* are generally shorter. However, in fruit, the styles of *Adelphacme* are persistent and remain united at their apices as the horns of the capsule separate, whereas in *Mitreola*, the styles separate soon after anthesis, and do not generally persist into fruit. The seeds of *Adelphacme* are smooth, ellipsoid, with a longitudinal groove on the ventral surface. This type of seed occurs in most species of *Mitreola* and in some species of *Mitrasacme*.

The habit, corolla and capsule of *Adelphacme* bear a strong resemblance to *Mitrasacme*. However, *Adelphacme* differs from *Mitrasacme* in its crowded uniflorescences (*Mitrasacme* uniflorescences generally lax), its almost free calyx lobes and its slightly semi-inferior ovary (*Mitrasacme* calyx lobes and tube ± equal and ovary superior). *Adelphacme* further differs from *Mitrasacme*, *Phyllangium* and *Schizacme* by its 5-merous calyx, corolla and androecium (4-merous in *Mitrasacme*, *Phyllangium* and *Schizacme*). *Adelphacme* resembles *Phyllangium* in its semi-inferior ovary. *Phyllangium* is distinguished from all other genera in Loganiaceae by its two-lobed involucral bract surrounding the flower and capsule and absent calyx (Dunlop 1996b). *Adelphacme* differs from *Schizacme* in having two styles united at the apex at anthesis and in fruit (*Schizacme* with styles free). The calyx of *Schizacme* is generally heteromorphic (Dunlop 1996c), with the exception of *S. montana* (Hook.*f.* ex Benth.) Dunlop, which occasionally has equal calyx lobes similar to those of *Adelphacme*. *Schizacme* is best distinguished from all other genera in Loganieae by its laterally compressed, cupuliform capsules (appearing broadly cuneiform in lateral view) and elongated, few-seeded placentation (Dunlop 1996c).

Capsule dehiscence in Loganieae

In *Adelphacme*, *Mitrasacme*, *Schizacme* and *Phyllangium*, dehiscence occurs along the ventral suture of the horns of the capsule, and not loculicidally as previously stated (Leeuwenberg & Leenhouts 1980; Dunlop 1996a, c, b; Gibbons et al. 2012). Confusion arises from alternative definitions of loculicidal in the literature.

Table 1. Morphological features diagnostic for *Adelphacme, Mitrasacme, Mitreola, Phyllangium* and *Schizacme*.

	Adelphacme	*Mitrasacme*	*Mitreola*	*Phyllangium*	*Schizacme*
Leaves	2.7–3.3 mm long, sessile	1–90 mm long, generally sessile	5–150 mm long, generally petiolate	2–13 mm long, sessile	2–14 mm long, sessile or subsessile
Stipules	persistent, membranous, interfoliar sheath	persistent, membranous, interfoliar sheath	persistent or reduced to a stipular line, well-developed triangular, ligulate or ochreate	persistent, membranous, interfoliar sheath	persistent, membranous, interfoliar sheath
Inflorescence	incompletely dichasial, uniflorescences crowded	variously cymose, generally lax, or flowers solitary	incompletely dichasial, generally becoming cinncinate distally, generally crowded	lax cymose, or flowers solitary	flowers solitary
Flowers	5-merous	4-merous	5-merous	4-merous	4-merous
Calyx	tube indistinct, lobes equal	tube distinct, lobes equal	tube distinct, lobes equal	absent, replaced by a two-lobed foliaceous involucre	tube indistinct, lobes usually heteromorphic
Corolla					
aestivation	valvate	valvate	generally quincuncial (valvate in *M.turgida*)	valvate	valvate or imbricate
ornamentation at mouth	glabrous or papillose	penicillate, pilose, papillose or glabrous	penicillate or pilose	glabrous	glabrous, pilose or papillose
Ovary	semi-inferior	superior	semi-inferior	semi-inferior	superior
Styles					
at anthesis	united	generally united (free in *M. secedens)*	united	united or free	free
in fruit	persistent, remaining united apically as horns separate	persistent, generally united apically (free in *M. secedens)*	separating soon after anthesis, not persistent or stigmas subsessile	united or free, sometimes withering in fruit	free, sometimes withering in fruit
Capsule	± globular, two horned	generally globular, ovoid ellipsoid or obovate, two horned	ellipsoid or ovoid, two-horned or bilobed	ellipsoid to obovate, two-horned (horns not well developed)	laterally flattened, horns widely divergent (appearing broadly cuneiform in lateral view)
Placentation	axile, hemispherical, seeds many	axile, hemispherical, seeds many	axile, hemispherical, seeds many	axile, hemispherical, seeds many	axile-apical, elongate, seeds 2–3 per locule

In some texts, loculicidal is defined as "longitudinal dehiscence radially aligned with the locules" (Simpson 2006, p. 562). However, loculicidal dehiscence is more accurately described as longitudinal dehiscence along the dorsal rib of the carpels, or (less frequently) between the dorsal rib and the septum (Spjut 1994, Beentje 2010). In completely syncarpous capsules, these definitions are equivalent. In semi-apocarpous capsules, dehiscence along the ventral suture of the horns, although perpendicular to the septum, is most correctly considered a form of septicidal dehiscence, the ventral aspect of the horns being continuous with the septum. In *Mitreola*, the degree of fusion of the carpels is variable, so that in some species the capsule first dehisces along the septum, although never to the base of the capsule, before dehiscing along the ventral suture. In *Logania* and *Geniostoma*, capsules appear completely syncarpous and styles generally appear single. However, in some species of *Logania*, there appear to be two styles connate along their length, with the stigma bilobed. Additionally, the septicidal capsules of *Logania* initially dehisce only on their distal half, and although the persistent valves subsequently separate along the septum to the base, dehiscence along the ventral suture remains confined to the distal half of the valves (Conn & Brown 1996). These observations suggest the syncarpous capsules of *Logania* are secondarily derived, supporting the hypothesis of Backlund et al. (2000) that semi-apocarpy provides a morphological synapomorphy for Loganieae.

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Eight additional new records of Philippine Mosses

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Abstract

Eight new taxa are added to the Philippine moss flora: *Acroporium rigens* (Broth. ex Dixon) Dixon, *Braunfelsia plicata* (Sande Lac.) Broth., *Brotherella fauriei* (Cardot) Broth., *Bryoerythrophyllum recurvirostrum* (Hedw.) P.C.Chen, *Gammiella pterogonoides* (Griff.) Broth., *Oxyrrhynchium hians* (Hedw.) Loeske, *Pterogonidium pulchellum* Hook. and *Vesicularia ferriei* (Cardot & Thér.) Broth. The genus *Pterogonidium* is new to the Philippine flora.

New records

Linis and Tan (2008), as well as subsequent publications by Linis (2010) and Linis and Tan (2010), estimate the total moss flora for the Philippines as 755 species in 238 genera and 56 families. However, continued study of the many unidentified bryological collections kept at the Philippine National Herbarium (PNH), including those of the senior author, has added eight new species and one generic record. These additions bring the total moss taxa known to occur in the Philippines to 763 species and 239 genera.

All voucher specimens of these Philippine mosses are held in PNH with some duplicates distributed to the Herbarium of Singapore Botanical Gardens (SING) for reference purposes.

1. ***Acroporium rigens*** (Broth. ex Dixon) Dixon Sematophyllaceae

In the field typical plants of *Acroporium rigens* are tufted, with erect, acrocarpous-like branches which can often be mistaken for small plants of *Pyrrhobryum spiniforme* (Hedw.) Mitt. *Acroporium rigens* is most similar to *A. johannis-winkleri* Broth., with which it shares the bristly plant habit and similar erect-divergent, narrowly lanceolate-linear and tubulose leaves (Tan 1994, Tan *et al.* 2007). *Acroporium rigens*, however, is much larger with stems and branches ascending to 2 cm in height. Moreover, the rigid and setaceous leaves of *A. rigens* are longer than those of *A. johannis-winkleri* with their length reaching to 5 mm as compared to the latter with leaf length only to 2 mm.

Distribution: Malay Peninsula, Philippines, and Borneo (West Malesia) and Papua New Guinea (Western Melanesia) (Tan 1994, Tan *et al.* 2007).

Specimens examined: PHILIPPINES: Panay Island, Antique Province, Mount Baloy, on moist stone; 1,650 m, 9 Oct 1989, *J.R. Cabalquinto 1229 & E. Sagcal, Jr.* (PNH). **MALAYSIA:** State of Penang, Penang Hill, base of frond of *Cyathea*; 700 m, 13 Apr 1971, *H.N. Ridley 5605* (SING). State of Johor, Gunung Belumut, on lower part of tree trunk in mossy forest; 914 m, May 1923, *R.E. Holttum 10998* (SING).

2. ***Braunfelsia plicata*** (Sande Lac.) Broth. Dicranaceae

Apart from its deeply plicate curved leaves, *B. plicata* is similar in size, habit, color and other morphological details to *B. dicranoides* (Dozy & Molk.) Broth. *Braunfelsia plicata* tends, however, to have a more sharply defined costa and blunter leaf apices.

Distribution: a West Malesian endemic recorded in Indonesia (Java, Sumatra) and the Malay Peninsula (Eddy 1988), now found in the Philippines.

Specimens examined: PHILIPPINES: Mindanao Island, Bukidnon Province, Malaybalay City, Barangay Busdi, Sitio Magantol, on tree trunk; transitional lowland forest, 1,220 m, 17 May 2008, *V.C. Linis 3617-08* (PNH); *ibid.*, *V.C. Linis 3624-08* (PNH). **MALAYSIA:** State of Kedah, Kedah Peak, in very mossy place, on ground, just below summit; 1158 m, 1 Apr 1925, *R.E. Holttum 14869* (SING). Borneo, State of Sarawak, Mount Dulit, Dulit Range, on tree trunk in moss forest; 1300 m, 6 Oct 1932, *P.W. Richards M2167* (SING).

3. ***Brotherella fauriei*** (Cardot) Broth. Pylaisiadelphaceae

Brotherella was at one time combined with *Pylaisiadelpha* retaining the latter as the name of the merged genus (Buck 1984), but the move did not meet full acceptance (Jia & He 2006; Afonina *et al.* 2007). Ando *et al.* (1989) had clarified the distinction between *Brotherella* and *Pylaisiadelpha* and their differences include poorly differentiated leaf alar cells and the presence of filiform propagules in *Pylaisiadelpha*. Furthermore, Tan and Jia (1999) observed that the exothecial cell walls of *Pyliasiadelpha yokohamae* and *P. tenuirostris* exhibit weak collenchymatous thickening, quite unlike the uniformly, thick vertical walls with thin lateral walls in exothecial cells in species of *Brotherella*. Although recent phylogenetic studies using a limited number of gene sequences have shown the species of the two genera to be inseparable molecularly, we are keeping them apart based on their morphological distinction.

Recent molecular studies (Buck *et al.* 2000; Tsubota *et al.* 1999, 2000, 2001a, b, 2002) have shown that Sematophyllaceae *s.l.* includes two sister clades: the core sematophyllous taxa (e.g. *Acanthorrhynchium* Fleisch., *Acroporium* Mitt., *Meiothecium* Mitt., *Papillidiopsis* Buck & Tan, *Sematophyllum* Mitt. and *Trichosteleum* Mitt.), and a clade that includes *Brotherella* Loeske ex Fleisch., *Heterophyllium* (Schimp.) Kindb. in Fleisch., some species of *Hypnum* Hedw., *Isocladiella* Dix., *Platygyrium* Schimp., *Pylaisiadelpha* Cardot, *Taxithelium* Spruce ex Mitt. and *Wijkia* Crum. Tsubota *et al.* (2001a) called the latter clade the '*Brotherella* lineage', while Goffinet and Buck (2004) described a new family Pylaisiadelphaceae for it. Although this clade lacks any obvious morphological synapomorphy, we follow Goffinet and Buck (2004) in placing *Brotherella* in the family Pylaisiadelphaceae.

Brotherella fauriei is another addition to the growing number of *Brotherella* species reported from the Philippines. Unlike other Philippine species of *Brotherella*, however, *B. fauriei* is a slender plant with distantly spaced branches. The mostly erect-patent stem and branch leaves with more or less falcate leaf acumina are distinctive.

Distribution: Temperate East Asia mainly in China and Japan (Tan & Jia 1999).

Specimens examined: PHILIPPINES: Luzon Island, Benguet Province, Mount Santo Tomas, on exposed roots of pine (*Pinus kesiya*) tree, 1,900 m, 29 Nov 1988, *J.R. Cabalquinto 332, J.F. Barcelona & M.Y. Bangis* (PNH). **CHINA:** Jiangxi Province, Zixi County, Mount Ma-Tou, on decaying log, 890 m, 26 May 2001, *M.C. Ji 12668* (SING).

4. ***Bryoerythrophyllum recurvirostrum*** (Hedw.) P.C.Chen Pottiaceae

Recent phylogenetic analysis of eight Russian *Bryoerythrophyllum* suggested the genus is monophyletic (Fedosov & Ignatova, 2008). In the Philippines, these *Barbula*-like plants can normally be identified in the field by the markedly rufous coloration of their older parts.

Among its congeners, *Bryoerythrophyllum recurvirostrum* is closest to *B. ferruginascens* (Stirt.) Giac. However, unlike the latter which is dioicous, *B. recurvirostrum* is synoicous and/or paroicous. *Bryoerythrophyllum recurvirostrum* also differs from *B. ferruginascens* by being bigger with stems reaching 3 cm compared to 17 mm. Furthermore, *B. recurvirostrum* has flexuose leaves up to 3 mm long with margins recurved nearly to apices, with few teeth near the tips vs leaves reaching 1.3 mm in length with entire margins recurved only up to mid-leaf. The lack of rhizoidal gemmae, which are present in *B. ferruginascens*, is also helpful in identifying *B. recurvirostrum*.

Distribution: almost cosmopolitan in both Northern and Southern Hemispheres, reaching Malesia. Recorded from the island of New Guinea and Indonesia (Sulawesi) (Eddy 1990).

Specimen examined: PHILIPPINES: Luzon Island, Benguet Province, Kabayan, Mount Pulag, on soil; 1,600 m, 18 Oct 1988, *J.R. Cabalquinto 211 & E. Sagcal, Jr.* (PNH).

5. ***Gammiella pterogonioides*** (Griff.) Broth. Sematophyllaceae

This species is distinguished from its congeners by its relatively large size. The imbricate, cordate and ovate to oblong-lanceolate leaves with abruptly cuspidate leaf apices are also distinctive. This is the fourth species of *Gammiella* reported from the Philippines.

Distribution: Eastern India, Himalayas, Indochina and southwest China (Gangulee 1969–1980; Tan & Jia 1999) to the Philippines.

Specimen examined: PHILIPPINES: Luzon Island, Benguet Province, Baguio City, Wright Park, on bark of pine (*Pinus kesiya*) tree; 1,400 m, 27 Jan 1989, *J.R. Cabalquinto 474 & B.O. van Zanten* (PNH)

6. ***Oxyrrhynchium hians*** (Hedw.) Loeske Brachytheciaceae

This is the second species of the genus reported in the Philippines and it is superficially very similar to *O. vagans* (Jaeg.) Ignatov & Huttunen in the field with both taxa possessing subjulaceous branch foliage. However, *O. hians* has shorter median laminal cells (35–105 µm) in its well-developed branch leaves compared to those of *O. vagans* measuring 70–145 µm (Ignatov *et al.* 2005). When fertile, *O. hians* has rough setae compared to those of *O. vagans* being smooth (Ignatov *et al.* 2005).

Distribution: widespread in warm temperate areas of North America, Europe, East Asia (China, Japan, the Philippines) and the Himalayas (India, Nepal and Bhutan) and also in Africa (Ignatov *et al.*, 2005).

Specimens examined: PHILIPPINES: Luzon Island, Benguet Province, Mount Santo Tomas, on rocky trail; 7,300 ft, 17 Apr 1956, *N. Veloira 1* (PNH); Luzon Island, Nueva Vizcaya, 1 km. east of Dalton Pass, on fallen, rotting log near creek; 1,500 m, 4 Mar 1967, *R.M. del Rosario 587* (PNH); Luzon Island, Camarines Sur Province, north slope of Mount Isarog, on stone; 16 May 1991, *J.R. Cabalquinto 2192* (PNH). **ROMANIA:** Moldavia, Iasi, in opp. Iasi in loco nominato Copou, ad terram uliginosam; 80 m, 16 Mar 1916, *C. Oescu s.n.* (SING).

7. ***Pterogonidium pulchellum*** Hook. Hypnaceae

This is the second report of this invasive moss species from the Neotropics in Asia. The first report was made by Tan & Buck (2002), when the authors discovered two populations on a tree trunk (*Melaleuca* sp.) inside the National Orchid Garden of the Singapore Botanic Garden. Re-examination of *P. pulchellum* using data from *rbc*L gene sequences showed that it has a close relationship with members of Hypnaceae (Chang *et al.* 2006).

Distribution: common in West Indies and Central America reaching northern South America (Sharp *et al.* 1994; Tan & Buck 2002), reported now in SE Asia from Singapore and the Philippines.

Specimens examined: PHILIPPINES: Luzon Island, Benguet Province, Baguio City, Barangay Pacdal, Baguio Botanical Garden, on lower trunk of an ornamental tree, near a human settlement area; 1,476 m, 22 Jan 2011, *V.C. Linis 4754-11* (PNH). **SINGAPORE:** Botanical Gardens of Singapore, on *Melaleuca* tree trunk; 6 Nov 1998, *B.C. Tan 98-472* (SINU).

8. ***Vesicularia ferriei*** (Cardot & Thér.) Broth. Hypnaceae

Tan and Iwatsuki (1991) reported five taxa of genus *Vesicularia* (Müll.) Müll. for the Philippines. *Vesicularia ferriei* is somewhat similar to *V. montagnei* (Bél.) Broth. in having ovate dorsal leaves and suborbicular lateral leaves with short leaf apices. However, *V. ferriei* is readily distinguished by the broadly acute or obtuse leaf apices rather than shortly acuminate as in *V. montagnei*. Furthermore, the median laminal cells of both dorsal and lateral leaves in *V. ferriei* are linear-hexagonal or elongate-rectangular compared to oblong-hexagonal in *V. montagnei*.

Distribution: in temperate East Asian regions of Japan and China (Noguchi *et al.* 1994), also in the Philippines.

Specimens examined: PHILIPPINES: Mindanao Island, Cotabato Province, Kidapawan City, Barangay Ilomavis, Sitio Agco, on tree fern trunk along trail leading to waterfalls near small lake; 1,600 m, 29 Mar 2011, *V.C. Linis 4900-11* (PNH). **JAPAN:** Honshu Island, Hiroshima-ken, Hiroshima-shi, Asa-kita-ku, Uga George, along Takayama River, on wet boulder by stream; 200 m, 26 Mar 1998, *H. Deguchi s.n.* (SINU). **CHINA:** in confinibus provinces of Kianghsi and Fukien, Mt. Dangwa-schan, inter Schitsheng and Ninghwa, in lacuna quadam in cacumine cum Glossadelpho; 1400 m, May 1921, *T. H. Wang s.n.* (SING).

Discussion

The distributional patterns exhibited by the eight newly reported Philippine moss taxa are relevant and useful to phytogeographical studies of the Philippine moss flora. The additions of *Brotherella fauriei*, *Oxyrrhynchium hians* and *Vesicularia ferriei* for the Philippine moss flora further fortify its predominantly East Asiatic composition (Tan 1992, Linis & Tan 2008) while the discovery in the Philippines of *Acroporium rigens* and *Braunfelsia plicata* from Western Malesia and *Gammiella pterogonoides* from the Himalayan/ Indochina/ Hainan areas maintains the current relationships of moss floras between Philippines and these regions.

Bryoerythrophyllum recurvirostrum adds to the growing list of cosmopolitan taxa already recorded in the country. *Pterogonidium pulchellum* is the first record of an introduced moss taxon in the country.

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Phebalium speciosum (Rutaceae: Boronieae), an endangered, narrowly endemic new species of north-eastern New South Wales, Australia

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Abstract

Phebalium speciosum I.Telford, endemic to north-eastern New South Wales and previously included in *P. nottii* (F.Muell.) Maiden & Betche, is described as new. Information is presented on its distribution, habitat and conservation status. An image of an isotype specimen, a table comparing distinguishing attributes of the new species, *P. nottii* and *P. woombye*, and a modification to the key to the species of *Phebalium* occurring in New South Wales are included.

Introduction

Phebalium nottii (F.Muell.) Maiden & Betche is currently applied to a variable taxon widespread through coastal and inland eastern Australia (http://avh.chah.org.au/occurrences/search?taxa=phebalium+nottii#mapView; accessed 23 April 2012).

Wilson (1970) regarded *P. nottii* and *P. woombye* (F.M.Bailey) Domin as constituting an intergrading pair in south-eastern Queensland. People often confuse the species, as in the *New South Wales Flora Online* (Weston & Harden 2012). In the latter treatment specimens from diverse habitats on the North Western Slopes and Central Western Slopes between Coonabarabran and Peak Hill, the North Coast region from the sandstone country between Copmanhurst and Glenreagh, and acid volcanic outcrops near Urbenville have all been assigned to *P. nottii*. Gross morphological differences, as well as differences in habitat preference and the considerable disjunctions in distributions, suggest more than one taxon may be involved.

Materials and methods

The study is largely based on morphological observations of herbarium specimens held in BRI, CANB, CFSHB, NE and NSW, as well as field studies by the author in Queensland and New South Wales.

Results and Discussion

Specimens attributed to *P. nottii* from the Grafton–Coffs Harbour area (north-eastern New South Wales) exhibit a glabrous adaxial leaf surface, 6–10-flowered inflorescences, and cream–white petals, sometimes turning pink with age. These are attributes of *P. woombye*; the specimens are misidentified. Collections/ plants from the Urbenville area (north-eastern New South Wales) have the adaxial leaf surface stellate-hairy, 4–8-flowered inflorescences and pink petals. These Urbenville collections are sufficiently distinct from *P. nottii* (Table 1) to be recognised as a new species described below. The species is regarded as under threat.

The residual populations of *P. nottii*, after segregation of the new species, still appear to represent a species complex. Morphological variation in *P. nottii* pointed out by Wilson (1970) and its putative intergrading with the variable *P. woombye* are currently under investigation in an attempt to resolve taxonomic limits.

Note that the description of *P. nottii* in Weston and Harden (2002: 304) contains elements of *P. woombye*. The upper leaf surface of *P. woombye* is glabrous, while the upper leaf surface in *P. nottii* is initially stellate tomentose, becoming minutely papillose with age as hair branches are lost, not glabrous as stated (Table 1).

Table 1. Comparison of some distinguishing attributes between *Phebalium speciosum, P. nottii* and *P. woombye*.

Character	***P. speciosum***	***P. nottii***	***P. woombye***
Leaf shape	lanceolate or elliptical	elliptical	elliptical or narrowly elliptical
Leaf length (mm)	25–84	6–45	10–66
Leaf width (mm)	7.5–22	1.8–4.5	3–10
Upper leaf surface	stellate hairy, becoming papillose	sparsely stellate hairy, becoming papillose	glabrous
Flowers per inflorescence	4–8	1–5	4–9
Calyx lobe length (mm)	2.3–3	1.2–2.4	1.6–2.6
Petal length including claw (mm)	10–12.2	5.5–8.6	4–5.3
Filament length (mm)	6.5–11	2.6–6.5	3.6–6.4
Cocci length (mm)	4–4.2	3.5–3.8	3.2–3.6
Seed length (mm)	2.6–3	1.6–2.2	1.8–2.3

Taxonomy

Phebalium speciosum I.Telford, ***sp. nov.***

Diagnosis: similar to *P. nottii*, differing in wider (7.5–22 vs 1.8–4.5 mm), mostly lanceolate leaves, more flowers per inflorescence (4–8 vs 1–5), larger calyx lobes (2.2–3 vs 1.2–2.4 mm long) and petals (10–12.2 vs 5.5–8.6 mm long), longer filaments (6.5–11 vs 2.6–6.5 mm), larger cocci (4–4.2 vs 3.5–3.8 mm long) and seeds (2.6–3 vs 1.6–2.2 mm long).

Type: New South Wales: North Coast: Battery Hill, 6 km SSW of Urbenville, 4 Aug 2007, *I.R.Telford 13171, T.Vollbon & D.H.Moffatt*; holo: NSW; iso: BRI, CANB, HO, K, MEL, MO, NE, PERTH (Fig. 1).

Shrub to 3 m tall. Branchlets ferruginous lepidote. *Leaves* with petioles 3–4.7 mm long, channelled above, silver and ferruginous lepidote; lamina lanceolate or narrowly elliptical, 25–84 mm long, 7.5–22 mm wide, obtuse; margin undulate, slightly recurved; adaxial surface dark green, silvery stellate, becoming minutely papillose by erosion of hair branches, the midvein deeply impressed; abaxial surface silvery and ferruginous lepidote. *Inflorescences* terminal, sessile umbels of 4–8 flowers; pedicels 7.5–10 mm long, slightly thickening distally, ferruginous lepidote. *Calyx* cup-shaped with 6–8 lobes, silvery and ferruginous lepidote outside, silvery lepidote inside; cup c. 2 mm long, 4.2–4.8 mm diam.; lobes erect, triangular, 2.2–3 mm long, acute. *Corolla* of 6–8 petals, of which 4 adjacent spreading, the other 2–4 more or less erect, clawed; claw 1.5–2 mm long, glabrous, white to pale pink lamina obovate or elliptical, 8.4–10.2 mm long, 3.2–5 mm wide, shortly acuminate, margin minutely crenulate; adaxial surface glabrous, deep pink paling with age; abaxial surface silvery and ferruginous lepidote with a glabrous marginal band. *Stamens* 12–14, inclined over the 4 spreading petals; filaments filiform, 6.5–11 mm long, glabrous, pink; anthers oblong, 1.7–2.5 mm long, yellow. *Ovary* subglobose, 2–3 mm diam., of 6 or 7 free carpels; carpels 2–2.3 mm long, ferruginous lepidote; style 5–5.5 mm long, glabrous, recurved above stamens; stigma capitate, minutely papillose. *Cocci* ellipsoidal, 4–4.2 mm long, 2.4–3.2 mm wide, ferruginous lepidote. *Seeds* ellipsoidal, 2.6–3 mm long, 1.2–1.6 mm wide, longitudinally striate, black.

N.C.W. Beadle Herbarium (NE)
The University of New England

ISOTYPE

Phebalium speciosum I. Telford

Det.: 2 May 2012

N.C.W. Beadle Herbarium (NE)
The University of New England
Armidale NSW 2351 Australia

Notification of change of determination would be appreciated by NE

NE 90663

Rutaceae

Phebalium

Australia. New South Wales: North Coast:
Battery Hill, 6 km SSW of Urbenville

28° 31' 13" S 152° 31' 19" E 400 m

Steep slope at foot of cliff, N aspect. Sleletal loam on acid volcanics. *Eucalyptus microcorys. Corymbia intermedia* shrubby open forest with *Bossiaea rupicola, Keraudrenia hillii, Astrotricha latifolia.*

Common, localised along base of cliff Shrub, 2.5 m.

Photo. Cuttings. Si gel.

Coll.: **I.R. Telford 13171** 4 Aug. 2007
T. Vollbon & D.H. Moffatt

Det.:

Rep(s) to: BRI, CANB, HO, MEL, MO, NSW, PERTH

Fig. 1. Isotype of *Phebalium speciosum* I.Telford (NE).

Additional specimens examined (selection): **New South Wales**: North Coast: rock just N of Battery Hill near Tooloom Falls at end of Wood Duck Rd, Yabbra State Forest, c. 6 km SW of Urbenville, 22 May 2004, *Phillips 1172 & Phillips* (BRI); Battery Hill, c. 6 km S of Urbenville, 19 Feb 1997, *Gilmour* (CANB, CFSHB, NSW); Battery Hill, c. 5.5 km SSW of Urbenville, 21 Nov 1987, *Coveny 12802, Donabauer & Dunn* (BRI, NSW); Mt Cullawajune, near Urbenville, 29 Jun 1987, *Neville s.n.* (CFSHB); ibid., 26 May 2012, *Sadgrove 232* (BRI, CANB, NE, NSW).

Distribution: apparently restricted to Battery Hill and Callawajune Mountain (South Obelisk), 6–8 km SSW of Urbenville, North Coast Bioregion, New South Wales (Fig. 2).

Habitat: grows on steep slopes below cliff lines on acid volcanic plugs at 350–400 m altitude in open forest or heath on skeletal clay-loam soils. Associated species include *Eucalyptus microcorys, Corymbia intermedia, Allocasuarina littoralis, Bossiaea rupicola* and *Leptospermum polygalifolium.*

The acid volcanic outcrops of the McPherson Range and adjacent areas between Boonah, Queensland and Woodenbong and Urbenville, New South Wales, constitute a well-known area of endemism. Many of the taxa restricted to these rocky sites occur widely in the area, e.g. *Acacia brunioides* subsp. *brunioides, A. acrionastes, Pultenaea whiteana and Coronidium lindsayanum*, but several are recorded only from a single mountain, e.g. *Bertya ernestiana* on Mount Ernest, *Arundinella grevillensis* on Mount Greville, *Jacksonia chappilliae* on Bald Knob.

Phenology: flowers recorded June–August and February. Fruit recorded in August.

Conservation status: *Phebalium speciosum* is known from two populations, one at the type locality below Battery Hill, the other at the foot of Mount Cullawajune, 1.5 km to the south-west. The Battery Hill population consisted at the time of the type gathering of some 200 mature plants confined to a narrow strip between the perimeter road of a *Pinus* plantation in Yabbra State Forest and the cliff line. The Mount Cullawajune population is larger, of some 250 plants in an undisturbed rocky gully (pers. obs., May, 2012).

Possible threats to survival of the species are of concern, particularly for the Battery Hill population with its

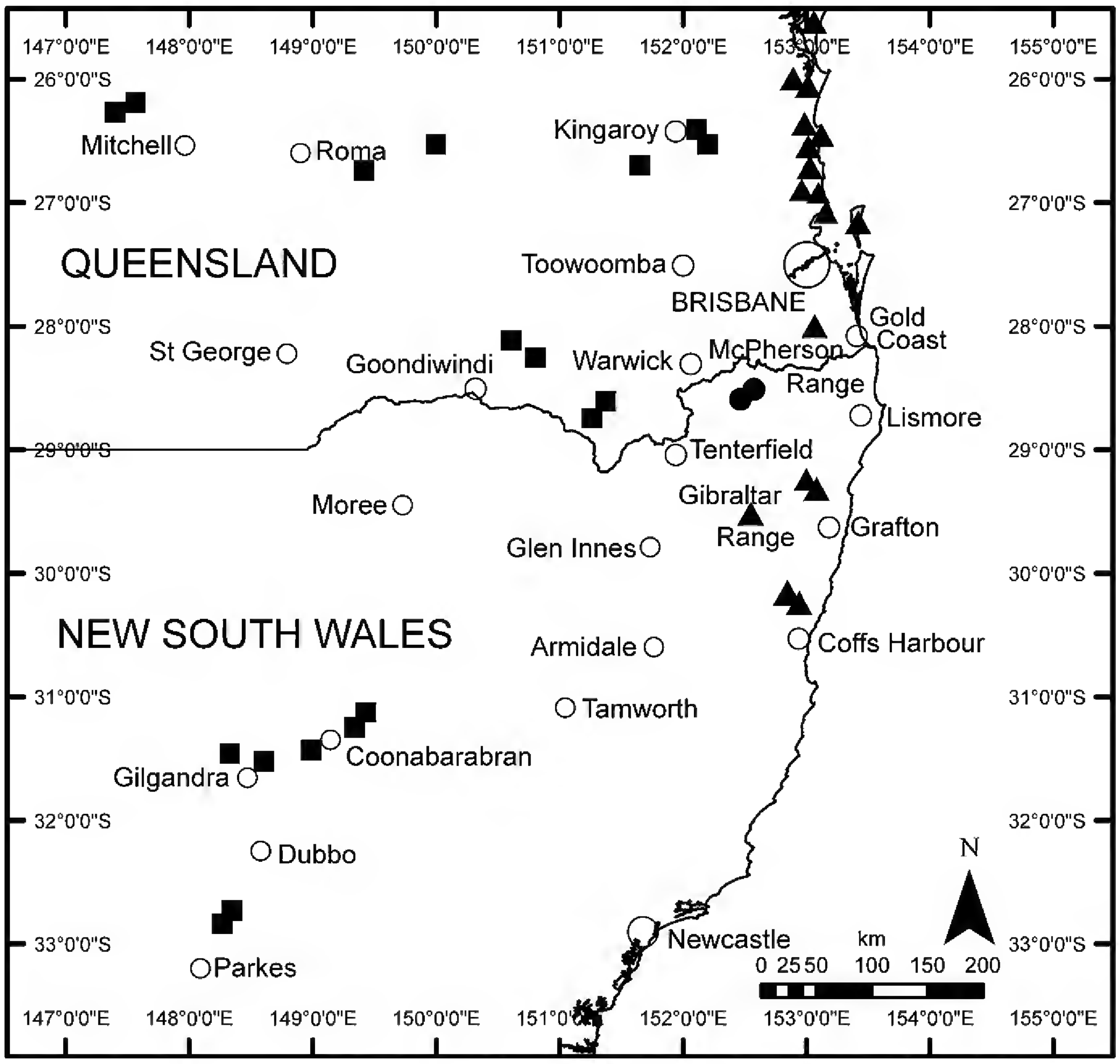

Fig. 2. Distribution of (●) *Phebalium speciosum,* including partial ranges of (■) *P. nottii* and (▲) *P. woombye.*

confined habitat and proximity to the plantation road. Too frequent fires would present a major threat to survival of both populations. Accessibility of the Battery Hill cliffs makes them a favourite with rock climbers and some trampling of plants has been observed. Extension of Toonumbar National Park to include the populations within the reserve system is recommended.

A coding of "Endangered" is suggested following the New South Wales Environmental Planning and Assessment Act 1979, and "Data Deficient" following IUCN guidelines (IUCN 2012).

Etymology: epithet is from the Latin *speciosum* (beautiful), in reference to the showy effect of pink corollas and silvery under-surfaces of the leaves.

Modification to key in Flora of New South Wales

The key to *Phebalium* species in *Flora of New South Wales* (Weston & Harden 2002: 300) and the *New South Wales Flora Online* (Weston & Harden 2012) may be modified to accommodate the new species as follows:

1 Corolla pink; flowers 5–8 merous
    1a Leaves >7 mm wide, lanceolate or elliptic........ ***P. speciosum***
    1a* Leaves <5 mm wide, narrowly elliptic........ ***P. nottii***
1* Corolla white or bright yellow, sometimes ageing pink; flowers 5-merous

Acknowledgments

I wish to thank Directors of the herbaria BRI, CANB and NSW for access to collections and Alex Floyd at Coffs Harbour Botanic Gardens for use of CFSHB. Thanks to John Nevin for the image of the isotype specimen.

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Emendments to *Sprengelia* Sm., (Epacridoideae Ericaceae), Tasmania, Australia

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Abstract

Sprengelia montana R.Br. and *S propinqua* A.Cunn. ex DC are separated from *S. incarnata* and restored to species status. Emended descriptions for *S. incarnata*, *S. montana* and *S. propinqua* are given. A new endemic species for Tasmania, ***S. minima***, R.K.Crowden is described and the relationship between the Tasmanian endemics, *S. distichophylla* (Rodw.) Curtis and *S. minima*, and the New South Wales endemics, *S. monticola* (A.Cunn ex DC) Druce and *S. sprengelioides* (R.Br.) Druce is discussed. An identification key for *Sprengelia* is provided.

Introduction

Early botanists recognised three species of *Sprengelia* in Tasmania, *S. incarnata* Sm., *S. montana* R.Br. and *S. propinqua* A.Cunn. ex DC. Rodway (1903) distinguished *S. incarnata* var. *distichophylla*, but this was later accorded species status by Curtis (1962). Bentham's (1868) notes for *S. incarnata* draw attention to the species' variability and to J.D. Hooker's (1860) suggestion that *S. montana* and *S. propinqua* be submerged in *S. incarnata* Bentham agreed with Hooker, as did Rodway (1903) and Curtis (1962) in their respective Tasmanian Floras. Curtis regarded '*S. propinqua*' and '*S. montana*' as "extreme and distinctive forms of a highly variable *S. incarnata*, there being intermediate forms with variable character combinations" (Curtis 1962, p. 455).

I have examined herbarium specimens held at HO and extensive living material of *S. incarnata* and the two distinctive '*S. propinqua*' and '*S. montana*' variants from their range throughout Tasmania. Populations of *S. incarnata* from mainland Australia have also been studied. From these observations, intermediate forms are uncommon and restricted to just a few locations where *S. incarnata s. str.* and *S. incarnata* var. *propinqua* cohabit, suggesting possible hybridisation. Collections from areas free of cohabitation are morphologically consistent, the only perceptible variations found are in size and habit.

Materials and Methods

Flower and leaf measurements were made using living plants, twenty five each of *S. incarnata*, and the variants, *S. incarnata* var. *montana* and *S. incarnata* var. *propinqua*, using one fully opened flower and one mature leaf from each plant. The leaf used was taken from the 5th or 6th most distal node from the involucre. Flower measurements included sepal length and width, petal lobe length and width, corolla tube length, style length and anther length. Leaf measurements were as shown in Fig. 1 (a = length of sheath, b = lamina blade length from top of sheath to apex, c = width of lamina blade at the widest point). There are two components to the sheath. For the top part (about 2/3) the lower lamina margins overlap, completely wrapping around the stem. Below this the margins are fused to form a ring. The two components added together are included as the measurement. Only Tasmanian plants were included in this study as the main objective was to distinguish between the three Tasmanian forms of *S. incarnata sensu* Curtis.

Results and Discussion

Morphological features in which the three taxa differ include style length, length of the sheathing leaf base, length and width (shape) of lamina, leaf projection and apex. These differences are summarised in Table 1. In *S. incarnata,* lamina length varied greatly from 4 to 22 mm, but much less so in the other species. However, ratios remained more or less constant and some, where relevant, are included in the Table. The most striking difference between the taxa, however, is in floral morphology. In flowers of *S. incarnata s. str.*, the anthers are coherent to the upper style below the stigma and this condition is evident in the bud and early anthesis and persists throughout the life of the open flower. However, in both *S. montana* and *S. propinqua* the anthers are connivent to the style in bud and at the onset of anthesis, but as flowering progresses the anthers separate from the style, and become spreading in the open flower. This difference between *S. incarnata* and the other two taxa

Table 1. Morphological comparisons of *S. incarnata, S. montana* and *S. propinqua.*

(The range and means of measured values are given as well as ratios of the means where relevant; all lengths in mm.)

	S. incarnata	***S. montana***	***S. propinqua***
Leaves			
Phyllotaxy	spreading, maybe twisted or reflexed.	sub-erect	sub-erect
Apex	acuminate, pungent	shortly mucronate	acute,+/-blunt
	straight	upturned	upturned
Texture	thin, flexible	thick, stiff	thick, stiff

	Range	**Mean**	**Ratio**	**Range**	**Mean**	**Ratio**	**Range**	**Mean**	**Ratio**
Blade length	5–16	9.38		3–8	4.21		6–20	11.09	
Blade width	2–5	2.93		2–3	2.5		3–6	4.48	
Blade length/width			3.20			1.68			2.48
Sheath length	2.5–3.5	2.86		1.8–2.5	1.97		3–4	3.36	
Sheath/Blade length			0.30			0.47			0.30
Flowers									
Sepal length	4.1–4.8	4.38		4.5–5.1	4.84		7.6–8.4	7.88	
Sepal width	0.9–1.2	1.04		1.2–1.5	1.37		1.5–1.9	1.76	
Sepal length/width			4.22			3.53		4.48	
Lobe length	3.8–4.4	3.99		3.5–4.4	3.98		6.2–7.9	6.90	
Lobe width	1.0–1.3	1.17		1.0–1.4	1.16		1.5–2.0	1.67	
Lobe length/width			3.41			3.43			4.13
Corolla Tube length	0.8–1.0	0.90		0.9–1.2	1.02		1.4–2.0	1.69	
Corolla/Lobe length			0.23			0.26			0.24
Anther length	1.2–2.3	1.68		1.1–1.3	1.20		3.0–4.0	3.50	
Style length	3.2–3.7	3.37		1.8–3.0	2.13		5.0–6.7	6.43	
Style/Lobe length			0.84			0.54			0.93
Stigma position	exserted above anthers		mid–anthers			exserted above anthers			

is evident in both fresh and dried specimens. Bentham (1868), in uniting the three Tasmanian forms under *S. incarnata*, recognised that all three anther configurations, connivent, coherent and spreading, occurred in the genus, but apparently assumed that the variation was infraspecific, rather than between species. With access to considerably more specimens, I have formed the view that variation in anther disposition occurs between rather than within species. Taking the difference in anther disposition into consideration with other differences shown in Table 1, it is possible to recognise three morphologically distinct, consistent taxa. Accordingly it is proposed that both *S. montana* and *S. propinqua* be restored to species status. Emended descriptions for these species, as well as *S. incarnata s. str.* are provided below, together with a key for the identification of *Sprengelia* species.

Curtis (1962, p. 455) also refers to forms which inhabit some alpine cushion plants, notably *Dracophyllum minimum* F.Muell. Examination of collections at HO together with fresh field collections from various sites, show two distinct forms of *Sprengelia* resident in or associated with cushion plants. Form 1 is *S. montana*, It occurs mainly around the edges and in the interstitial regions between cushions, but plants may also grow within the cushion clumps, more so in aged and partially degrading cushions. Form 2 is distinctive from other *Sprengelia* species, and is here named *Sprengelia minima*.

A collection of *Sprengelia* from Mt. Read *Crowden 0802 006*, occurring in *Donatia novae-zelandiae* near the summit cairn, appears distinctive (see below). Further study of flowering material is required. The informal phrase-name *Sprengelia* sp. Mt Read (R.K. Crowden 0802 006) is given to this plant, and a tentative description provided.

Notes on New South Wales species of *Sprengelia*

Brown (1810) described the genus *Ponceletia* with one species *P. sprengelioides* R.Br. A second species *Ponceletia monticola* A.Cunn. ex DC, was later added. *Ponceletia monticola* subsequently was referred to *Sprengelia* as *Sprengelia ponceletioides* Sond. (Sonder 1854), and Mueller (1867) renamed *Ponceletia sprengelioides* as *Sprengelia ponceletia* F.Muell., however, both these are superfluous names and therefore illegitimate. Druce (1917) restored the basionyms and provided the new combinations *Sprengelia sprengelioides* and *Sprengelia monticola*. These names now are accepted in recent flora accounts (e.g. Powell 1992). However, as recorded by Brown (1810) the floral morphologies of *Ponceletia* and *Sprengelia incarnata* differ, ('*Corolla breviter campanulata*' in *Ponceletia*, '*Corolla 5-partita, rotata*' in *Sprengelia*). In this regard *Ponceletia* (i.e. *S. sprengelioides*

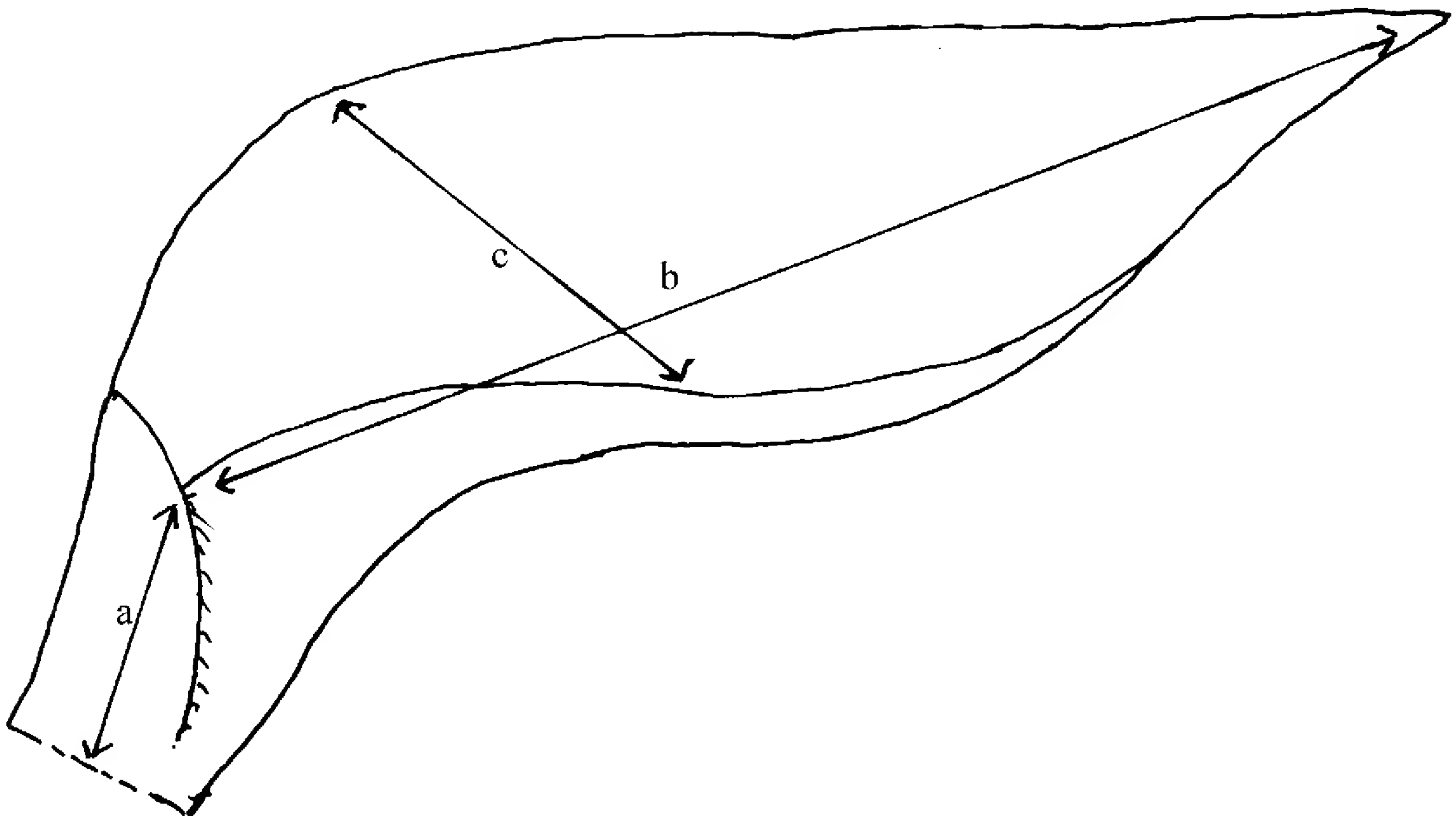

Fig. 1. Schematic leaf of *Sprengelia propinqua*. a = sheath; b = blade length; c = blade width.

and *S. monticola*) more closely resemble the two more recently described Tasmanian species *S. distichophylla* and *S. minima*. The flowers are borne solitary and terminal on the main branches rather than on numerous short, axillary branchlets forming a many-flowered cone, and are goblet-shaped (campanulate) with erect, broader, partially overlapping petals and sepals, rather than the star-shaped (rotate) form of *S. incarnata* with narrow, spreading petals and sepals. Thus it appears sensible to recognize two subgroups of *Sprengelia*, Group A, comprising *S. incarnata, S. montana* and *S.propinqua* and Group B with *S. distichophylla, S. minima, S. sprengelioides, S. monticola* and *S.* sp. Mt. Read (R.K. Crowden 0802 006). Consideration may also be given to restoration of the genus *Ponceletia* for Group B, but additional work, involving a molecular study, is required.

Key to *Sprengelia*

Flowers few to numerous, each one terminating a short axillary branchlet, often forming dense conical heads; sepals and petals narrow, spreading, forming a star-shaped flower .... GROUP A

Flowers single at the ends of main branches, or rarely a second on a short axillary branchlet; sepals and petals ± erect, partially overlapping, forming a cup-shaped flower .... GROUP B

GROUP A

1. The anthers and distal part of the staminal filaments coherent around the top of the style and remaining coherent throughout anthesis .... **1. S. incarnata**

1* Filaments and anthers adnate to style at the onset of anthesis, but separate and becoming erect and spreading as anthesis progresses 2

2. Plant rarely above 30 cm high; flowers pink; stamens mainly glabrous or with sparse hairs; stigma held about middle of anthers .... **2. S. montana**

2* Tall, robust plant, up to 2 m high; flowers white; stamens hirsute; stigma exserted .... **3. S. propinqua**

GROUP B

1. Plant scrambling, procumbent, or a low bush 2

1* Plant erect, free growing or inhabiting an alpine cushion plant 3

2. Leaves flattened against stem, distichous; flowers deep pink .... **4. S. distichophylla**

2* Leaves spreading, not distichous; flowers white .... **5. S. monticola**

3. Plant usually 50–100 cm tall; anthers glabrous .... **6. S. sprengelioides**

3* Plant usually <20 cm tall, branching stem mostly hidden within the host cushion plant; anthers hirsute **4**

4. Anthers spreading at anthesis .... **7. S. minima**

4* Anthers remain coherent to style at anthesis .... **8. S. sp. Mt Read**

Taxonomy

Sprengelia incarnata Sm., Kongl. Vetensk. Acad. Nya Handl. 15: 263 (1794)

An erect shrub, sometimes low and straggling, usually 15–100 cm tall, rarely to 200 cm or more tall in sheltered habitats, glabrous, the older stems lacking leaf scars. Leaves imbricate; sheathing base 2.5–3.5(–10) mm long, blade widening from base, then tapering to an acute, hard, often pungent point, spreading, almost at right angles to the stem; blades of the larger leaves are often recurved and in very lush plants the leaves become twisted or take on a spiral aspect. Leaf blades relatively thin, lanceolate to narrowly ovate, concave, 4–20 (–50) mm long, 2–5 (–11) mm wide, mucro 0.4–0.6 mm long; margin entire or ciliolate where stem-clasping; floral leaves similar but smaller, the innermost with margin hyaline, shorter than calyx and forming an involucre around it. Flowers terminal or terminating short axillary branchlets (in large, very lush plants, the branchlets may show secondary branching), solitary or rarely 2 or 3 together, often crowded in tight clusters up to 20 or more, forming ovate heads; bracts and bracteoles numerous, grading from floral leaves to about 2.5 mm long, 1.3 mm wide, ovate, with margin hyaline and apex acuminate, ultimately mucronate,. Sepals pink or white, generally spreading, somewhat scarious, glabrous, narrowly lanceolate, 4.1–4.8 mm long 0.9–1.2 mm wide, shortly united at base. Corolla pink or white, about equal in length to calyx; petals almost free, with a short tube 0.8–1 mm long; at onset of anthesis the corolla tube is fully closed but soon thereafter may develop splits in lower part assuming a clawed appearance; lobes narrowly triangular, 3.8–4.4 mm long, acute, glabrous, spreading and reflexed. Stamens inserted on receptacle; filament ± flattened; anthers 1.2–2.3 mm long persisting in a coherent ring around style, papillose-hairy externally. Ovary c. 1.1 mm wide × 0.9 mm high, ridged, glabrous; style filiform, 3.2–3.7 mm long, exceeding anthers; stigma small. Fruit c. 2 mm diam. Flowering Sep–Nov.

Distribution and habitat: Tasmania (all regions except Macquarie Island); also South Australia, New South Wales, Victoria, New Zealand (South Island). A widespread and abundant species especially in peaty heaths, from sea level to sub-alpine altitudes. Re-examination of specimens held at HO showed (on the basis of anther coherence and style length) that past collections from the highest altitudes in Tasmania lodged as *S. incarnata,* almost without exception are *S. montana*. *Sprengelia incarnata* appears not to occur above middle altitudes in Tasmania, the actual altitude limit varying across the state depending on rainfall and substrate.

Selected specimens examined: South Australia: Southern Lofty Region: c. 1.6 km NE of Myponga, c. 55 km SSW of Adelaide, *Donner 5994*, 5 Nov 1977 (HO44941). **New South Wales:** Central Coast: roadside seepage on old Pacific highway, N of Calga, *Crowden 0808 042*, 19 Aug 2008 (HO364910); Royal National Park: S of Sydney, *Tillyard*, 22 Apr 1933 (HO5819). South Coast: Beecroft Peninsular. c. 1.6 km NE of Currawong, 10 m, *Lyne 358*, 27 Aug 1991 (HO301184); roadside swamp along Bareera Rd, near Currawong, *Crowden 0808 001*, 6 Aug 2008 (HO364913). Southern Tablelands: Canowie Brook, N Budawang Range, 2 km NNE of Corung Trig., 700m, *Telford 10738*, 14 Oct 1988 (HO116249). **Victoria:** Wannon: c. 5.7 km along Range Rd. from main Casterton–Dartmoor Rd., *Short 1333*, 1 Oct 1981 (HO46122); Lower Glenelg National Park: near Blackwood Ck, near Portland, *Melville 1580*, 13 Oct. 1952 (HO581713). **Tasmania: Flinders:** Mt. William National Park: 20 m. *Williams s.n.*, 27 May 1986 (HO535110); Goshen Road, *Simson 902*, 4 Aug 1876 (HO514540). **Central Highlands:** Lyell Highway, slopes of Mt. Alma, 410 m, *Cave 642*, 6 Oct 2006 (HO542805). **South East:** Wielangta Road, 1.5 km S of Orford, *Buchanan 16269*, 25 Nov 2004 (HO532564); McManus Hill, Tasman Peninsula, *Cave 488*, 23 Oct 2005 (HO535147); Track to Waterfall Bay, 0.75k S of Devils Kitchen, Tasman Peninsula, *Duretto 1768*, 10 Oct 2004 (HO530748); Alberts Marsh, SE of Fingal, 530 m, *Rozefelds 365*, 31 Oct 1996 (HO328489); Lunawanna, Bruny Island, 15 m, *Baker 1913*, 9 Sep 2008 (HO550675). **West:** Jane River, track near Adelaide River, *Buchanan 16989*, 16 Apr 2008 (HO553683).

Sprengelia montana R.Br., Prodr. Fl. Nov. Holland. 555 (1810)

Sprengelia incarnata f. *montana* (R.Br.) Siebert & Voss, *Vilm. Ill. Blumengärtn., ed. 3* 1: 610 (1896); *S. incarnata* var. *montana* (R.Br.) Domin, *Biblio. Bot.* 22(89): 1055 (1930); *Sprengelia incarnata pro parte* W.M.Curtis, *The Student's Flora of Tasmania* 2: 454 (1962).

A small erect shrub up to 30 (–50) cm high, usually branched from base, the older stems bare without leaf scars, often growing in fairly dense tufts in or edging alpine cushion plants. Leaves imbricate, with bases sheathing the stem, 1.8–2.5 mm long, the leaf blade thick and stiff, ovate, 3–8 mm long, 2–3 mm wide, keeled in the upper part, spreading to sub-erect, concave, widest at the shoulder, then tapering towards the often upturned apex; apex acute, blunt or with a short mucro; margin entire or ciliolate, hyaline at least in the lower part, infolding and touching just below the apex; Flowers pink, up to 10, solitary or 1 or 2 together terminating short axillary branches, in very crowded heads at the branch tips; bracts ovate, graduating and reducing in size from the foliage leaves to c. 2.5 × 3.0 mm, with a broad hyaline margin. Sepals narrow lanceolate, straight, 4.5–5.1 mm long, 1.2–1.5 mm wide, acute, spreading. Corolla tube very short, c. 0.9–1.2 mm, lobes lanceolate, squarrose, 3.5–4.4 mm long 1–1.4 mm wide, glabrous, spreading. Staminal filaments inserted on the receptacle, ± thickened, bent around the ovary, the anthers connivent to the style in the bud but separating and spreading on anthesis; anthers 1.1–1.3 mm long, (glabrous or) sparsely to densely hirsute. Ovary ribbed, 0.9–1.1mm high, 1.1–1.3 mm wide, glabrous to pubescent, style slender, 1.8–3.0 mm long, stigma amidst the anthers. Flowering Nov–Jan.

Distribution and habitat: Tasmania (Ben Lomond, Central Highlands, Southern Ranges, West); endemic. Localised populations of *S. montana* are widespread in montane regions, occurring in wet areas and often inhabiting or close to cushion plants. I am not aware of any populations where *S. incarnata* and *S. montana* cohabit or have an actual interface, so the chance of interspecific hybridization is remote.

Selected specimens examined: Tasmania: Central Highlands: Track below Crater Lake Scouts hut, Cradle Mt., 1080 m, *Powell 1556*, 29 Nov 1981 (HO410762). **Southern Ranges:** Mt. Field National Park: Tarn Shelf, , 1200 m, *Smith 359*, (HO36471). Near summit of Mt. Wellington, *Burbidge 3204*, 19 Jan 1949 (HO5803). Hartz Mountains National Park: Hartz Mts., 900 m, *Comber 2245*, 2 Apr 1930 (HO5779); Hartz Mt. track, *Wiecek 580* & *Brown*, 10 Feb 1995 (HO318372); Jubilee Ra. Head of South Styx R., 840 m, *Buchanan 5176*, 8 Jan 1985 (HO407256); **West**: Mt. Humboldt, 920 m, *Jarman s.n.*, 17 Jan 1978 (HO411794). **Ben Lomond:** Mt Arthur, above tree line, *Noble 29096*, 13 Mar 1980 (HO79291). SE slope of Mt. Lloyd, 800 m, *Buchanan 5642*, 13 Feb 1985 (HO406623).

Sprengelia propinqua A.Cunn. ex DC., Prodr. (DC.) 7(2): 768 (1839)

Sprengelia incarnata f. propinqua (A.Cunn. ex DC.) Siebert & Voss, *Vilm. Ill. Blumengärtn., ed. 3* 1: 610 (1896). *Sprengelia macrantha* Hook.f., *Lond. J. Bot.* 6. 273 (1847). *Sprengelia propinqua* var. *demissa* F.Muell., *Fragm. (Mueller)* 1(5): 39 (1859). *Sprengelia incarnata* pro parte. W.M.Curtis, *The Student's Flora of Tasmania* 2: 454 (1962).

An erect, robust shrub, multiple branches from the base, up to 2m high; branches glabrous, older parts bereft of leaves, without leaf scars. Leaves imbricate, crowded on distal branches, sheathing stem basally, 3–4 mm long; leaf blade ovate, 6–20 mm long, 3–6 mm wide, concave, stiff, spreading to sub-erect, upturned towards apex, widest at shoulder then tapering to a barely pungent mucro, glabrous, lower surface striate, margin ciliolate near the apex, hyaline towards the base. Flowers white, terminating short branches (often with secondary branchlets) crowded in the upper axils; bracts ovate, similar to foliage leaves, but graduating from them to a smaller size 3.5–5 mm long, 3–4.5mm wide. Sepals narrowly lanceolate, straight, 7.6–8.4 mm long 1.5–1.9 mm wide, spreading. Corolla tube 1.4–2 mm long, becoming clawed at base as a result of ovary swelling after fertilization; lobes narrowly lanceolate, 6.2–7.9 mm long, 1.5–2.0 mm wide, spreading and reflexed. Staminal filaments inserted on receptacle, bent around ovary, upper part and anthers connivent to style in bud, but separating and spreading with onset of anthesis; anthers 3–4 mm long, densely hairy. Ovary ridged, slightly pubescent, 0.9–1.1 mm high, 1.3–1.4 mm wide, style slender, 5.9–6.7 mm long, stigma exserted above anthers. Fruit a capsule. Flowering Nov–Jan.

Distribution and habitat: Tasmania (Central Highlands, Southern ranges, West); endemic. Found in poorly drained shrubberies, heaths and sedge communities on Precambrian silicates of high rainfall areas in the southwest from near sea level to an altitude of > 1000 m. It is frequently found in cohabitation with *S. incarnata* and there is evidence of intermediate forms and hybridization between these two species. An analysis of probable hybridization in several communities will be reported elsewhere.

Selected specimens examined: Tasmania: Southern Ranges; 1.5 km SSE of Elliott Hill, Port Davey, 40m, *Buttermore 82*, 17 Jan 1986 (HO95523). The Coronets, rocky ridge top, 800 m, *Collier 2214*. 24 Jan 1987 (HO103899). Kathleen Is, Port Davey, 120 m, *Buchanan 9184*, 4 Jan 1987 (HO125938). Mt. Frederick, Weld R., 920 m, *Collier. 3838*, 19 Nov 1988 (HO118240). 1 km N of Reservoir Lakes, 770 m, *Adams 62*, 13 Jan 1984 (HO76339). Southern Jubilee Ra., 740 m, *Buchanan 5359*, 16 Jan 1985 (HO120776). **West;** Eagle Creek track, Franklin R. drainage side N of Elliott Ra., *Jarman s.n.*, 16 Jan 1978 (HO30290). Trappers Inlet, Lake Pedder, *Morris 8007*, 11 Jan 1980 (HO32606). 1 km NE of Strahan, 60 m, *Moscal 5278*, 6 Jan 1984 (HO80566). Point Hibbs, Meerim Beach–Whitehorses Beach, *Moscal 5705*, 17 Jan 1984 (HO74503).

Sprengelia minima R.K.Crowden, ***sp. nov.***

Diagnosis: inter plantas pulvinatas, incolens; a *Sprengelia incarnata* floribus cupulatis non stellaribus, sepalis petalisque erectis, antheris stylo in alabastro conniventibus, in flore aperto patentibus differt.

Type: Mawson Plateau, Mt. Field National Park, 100 m NW from top end of ski tow (now abandoned) in *Dracophyllum minimum* cushions, 42 41 S 146 34 E, 1285 m, *AM Gray 1513*, (holo: HO530529; iso: MEL, CAN, NSW).

A small much branched shrub, known mostly as an inhabitant of the alpine cushion plants *Dracophyllum minimum* and *Donatia novae-zelandiae*, either wholly contained within the cushion, or with short branchlets prostrate on the surface. Leaves imbricate, sheathing stem basally 1–1.5 mm long, blade erect to sub-erect, 3–5 mm long, 1–2 mm wide, concave, broadest just above shoulder, tapering sharply for half its length then more gradually to a blunt mucro, thick, keeled in upper half, glabrous, weakly striate in lower part of both surfaces, margins involute and touching below apex forming a solid cylinder, microciliate above and a thin hyaline edge in lower part. Flowers white, solitary, terminal on main branches, rarely a single floret on a short, axillary branchlet; bracts similar to foliage leaves though grading to a lesser size 2–2.35 mm long 1–1.5 mm wide, those immediately subtending the flowers with a broad hyaline margin; Sepals broadly lanceolate, erect, 3.5–4 mm long, 1–1.5 mm wide, concave, acute. Corolla tube c. 0.5mm, lobes 3–3.5 mm long, 0.5 mm wide, lanceolate-ovate, generally erect, slightly spreading at tips in older flowers, slightly wavy. Staminal filaments inserted on receptacle, flattened below then cylindrical, at first bent around style, but straightening and spreading with anthers as anthesis progresses, anthers papillose-hairy, 1–1.5 mm long. Ovary c. 1 mm wide, 0.8 mm high, 5-locular, glabrous; style slender, deeply inserted in a depression at top of ovary, short 0.7–1.3 mm, stigma held below top of the anthers. Fruit a capsule. Flowering Dec–Jan.

Distribution and habitat: Tasmania (Southern Ranges, West); endemic. Found on Mt Field, the Hartz Range and elsewhere as an inhabitant of the bolster plants, *Dracophyllum minimum* F.Muell. and *Donatia novae-zelandiae* J.R.Forst & G.Forst.

Etymology: the name minima was chosen because the plant is of much smaller habit than other species of *Sprengelia*.

Conservation: not considered to be at risk. All populations known to date are in National Parks or other conservation areas.

Notes: this taxon appears to be exclusively a cushion inhabitant. On Mt. Field (K Col & Mawson Plateau) it is associated only with *Dracophyllum minimum*, but at Lake Esperence (Hartz Ra.) and elsewhere it also inhabits *Donatia novae-zelandiae*. Plants growing in *Dracophyllum minimum* (Mt. Field–dolerite) barely emerge above the surface contour of the host cushion (Fig. 2) whilst those in *Donatia novae-zelandiae* (Lake Esperence – Precambrian silicates) are more exposed, with several short, prostrate branchlets spreading on the cushion surface (Fig. 3). The much branched stems within the cushion are bare or clothed with dead leaves, with only a few green leaves near the tips (Fig. 4). Drawings of leaf and flower section are given in Fig. 5.

Selected specimens examined: Tasmania: Southern Ranges: Mt. Snowy, within cushion plant community in fjelmark bolster plant community, 1080 m, *Moscal 10748*, 28 Apr 1985 (HO401725). Lake Cygnus, W. Arthur Ra., 860 m, *Collier 2011*, 7 Dec 1986 (HO121415). Mt. Damoin, 1030 m, *Collier 4406*, 25 Nov 1989 (HO119821). Propsting Ra., 600 m, *Jarman s.n.*, 16 Feb 1977 (HO323143). K Col track to Mt Field West, *Curtis s.n.*, 7 Jan 1948 (HO94830). Abrotanella Rise, 1000 m, *Buchanan 15172*, 26 Mar 1998 (HO324939). Mt. Sprent, 900 m, *Jarman s.n.*, 8 Feb 1977 (HO323145). Hartz Mts., 900 m, *Comber 2244*, 2 Apr 1930 (HO5771). Lake Esperence, Hartz Ra. National Park, *Crowden 0912 007*, 11 Dec 2009 (HO565495). K Col. On track to Field West, Mt. Field National Park, 1200 m, *Crowden 0505 001*, 22 Jan 2005 (HO530152). **West:** Mt Sedgewick, 600 m, *Comber s.n.*, 28 Feb 1930 (HO5769).

Sprengelia sp. Mt Read (R.K. Crowden 0802 006)

A small shortly branched shrub, known only as an inhabitant of the alpine cushion plant *Donatia novae-zelandiae*, from a single location (Mt. Read, near the summit cairn). In habit similar to *S. minima* with short branchlets prostrate on the cushion surface, but becoming more dense at the cushion margins, sometimes spilling over onto the substrate. Leaves similar in all respects to *S. minima,* imbricate, the base sheathing the stem 1–1.5 mm long, the blade erect to sub-erect, 3–5 mm long, 1–2 mm wide, concave, broadest just above the shoulder, tapering sharply for half its length then more gradually to a blunt mucro, thick, keeled in the upper half, glabrous, weakly striate in the lower part of both surfaces, the margins involute and touching below the apex forming a solid cylinder, minutely ciliate above and a thin hyaline edge in the lower part. Flowers not seen, the developing capsules solitary, terminal on the main branches, bracts similar to the foliage leaves though grading to a lesser size 2–2.35 mm long 1–1.5 mm wide, those immediately subtending the capsules (flowers) with a broad hyaline margin; A single capsule containing (probably) mature seeds was still attached to the style and coherent anthers, a significantly different state to *S. minima.* Further study of flowering material is required to determine whether this represents a true feature of the species or is just an aberration in this plant.

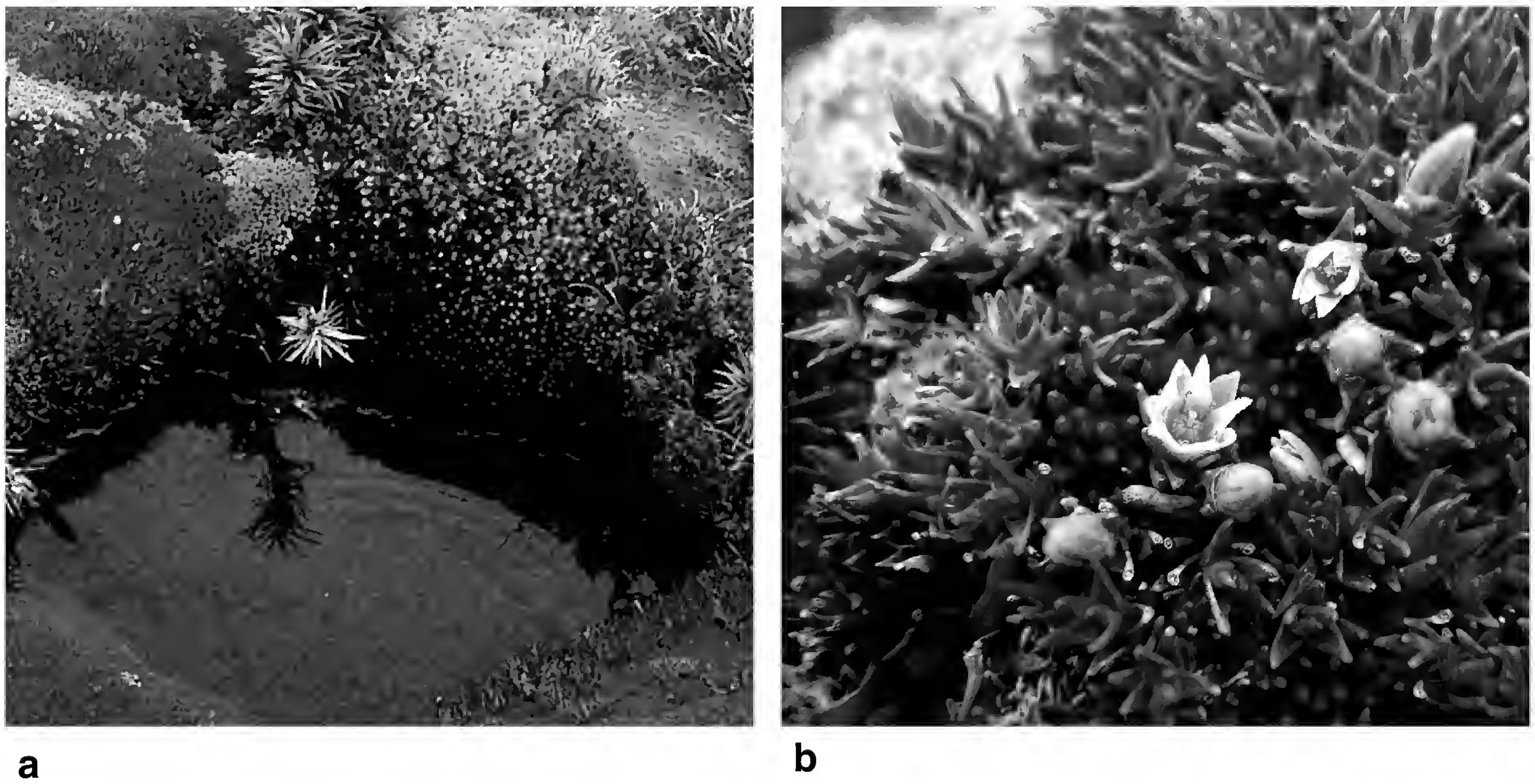

Fig. 2. *Sprengelia minima*. **a,** habitat photo showing several small flower clusters in a *Dracophyllum minimum* cushion on the Mawson Plateau, Mt. Field National Park; **b,** close-up photo of flower cluster.

Fig 3. *Sprengelia minima.* Habit/habitat photo, showing plant growing in *Donatia novae-zelandieae* cushion at Lake Esperence, Hartz Mts. National Park.

Fig.4. *Sprengelia minima.* Form. The green leaves only are at or above the surface contour of the host cushion plant.

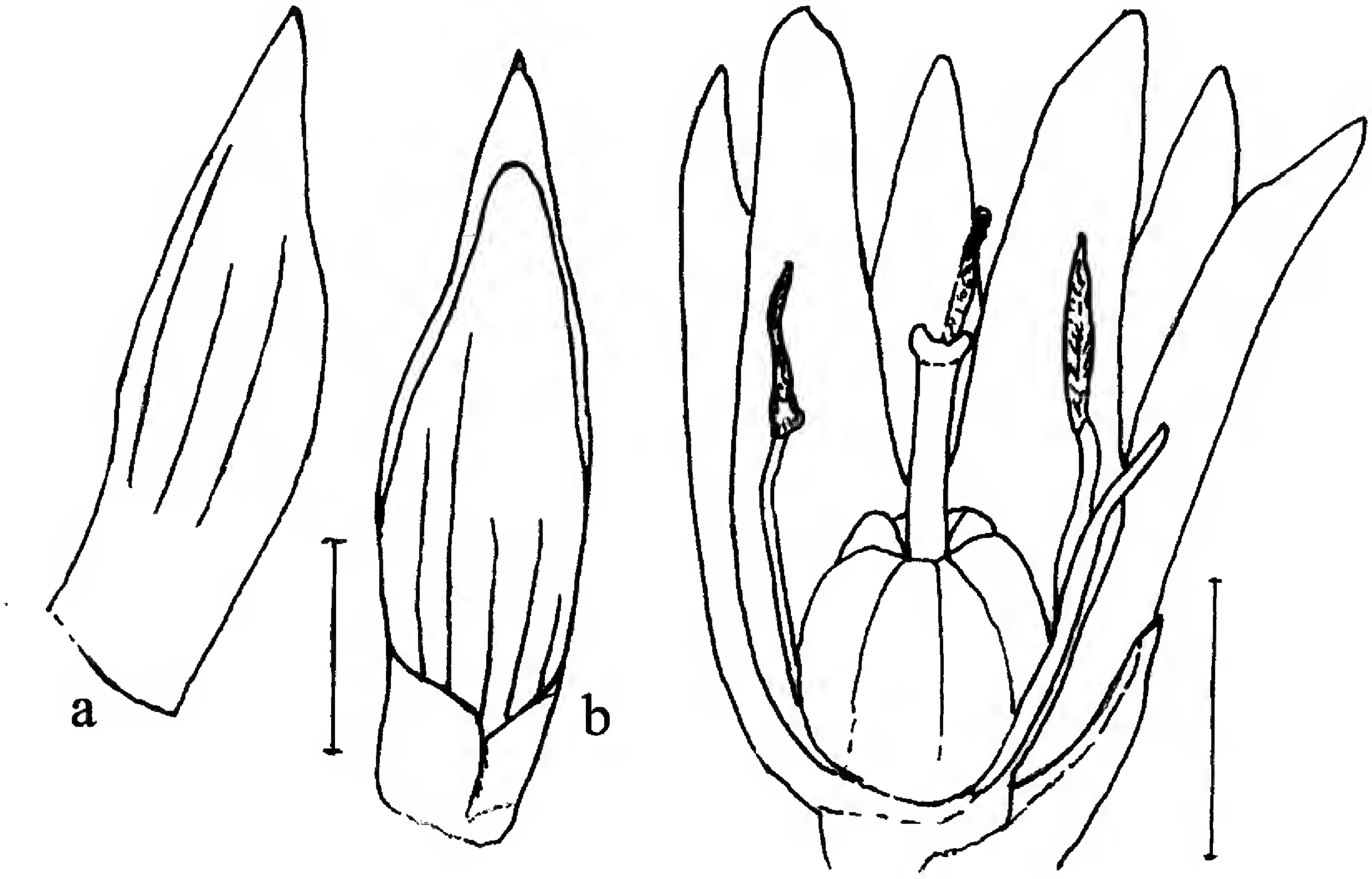

Fig. 5. *Sprengelia minima* **a,** leaf adaxial view; **b,** leaf abaxial view, scale bar =1mm; **c,** flower section, scale bar = 1mm.

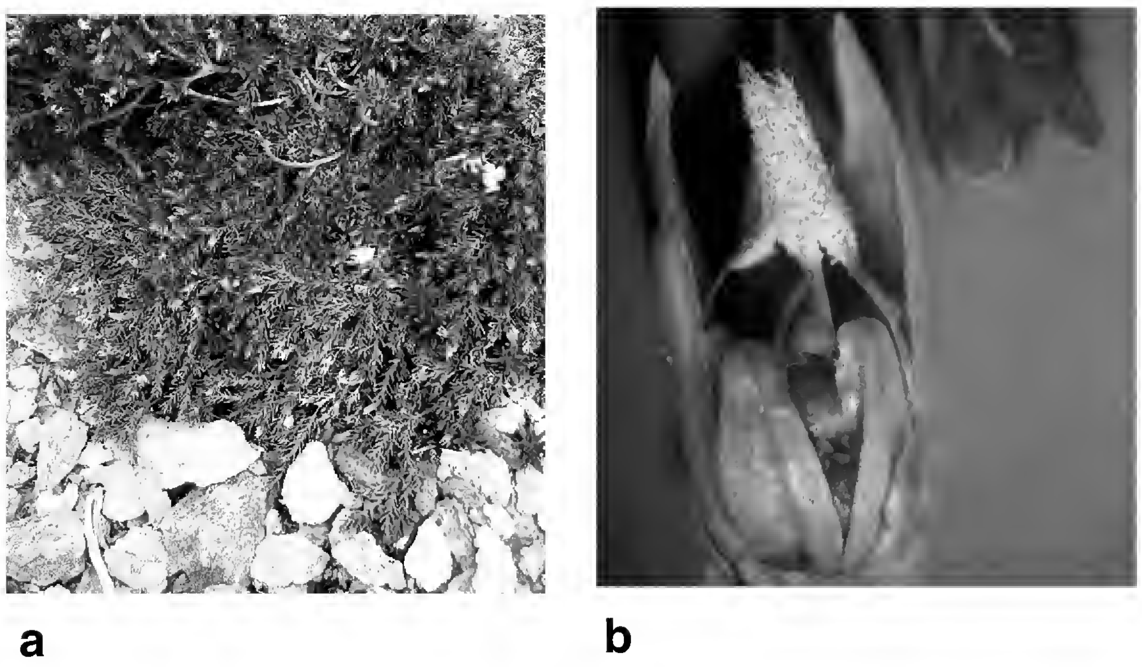

Fig 6. *Sprengelia* sp. Mt Read.**a,** habit photo, showing plant growing from edge of *Donatia zelandiae* cushion onto the quartzite substrate at Mt Read; **b,** anthers cohere persistently to the style in the Mt Read form. Note the petal residues (top right) above the specimen.

Notes: within the cushions, the plants present an appearance similar to *S. minima* as found at Lake Esperence, (Hartz Range) It is prostrate and straggling over the surface of the cushion and with presumably solitary flowers (not seen, but with solitary formed capsules) terminating the main branches. However, at the cushion margins they present a larger, more dense, prostrate form which may spread out from the cushion edge onto the surrounding substrate (Fig.6a). Unfortunately only vegetative or specimens past flowering have been observed to date, but on one plant, the detached remains of a single old flower showed anthers in a persistent ring around the style (Fig. 6b), as is usual in *S. incarnata,* rather than spreading as in *S. minima.* However, the corolla residue (Fig 6b) more likely resembles the remains of a cup-shaped rather than a star-shaped flower.

Specimen examined: Tasmania: West: Mt. Read in the cushion plant *Donatia novae-zelandiae*, near the summit cairn, 1114 m, *Crowden 0802 006*, 20 Feb 2008 (HO564911).

Acknowledgment

I thank Dr. G. Kantvilas, Tasmanian Herbarium, Hobart, for the Latin diagnosis.

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Correction of a typographical error in the protologue of *Banksia conferta* A.S.George var. *penicillata* A.S. George.

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Abstract

The protologue of *Banksia conferta* A.S.George var. *penicillata* A.S.George incorrectly cites R.G. Coveny 3537 as the type collection of this species, when it should have been cited as R.G. Coveny 3577.

Introduction

A perhaps unintended collateral benefit of *Global Plants* (see http://plants.jstor.org/), presently imaging types in the collections of Australian herbaria, is the discovery of errors in the citation of type specimens of Australian plants. The purpose of this note is to correct such an error.

When George (1981: 289) named and described *Banksia conferta* A.S.George var. *penicillata* A.S.George, he cited the type collection as "N of Clarence on the Newnes tunnel road, New South Wales, 6 April, 1971, *R. Coveny* 3537. Holo: NSW; iso: PERTH." George's description was accompanied by a photograph of the isotype of this species, as held at PERTH. That sheet has a type-written label from the National Herbarium of New South Wales in which the collecting number is clearly displayed as *3537*.

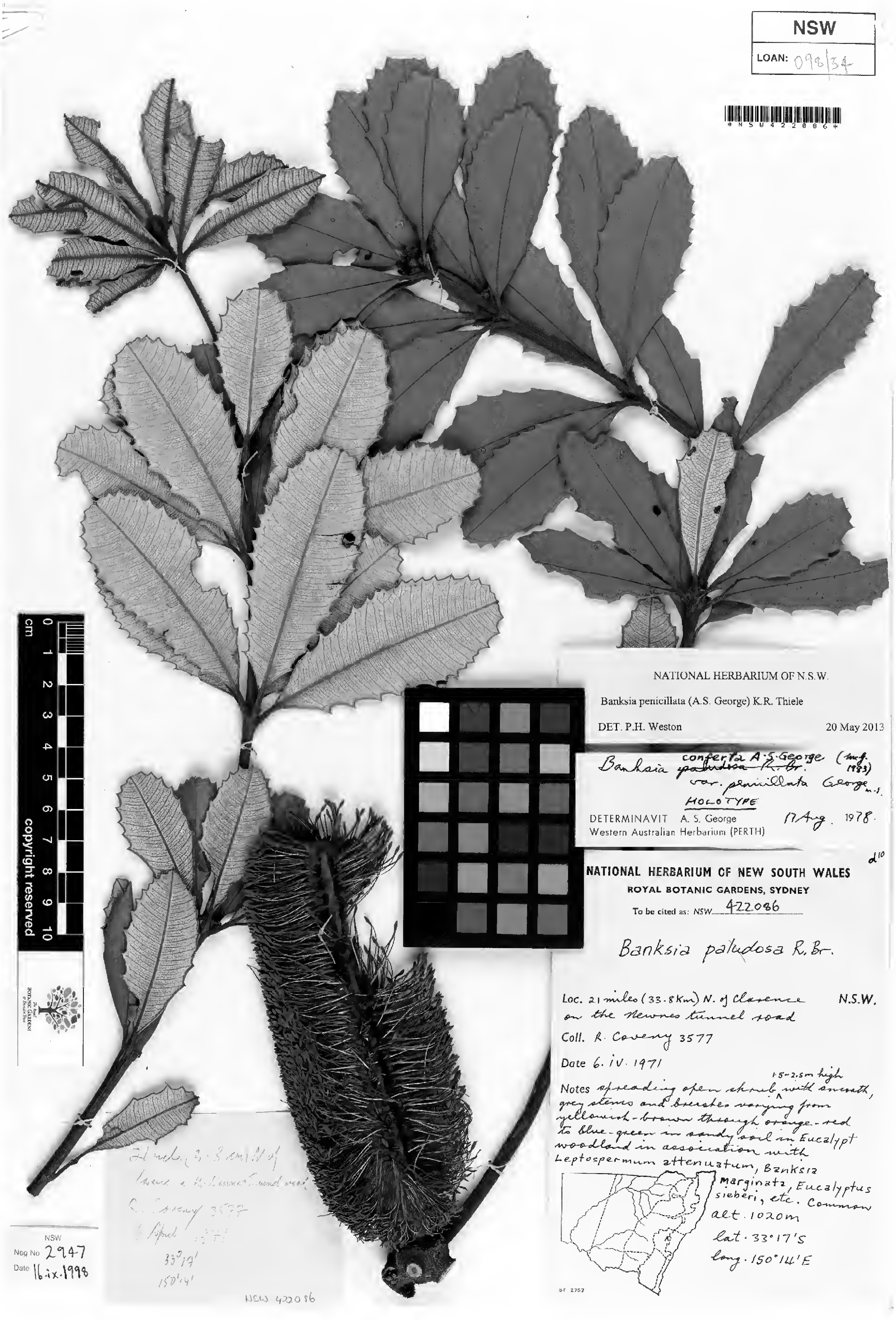
In May 2013 the holotype sheet of *Banksia conferta* var. *penicillata* (Fig. 1) (now treated as *Banksia penicillata* (A.S.George) K.R.Thiele) was retrieved from the collection at NSW for digitization for the *Global Plants* project. The label information was found to be:

21 miles (33.8 km) N. of Clarence on the Newnes tunnel road, *R. Coveny 3577*, 6. iv. 1971.

Glued to this sheet is a determinavit slip, in Alex George's hand, annotated "Banksia paludosa R.Br. var. penicillata George m.s. HOLOTYPE 17 Aug 1978." George's words "paludosa R.Br." have been crossed out and the following annotation, in Donald McGillivray's hand, has been added: "conferta A.S.George (McG. 1983)".

The field information provided for collection number *3577*, in Coveny's field note book (held at NSW), is identical to the label information on the holotype sheet. This *Banksia* was the only collection that Coveny made at that locality on that day. *Coveny 3537* is listed in Coveny's field notebook as a specimen of *Cyperus fulvus*, collected on 21 February 1971 at Glenugie Peak, N.S.W.

We here conclude that Coveny's collecting number was incorrectly transcribed at NSW during the preparation of the collection label included with the replicate specimen sent to PERTH; the specimen annotated as the isotype of *Banksia conferta* var. *penicillata*.



NATIONAL HERBARIUM OF N.S.W.

Banksia penicillata (A.S. George) K.R. Thiele

DET. P.H. Weston 20 May 2013

Banksia ~~paludosa R.Br.~~ conferta A.S.George (ined. 1983)
var. penicillata George n.s.
HOLOTYPE
DETERMINAVIT A. S. George 17 Aug. 1978.
Western Australian Herbarium (PERTH)

NATIONAL HERBARIUM OF NEW SOUTH WALES
ROYAL BOTANIC GARDENS, SYDNEY
To be cited as: NSW 422086

Banksia paludosa R.Br.

Loc. 21 miles (33.8 Km) N. of Clarence N.S.W.
on the Newnes tunnel road
Coll. R. Coveny 3577
Date 6. iv. 1971
Notes spreading open shrub 1.5–2.5m high with smooth, grey stems and brushes varying from yellowish-brown through orange-red to blue-green in sandy soil in Eucalypt woodland in association with Leptospermum attenuatum, Banksia marginata, Eucalyptus sieberi, etc. Common
alt. 1020m
lat. 33°17'S
long. 150°14'E

ST 2757

NSW
Neg No 2947
Date 16.ix.1998

Fig. 1. Holotype sheet (NSW422086) of *Banksia conferta* A.S.George var. *penicillata* A.S.George

Acknowledgment

Karen Wilson (NSW) provided helpful suggestions on an earlier draft of the manuscript.

Reference

George AS (1981) The genus *Banksia* L.f. (Proteaceae). *Nuytsia* 3: 239-473.

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Lectotypification of *Acacia gardneri, A. obtecta, A. sparsiflora* and *A. whitei* (Fabaceae, Mimosoideae)

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Mrs Macquaries Rd, Sydney, NSW 2000, Australia

Abstract

Lectotypes are here designated for the Australian species *Acacia gardneri* Maiden & Blakely, *A. obtecta* Maiden & Blakely, *A. sparsiflora* Maiden and *A. whitei* Maiden.

Introduction

This paper lectotypifies four *Acacia* species that were represented by a number of syntypes or confusing type designations. Collections were examined at NSW and MEL, while mainly images and specimen data were assessed for collections held elsewhere, including AD (data only), BM, BRI (data only), K, PERTH and US. The location and assessment of herbarium specimens that potentially represented types was assisted by searching records in *Australia's Virtual Herbarium* (AVH 2013) and *Global Plants* (2013). The latter site enabled the examination of images of a number of type specimens and their label details. Type citations by other authors for these species were also addressed.

Nomenclature

Acacia gardneri Maiden & Blakely, *Journal and Proceedings of the Royal Society of Western Australia* 13: 32, pl. 22, figs 6–11 (1927)

Type: Western Australia: [near] Prince Regent River, 12 June 1921, *C.A. Gardner 1368*; lecto (here chosen): NSW516385; isolecto: K793979, PERTH709018 *n.v.*, PERTH709026 *n.v.*, PERTH709034 *n.v.*

Residual syntypes: Western Australia: Packhorse Range, July 1905, *W.V. Fitzgerald* [*1253*] (NSW516386); Charnley River, Aug 1905, *W.V. Fitzgerald* (MEL2085981A, NSW516387).

In the protologue Maiden and Blakely cite the specimens "Near Prince Regent River, on the banks of streams in sandy soil, among quartzite rocks (C.A. Gardner, No. 1368, 12th June, 1921), also seen on the Moran and King Edward Rivers; Packhorse Range (W.V. Fitzgerald, No. 1253, July, 1905); Charnley River (W.V. Fitzgerald, August, 1905)". From the available syntypes the Gardner 1368 specimen NSW516385 (Figs 1 and 2) is selected as the lectotype for the following reasons: (i) it is cited by the authors as the primary specimen; (ii) the NSW specimen would have been seen by the authors (the NSW sheet label is in Blakely's handwriting); (iii) the specimen fits with the protologue description which repeats much of the information provided by Gardner;

and (iv) the specimen is a suitable representative branchlet with flowers and pods. As the species was named in honour of the collector of the specimen, the Western Australian botanist Charles Austin Gardner, it is fitting that his specimen is chosen as the lectotype.

The Packhorse Range specimen at NSW does not include Fitzgerald's collecting number "1253" that was cited in the protologue; however, the other details match and it would have been seen by the authors. The Charnley River specimen sheet at NSW is annotated indicating material from it was used for a drawing made by Ethel King (given as initials 'EK'), 19 April 1923. Components of King's line drawing appear in plate 22 of the protologue (the drawing was possibly altered and abbreviated by Margaret Flockton for the final plate since her initials also occur there). Although the original drawing by King indicates the use of the Charnley River specimen only (which has pods but no flowers), other material must have been used for the inflorescence and flower features in the final plate.

Acacia obtecta Maiden & Blakely, *Journal and Proceedings of the Royal Society of Western Australia* 13: 20, pl. 5, figs 1–6 (1927)

Type: Western Australia: between Kunnunoppin [Kununoppin] and Mount Marshall about long. 118°, lat. 31°, and Lake Barlee (long. 119–120, lat. 29–30), Winter–Spring 1919, *Fitzgerald Fraser*, per *W.C. Grasby*; lecto (here chosen): NSW484887 (flowering branchlet); probable isolecto: K806144; possible isolecto (otherwise residual syntype): MEL501393A *n.v.*, PERTH703125 (fragment, ex K806144). Possible isolecto: PERTH766348 *p.p.* (flowerhead in attached bag).

Residual syntype(s): Western Australia: Lake Giles, Oct 1919 (*viz.* label on lower left of sheet); between Kunnunoppin and Mount Marshall, about long. 118°, lat. 31°, and Lake Barlee (long. 119°–120°, lat. 29°–30°), Winter–Spring 1919, *Fitzgerald Fraser*, per *W.C. Grasby* (NSW484886; PERTH766356 – photograph of part of NSW collection – see below) (fruiting and sterile branchlets); PERTH766348 (*p.p.*, excluding loose flowerhead in attached bag which is possibly part of the flowering lectotype collection that got mixed with this sheet of fruiting and sterile branchlets).

The citation in the protologue "Between Kununoppin and Mount Marshall, and also near Lake Giles (Fitzgerald Fraser, per W.C. Grasby, winter and spring, 1919). The type." indicates, and indeed, covers a number of specimens that can be considered as syntypes. Several sheets have similar label details (generally fitting the protologue type citation), however, specimens differ between flowering and fruiting branchlets and the general date "Winter–Spring 1919" possibly indicates a group of specimens collected at different times as well as different places (the protologue cites two general localities).

The NSW484887 sheet (Fig. 3) is selected as the lectotype for the following reasons: (i) it was seen and cited by the authors (Blakely's handwriting occurs on the label); (ii) it has a single label, unlike sheet NSW484886 with its different labels causing some confusion and the possibility of being a mixed collection (see below), (iii) the specimen fits with the protologue description, and (iv) the specimen is a suitable representative flowering branchlet, with likely duplicates at other herbaria.

Herbarium sheet NSW484886 (Fig. 4) consists of both fruiting and sterile branchlets and has two labels, indicating that it may be a mixed collection. On the lower left of the sheet there is a handwritten label that may be the collector's field tag (that probably slipped over a branchlet(s) but since separated) citing "Lake Giles, Oct 1919, 8 ft [feet]". This label may be incongruous with the pre-printed herbarium label of NSW484886 (lower right) which cites the locality as "between Kunnunoppin [Kununoppin] and Mount Marshall … and Lake Barlee …". However, Lake Giles is just south of the more pronounced Lake Barlee which is cited on the label (it may be that the herbarium label was annotated with "Lake Barlee" because it is "near Lake Giles"). This sheet is likely to include the "near Lake Giles" specimen(s) cited in the protologue. There remains, however, the possibility of a mixed collection, with elements from several sites covered by the herbarium label collection details. Unfortunately the state of the collections prior to curatorial processing is unknown.

PERTH766356 (a photograph of part of NSW484886) might provide evidence of what could be the actual (or part of the) Lake Giles collection because it shows the same handwritten 'Lake Giles' and herbarium labels as found on NSW484886 but with a single branchlet. On the photograph there is a determinavit slip dated 2 Feb 1988 where R.S. Cowan indicates that it is a photograph of the 'holotype' of *A. obteca* held at NSW, while in the *Flora of Australia* account Cowan (2001, p. 53) cites the 'holotype' with the details of the herbarium label only ("between Kununoppin and Mt Marshall … and Lake Barlee"). Since this reference to the type was published after 1 January 2001, Cowan's misuse of the term 'holotype' cannot be treated as a typification and corrected to 'lectotype' (refer McNeill et al. 2012, Articles 7.10 and 9.9). The branchlet on the PERTH766356 photograph (minus some parts that have broken off) is currently mounted far left on NSW484886 with other branchlets to its right.

NATIONAL HERBARIUM OF N.S.W.
Lectotype
Acacia gardneri Maiden & Blakely
DET: P.G. Kodela 6 Nov 2012

Syntype
conf. 22 May
P. G. Kodela 2002

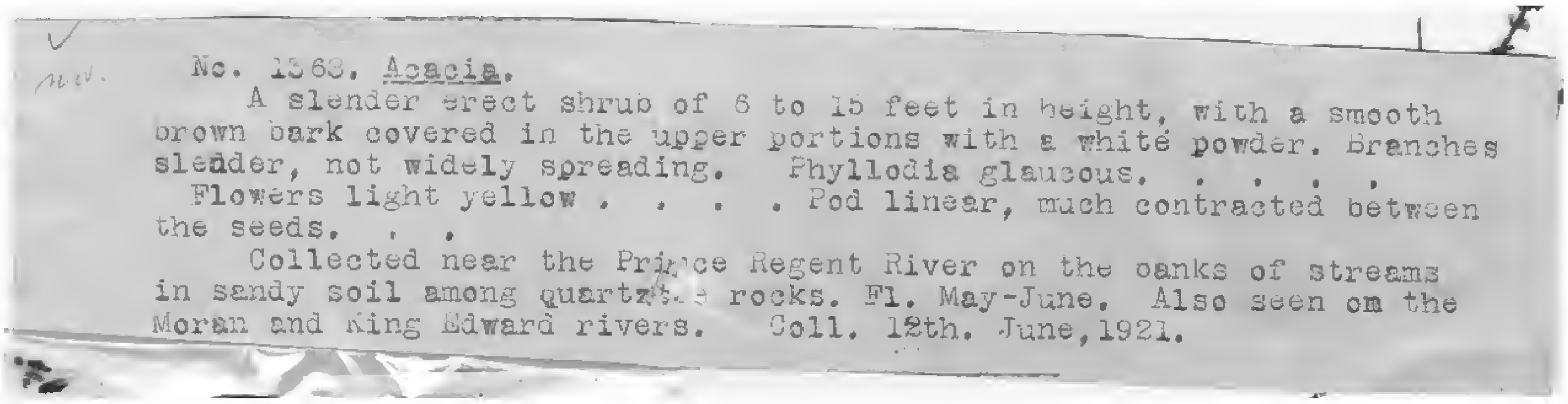
TYPE.

(c. 15°48'S, 125°35'E.)

HERBARIUM OF THE FORESTS DEPARTMENT.
FLORA OF WESTERN AUSTRALIA.
No. 1368
Acacia
Loc. Prince Regent River
Coll. C.A. Gardner Date 12 June 1921

NATIONAL HERBARIUM OF NEW SOUTH WALES,
BOTANIC GARDENS, SYDNEY.
Acacia Gardneri Maiden & Blakely
Loc. Prince Regent River. W.A.
Coll. C. A. Gardner Date 12th June 1921.

Fig. 1. Lectotype of *Acacia gardneri* Maiden & Blakely, NSW516385



No. 1363. Acacia.
A slender erect shrub of 6 to 15 feet in height, with a smooth brown bark covered in the upper portions with a white powder. Branches slender, not widely spreading. Phyllodia glaucous. . . . .
Flowers light yellow . . . . Pod linear, much contracted between the seeds. . .
Collected near the Prince Regent River on the banks of streams in sandy soil among quartzite rocks. Fl. May-June. Also seen om the Moran and King Edward rivers. Coll. 12th. June, 1921.

Fig. 2. Notes (attached to sheet) with the lectotype of *Acacia gardneri* Maiden & Blakely, NSW516385

Flowering and fruiting material of the above collections is likely to have been used by Margaret Flockton for the illustrations of *A. obtecta* in Maiden and Blakely (1927, plate 5); however, the annotation she usually provided in folders to indicate specimens were used in drawings is missing.

Acacia sparsiflora Maiden, *Journal and Proceedings of the Royal Society of New South Wales* 53: 221, pl. 15, figs 15–20, pl. 16, figs 1–4 (1920)

Type: Queensland: Eidsvold, *T.L. Bancroft* 5, Mar 1918; lecto (here chosen): NSW489921; isolecto: AD98582677 *n.v.*, BM796552 (branchlet with flowers), MEL2086584A, NSW830694, US288911 (branchlet with flowers).

Probable residual syntypes: Queensland: Eidsvold, *T.L. Bancroft* 5, Nov 1918 (BM796552 - branchlet with pods; MEL2086584B); Eidsvold, *T.L. Bancroft* 5 & 30 [see below], Nov 1918 (NSW830695–NSW830698).

In the protologue, Maiden (1920, p. 222) cites the type as "Dr. T.L. Bancroft's No. 5, Eidsvold, Queensland", which includes two flowering branchlets (dated March 1918) held at NSW (these would have been seen by Maiden and the folder was annotated by Margaret Flockton as being used for drawing "Phyllode and flower", "29.10.19" [29 Oct 1919], in plates 15 and 16 of the protologue). This collection has previously been interpreted as the "holotype" and cited as "Eidsvold, *Bancroft* 5 (NSW, holo), [*n.v.*]" (Pedley 1978, p. 153). Maslin and Cowan (2001, p. 275) accepted this interpretation. However, there are also "T.L. Bancroft 5" fruiting specimens from Eidsvold, collected in Nov 1918, at BM and MEL. Maiden (1920, p. 223) states that "I only know the type specimen, which came from Eidsvold …" and this could be interpreted to include a group of specimens of fruiting branchlets with a tag marked "No. 5 & No. 30" and an herbarium sheet label (in W.F. Blakely's handwriting except for the specific epithet where Maiden has written "sparsiflora Maiden") dated November 1918. These specimens would have been seen by Maiden for the description of the pods and seeds in the protologue; supported by an annotation in the folder that they were used by Margaret Flockton to draw "Pod & seed", "29.10.19" [29 Oct 1919], in plate 16 of the protologue. Furthermore, with the collection there is a copy of a letter to Bancroft dated 1 July 1919 in which Maiden states that "Your herbarium specimen 5 = 30 (a supposed new species)", which clearly indicates he regarded the numbers as representing the same taxon. A photograph of the habit was also provided by Bancroft of No. 5 showing several trees and including the annotation "5 = 30 new sp.". Since Maiden stated that he only knew the type specimen, it can be inferred that all the specimens he used for the description represent type material. This material includes a group of flowering and fruiting specimens with numbers 5 and 30 collected in March and November 1918. Under these circumstances it was desirable to select a lectotype.

Herbarium sheet NSW489921 (Fig. 5) is selected as the lectotype, because: (i) the original sheet label is in Maiden's handwriting and the specimen would have been seen by him; (ii) it fits the protologue description; (iii) it is clearly labelled with a tied tag with Bancroft's field number "No. 5"; (iv) it was in a folder annotated with wording that indicated the specimens were illustrated by Margaret Flockton for plates in the protologue; and (v) the specific epithet refers to sparse flowers (spikes interrupted) which is well demonstrated (particularly by the spikes in bud) of the lectotype.

Eidsvold is a small town in the North Burnett region of Queensland, Australia. It is named after Eidsvold Station, a nearby property. Thomas Lane Bancroft lived in the area 1910–1930 and collected extensively from the Eidsvold district and further afield (Bancroft *et al.* c. 2004). Pedley (1978, p. 154) suspects that Bancroft's "Eidsvold" specimens were collected over a wide area, and suggests Bancroft's *A. sparsiflora* specimens were probably not collected in the vicinity of Eidsvold (since no other collections appear to have been recorded

Lectotype NATIONAL HERBARIUM OF N.S.W.
Acacia obtecta Maiden & Blakely
DET. P.G. Kodela 31 May 2013

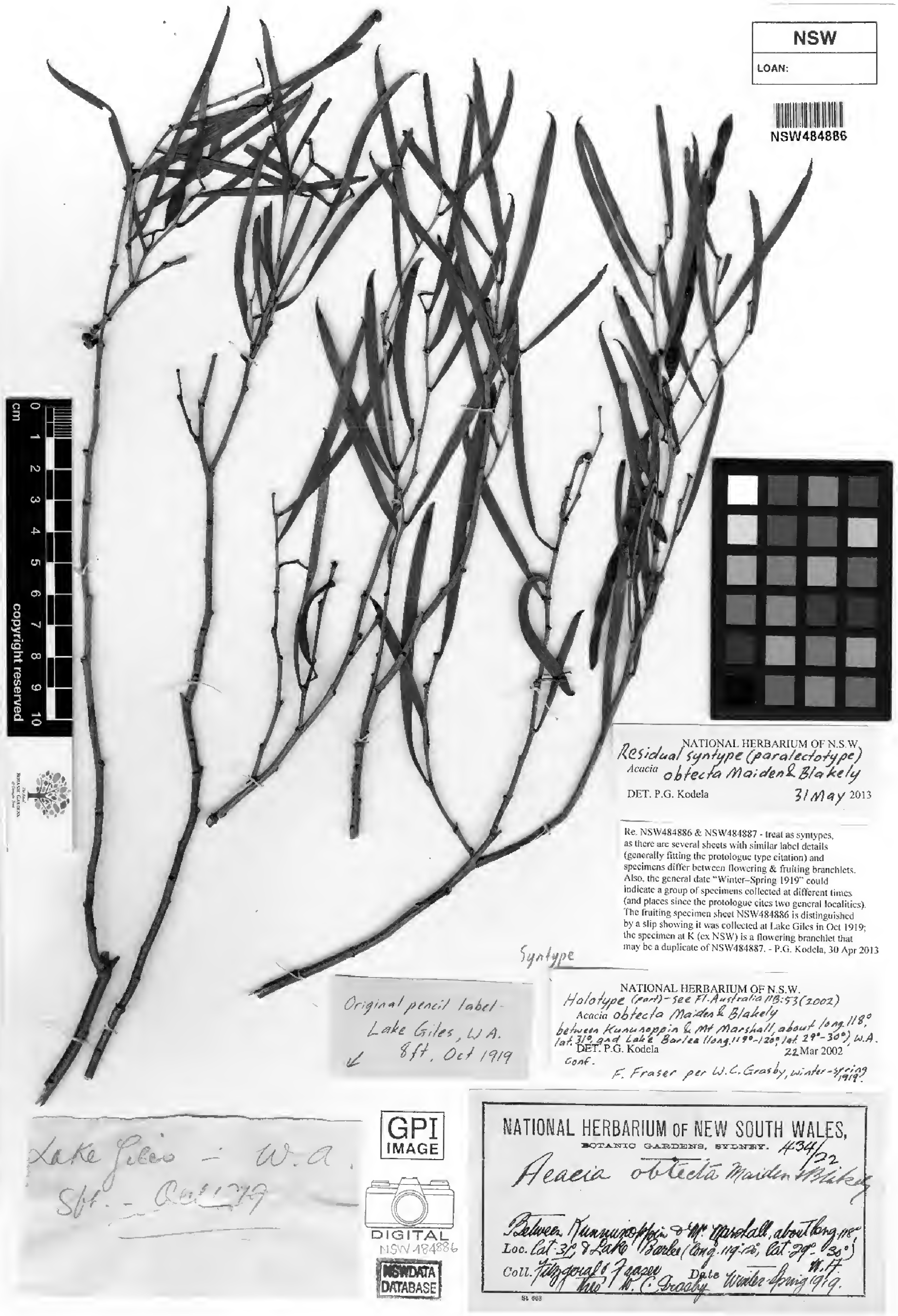
Re. NSW484886 & NSW484887 - treat as syntypes, as there are several sheets with similar label details (generally fitting the protologue type citation) and specimens differ between flowering & fruiting branchlets. Also, the general date "Winter–Spring 1919" could indicate a group of specimens collected at different times (and places since the protologue cites two general localities). The fruiting specimen sheet NSW484886 is distinguished by a slip showing it was collected at Lake Giles in Oct 1919; the specimen at K (ex NSW) is a flowering branchlet that may be a duplicate of NSW484887. - P.G. Kodela, 30 Apr 2013

syntype

NATIONAL HERBARIUM OF N.S.W.
CONFIRMAVIT
Holotype (part) fide Cowan, Fl. Australia 11B: 53 (2002)
P.G. Kodela 22 Mar 2002 19

NATIONAL HERBARIUM OF NEW SOUTH WALES,
BOTANIC GARDENS, SYDNEY. 434/22.
Acacia obtecta Maiden & Blakely
Between Kununoppin & Mt Marshall about
Loc. long 118°, lat. 31°, & Lake Barlee (long. 119-120, lat. 29-30)
W.F.
Coll. Fitzgerald Fraser thro' W.C. Grasby Date Winter-Spring 1919.

Fig. 3. Lectotype of *Acacia obtecta* Maiden & Blakely, NSW484887



NATIONAL HERBARIUM OF N.S.W.
Residual syntype (paralectotype)
Acacia obtecta Maiden & Blakely
DET. P.G. Kodela 31 May 2013

Re. NSW484886 & NSW484887 - treat as syntypes, as there are several sheets with similar label details (generally fitting the protologue type citation) and specimens differ between flowering & fruiting branchlets. Also, the general date "Winter–Spring 1919" could indicate a group of specimens collected at different times (and places since the protologue cites two general localities). The fruiting specimen sheet NSW484886 is distinguished by a slip showing it was collected at Lake Giles in Oct 1919; the specimen at K (ex NSW) is a flowering branchlet that may be a duplicate of NSW484887. - P.G. Kodela, 30 Apr 2013

Syntype

Original pencil label –
Lake Giles, W.A.
8ft, Oct 1919

NATIONAL HERBARIUM OF N.S.W.
Holotype (part) – see Fl. Australia 11B: 53 (2002)
Acacia obtecta Maiden & Blakely
between Kununoppin & Mt Marshall, about long. 118°, lat. 31°, and Lake Barlee (long. 119°–120°, lat. 29°–30°), W.A.
DET. P.G. Kodela 22 Mar 2002
Conf.
F. Fraser per W.C. Grasby, winter–spring 1919.

Lake Giles – W.A.
8ft. – Oct 1919

NATIONAL HERBARIUM OF NEW SOUTH WALES,
BOTANIC GARDENS, SYDNEY. 434/22
Acacia obtecta Maiden & Blakely
Loc. Between Kunnunoppin & Mt Marshall, about long. 118°, lat. 31°, & Lake Barlee (long. 119–120°, lat. 29°–30°) W.A.
Coll. Fitzgerald & Fraser thro' W. C. Grasby Date Winter-Spring 1919.
St 663

Fig. 4. Residual syntype of *Acacia obtecta* Maiden & Blakely, NSW484886

Fig. 5. Lectotype of *Acacia sparsiflora* Maiden, NSW489921

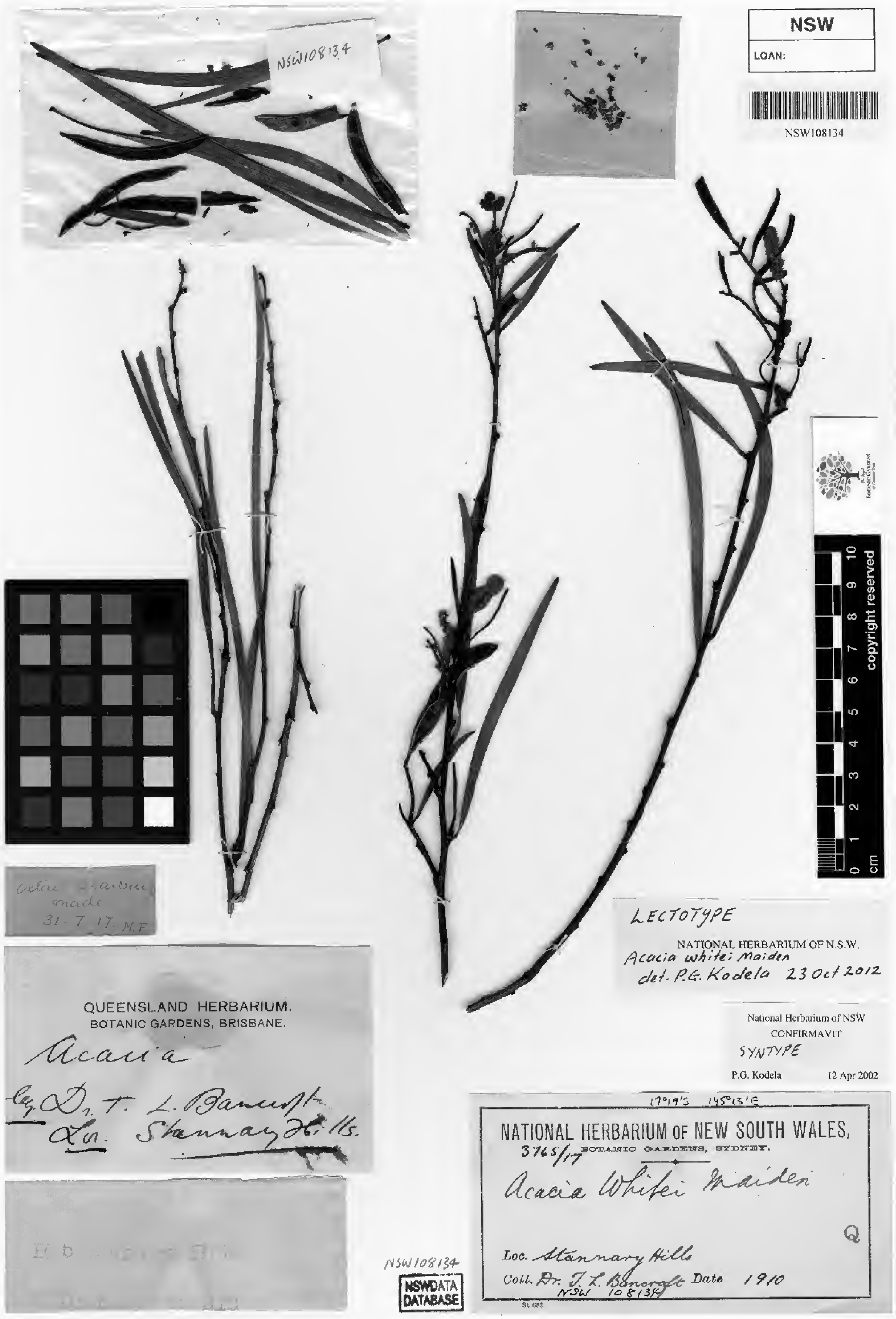


Fig. 6. Lectotype of *Acacia whitei* Maiden, NSW108134

from there), but rather the type locality for the species is likely to be north of Chinchilla. Efforts to trace the details of Bancroft's movements during this period of his collecting and photography were unsuccessful.

There are other specimens from Eidsvold labelled *T.L. Bancroft 30*, Mar 1918 (including NSW171416, a branchlet with buds and flowers and a tag attached annotated by Bancroft: "No. 30. Is this same as no. 5?. Small tree"); *T.L. Bancroft s.n.*, Mar 1918; *T.L. Bancroft 30*, Nov 1918; *T.L. Bancroft s.n.*, Nov 1918; and *T.L. Bancroft s.n.*, undated, at various herbaria (including AD, BRI, MEL, NSW, PERTH) of uncertain type status. These may include syntypes and isolectotypes.

Acacia whitei Maiden, *Proceedings of the Royal Society of Queensland* 30: 35, pl. 2, figs 1–7 (1918)

Type: Queensland: Stannary Hills, *T.L. Bancroft s.n.*, *anno* 1910 [1909]; lecto (here chosen): NSW108134 (ex BRI); possible isolecto (otherwise residual syntypes): *T.L. Bancroft 171*, 30 Nov 1909 (supplied as "1910") (as cited in AVH 2013), BRI AQ22805 *n.v.*; *T.L. Bancroft 171*, undated (as cited by AVH 2013), BRI AQ197844 *n.v.*

The lectotype (NSW108134; Fig. 6), selected here, comprises three branchlets, two of which include buds, flowers and immature pods, would have been seen by Maiden when he described the species. It suitably matches the type citation "Type. Stannary Hills, *via* Irvinebank, North Queensland (Dr. T.L. Bancroft, 1910, communicated by Mr. C.T. White)" (Maiden 1918, p. 35), as well as the description and illustrations in the protologue. This sheet is annotated as being used for a detailed drawing made by Margaret Flockton, "31.7.17" [31 July 1917] and is here regarded as represented in the illustration in Maiden (1918, plate 2). The collection year is likely to be 1909, as indicated by BRI data, as Bancroft had moved from the area by 1910 (E. Bancroft, pers. comm., 2013).

A possible isolectotype or residual syntype may be represented by NSW108135 (ex BRI) which has slightly different label details (*viz.* Stannary Hills, *T.L. Bancroft 230*, "a bush about 6 ft [feet] high") to that of the lectotype. Nevertheless the locality citation is similar to that in the protologue and morphologically it is congruent with the protologue description. However, it has longer phyllodes and so may be from a different plant to the lectotype. If the lectotype (NSW108134) is indeed a duplicate (ex BRI) of *T.L. Bancroft 171* then NSW108135 would not be an isolectotype. Although these NSW sheets contain exchange material from Queensland Herbarium, they cannot be readily associated directly with specimens held at BRI due to differences in label details (based on the currently available electronic information).

Based on material at BRI, indicating that the Bancroft number "171" may be related to the type collection, the undated *T.L. Bancroft 171* specimen AD98583530 (*n.v.*) is likely to be type material. Likewise, MEL0580857A may also be part of the type collection from Stannary Hills; however, it does not include a collection date or field number to further assess its status.

Acknowledgments

I am grateful for advice and comments on typification by Peter Wilson (NSW), and useful comments on the manuscript by Barry Conn (NSW). In late 2012 I had the opportunity to examine material held at MEL and would like to thank Pina Milne and Helen Barnes (both MEL) for their assistance. Bruce Maslin (PERTH) kindly provided details and images of *Acacia obtecta* specimens held at PERTH. I wish to thank the Bancroft family of Eidsvold, particularly Mrs Evelyn Bancroft, for investigating and providing various details on Thomas Lane Bancroft and his collections.

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Bursaria cayzerae (Pittosporaceae), a vulnerable new species from north-eastern New South Wales, Australia

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Abstract

Bursaria cayzerae I.Telford & L.M.Copel. (Pittosporaceae), a species endemic to north-eastern New South Wales, is described. Its distribution is mapped, and habitat and conservation status discussed. The attributes of the new species, *B. longisepala* and *B. spinosa*, are compared. A key to species of *Bursaria* that occur in New South Wales, including this new species, is provided.

Introduction

Bursaria (Pittosporaceae) is an endemic Australian genus with currently seven named species. In eastern Australia, the most common taxon is *Bursaria spinosa* Cav. subsp. *spinosa*, plants of which may flower in their juvenile stage. These neotonous plants superficially resemble small-leaved, long-spined species such as *B. longisepala* Domin. Revisionary studies by Cayzer et al. (1999) showed *B. longisepala s.str.* to be restricted to the Blue Mountains; material from elsewhere mostly represented misidentifications of specimens of neotonous plants of *B. spinosa* subsp. *spinosa* or collections from several populations from the Grafton area (Makinson 1992, 2011) that represent a distinct new species.

Morphological examination of herbarium material from these populations from the Grafton to Glenreagh area (as held at NE and CFSHB), together with field assessment of the plants, indicated that plants from the above area were morphologically different from both *B. longisepala* and *B. spinosa*. The new species *Bursaria cayzerae* is described to accommodate these plants. A comparison of selected morphological attributes of the new species with those of *B. longisepala* and *B. spinosa* is presented in Table 1.

Taxonomy

Bursaria cayzerae I.Telford & L.M.Copel. ***sp. nov.***

Bursaria cayzerae differs from *B. longisepala* by its adult leaves being larger than the juveniles, generally smaller sepals (2.4–3.6 mm long) and larger fruit (6–10.2 mm long).

Type: New South Wales: North Coast: 3 km ESE along Bostock Road from Tucabia Road, 20 km ENE of Grafton, 29°40'26"S, 153°09'08"E, 8 Dec. 2012, *L.M. Copeland 4513 & F.J. Edwards*; holo: NSW823160 (Fig. 1); iso: BRI, CANB, K, MEL, MO, NE.

Shrub to 2 m, sparsely branched. *Branchlets* tomentose with ± spreading hairs. *Juvenile leaves* subsessile, clustered around short spinescent axillary shoots to 10 mm long; lamina narrowly elliptic or narrowly oblanceolate, 2.4–9 mm long, 0.9–2 mm wide, shortly mucronate, glabrous. *Adult leaves* on spinescent shoots to 5.2 mm long (including spine); petiole c. 0.7 mm long; lamina narrowly elliptic to narrowly oblanceolate, 9.5–18.8 mm long, 1.7–3 mm wide, glabrous, with margin thickened. *Inflorescence* mostly axillary, solitary flowers, rarely 2–5-flowered racemes to 16 mm long, or terminal racemes or botrya to 30 mm long; pedicels 0.8–1.2 mm long, elongating up to 8.5 mm long in fruit, tomentose. *Sepals* 5, lanceolate, 2.4–3.6 mm long, 0.7–1 mm wide, acute, glabrous, green, persistent. *Petals* 5, narrowly oblanceolate, 7.2–9 mm long, 1.2–2.2 mm wide, acute, glabrous, white. *Stamens* 5, inserted opposite sepals; filaments 4.6–5 mm long; anthers elliptic, c. 0.8 mm long. *Ovary* compressed obovoid, 2.5–3 mm long, c. 1.2 mm wide, attenuate and tapering into style, glabrous; style c. 1.5 mm long. *Fruit* a compressed subglobose to broadly cordiform capsule, 6–10.2 mm long (excluding stylar remnants if present), 6.5–11.2 mm wide, apex rounded or slightly emarginate, often with stylar remnants, minutely transversely striate, glabrous, ripening brown. *Seeds* compressed, ovate to ± orbicular, 3.5–3.7 mm long, 2.5–2.8 mm wide, slightly winged, brown. Figs 2A & B

Distribution and habitat: *Bursaria cayzerae* is restricted to within 30 km of Grafton on the North Coast of New South Wales (Fig. 3). The species inhabits *Eucalyptus* shrubby woodland on shallow, sandy soils derived from sandstone of the Grafton Formation, Kangaroo Creek Sandstone and Malanganee Coal Measures. At the type locality, dominants are *Eucalyptus propinqua*, *E. fibrosa* and *Corymbia variegata* with *Allocasuarina littoralis* and *Acacia falcata* in the understorey. Dominant species at Shannon Creek are *Eucalyptus bancroftii* and *Angophora robur* with *Dodonaea* sp. Coaldale (H.J.Wissmann NE40546), another Grafton area endemic in the understorey. At Rocky Creek, *Lophostemon suaveolens* and *Eucalyptus* sp. Coaldale (J.B.Williams NE36714) are dominant, with two additional localised endemics, *Acacia ruppii* and *Prostanthera sejuncta,* in the shrub stratum. The dominant tree at the Wells Crossing Flora Reserve site is *Eucalyptus tetrapleura*, another Grafton Sandstone endemic.

Phenology: flowering appears to be restricted to November and December with mature fruits being formed a month later, in December and January, respectively. Dehisced capsules are retained on the plants.

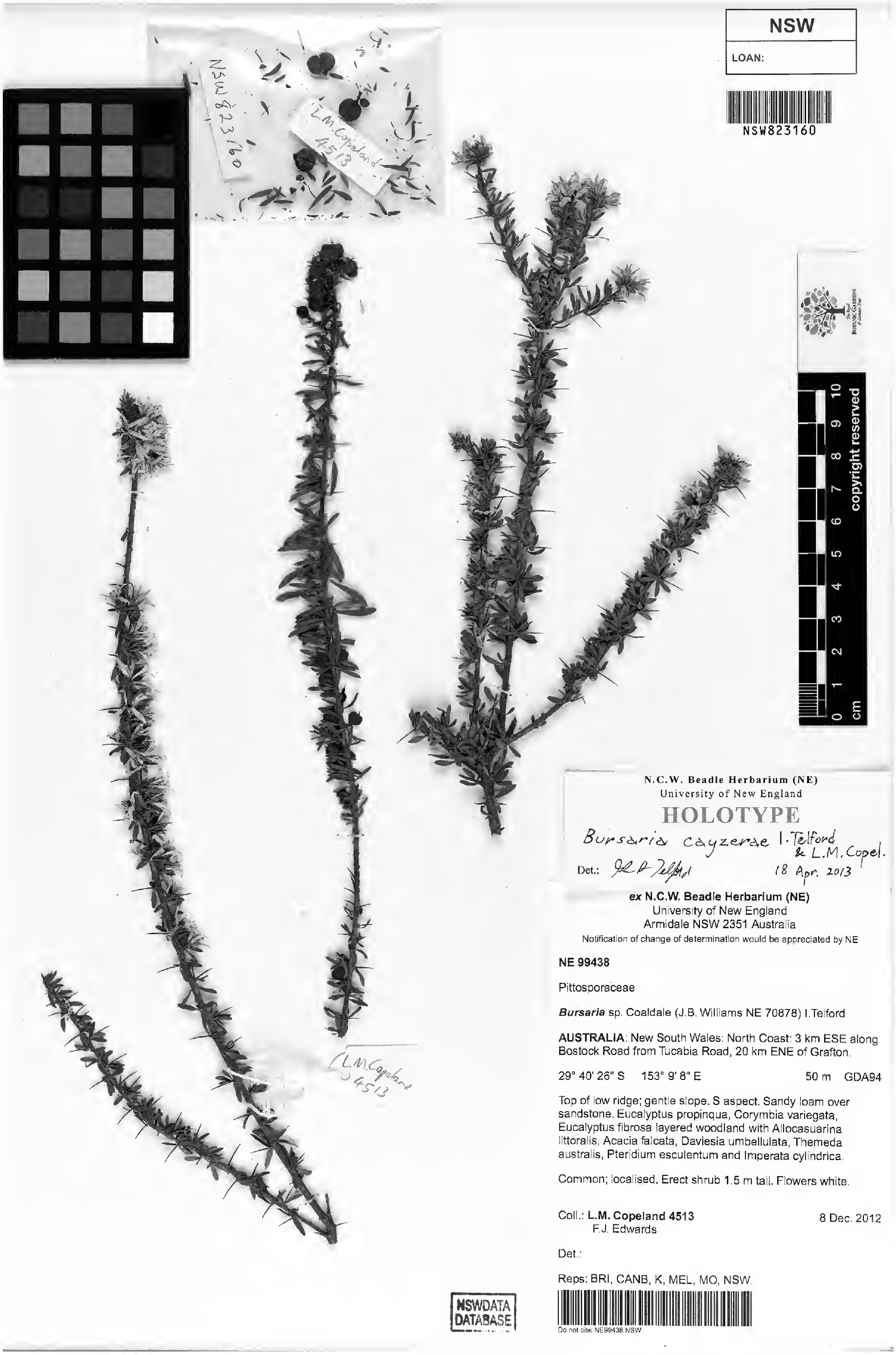
Specimens examined (selection): NEW SOUTH WALES: North Coast: Rocky Creek, c. 30 km NNW of Grafton, 100 m SW of Grafton–Coaldale road crossing, 14 Sep 2004, *Copeland 3780* (BRI, CANB, NE, NSW); Sportsmans Creek, Banyabba Nature Reserve, 15 Sep 1996, *Floyd 2239* (CFSHB); 4 km N of Upper Copmanhurst, 30 Dec 1982, *Wissmann NE40546* (CANB, NE, NSW); Wells Crossing Flora Reserve, Newfoundland State Forest, 2 Nov 1987, *Tweedie s.n.* (CFSHB); Shannon Creek Dam Compensatory Habitat Area, 1.5 km E of dam wall, c. 8 km W of Coutts Crossing, 8 Dec 2012, *Copeland 4514 & Edwards* (NE, NSW).

Conservation Status: *Bursaria cayzerae* is currently known from eight small populations with the largest of these appearing to be at the type locality east of Tucabia. At least 150 plants occur there although some of these are threatened by their close proximity to a road verge which appears to suffer occasional disturbance. The population near Shannon Creek Dam contains some 55 plants. Most other populations surveyed appear to consist of fewer than 20 plants and the total known population is less 300 mature adults. As such, the species meets the criteria to be considered 'Vulnerable' following the IUCN guidelines (IUCN 2011). It would probably meet the requirements to be listed as Vulnerable on both the *NSW Threatened Species Conservation Act 1995* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.* Small populations are known to be conserved in Banyabba Nature Reserve, Wells Crossing Flora Reserve, Fortis Creek National Park, Ramornie National Park and Chambigne State Conservation Area.

Etymology: the specific epithet, *cayzerae*, honours Lindy Cayzer, whose revisionary studies in Pittosporaceae considerably broadened our knowledge of the family.

Notes: this new species has been confused previously with *B. longisepala* and neotonous *B. spinosa* subsp. *spinosa. Bursaria cayzerae* differs from the former in its smaller juvenile and larger adult leaves, shorter sepals and larger capsules, from the latter in larger, persistent sepals (Table 1).

The species has been separated for some time at NE under the phrase name *Bursaria* sp. Coaldale (J.B.Williams NE70878) and some replicates have been distributed as such.



N.C.W. Beadle Herbarium (NE)
University of New England
HOLOTYPE
Bursaria cayzerae I.Telford & L.M.Copel.
Det.: I.R.H. Telford 18 Apr. 2013

ex N.C.W. Beadle Herbarium (NE)
University of New England
Armidale NSW 2351 Australia
Notification of change of determination would be appreciated by NE

NE 99438

Pittosporaceae

Bursaria sp. Coaldale (J.B. Williams NE 70878) I.Telford

AUSTRALIA: New South Wales: North Coast: 3 km ESE along Bostock Road from Tucabia Road, 20 km ENE of Grafton.

29° 40' 26" S 153° 9' 8" E 50 m GDA94

Top of low ridge; gentle slope. S aspect. Sandy loam over sandstone. Eucalyptus propinqua, Corymbia variegata, Eucalyptus fibrosa layered woodland with Allocasuarina littoralis, Acacia falcata, Daviesia umbellulata, Themeda australis, Pteridium esculentum and Imperata cylindrica.

Common; localised. Erect shrub 1.5 m tall. Flowers white.

Coll.: **L.M. Copeland 4513** 8 Dec. 2012
F.J. Edwards

Det.:

Reps: BRI, CANB, K, MEL, MO, NSW.

Do not cite: NE99438.NSW

Fig. 1. Holotype of *Bursaria cayzerae* I.Telford & L.M.Copel. (NSW823160).

Fig. 2. *Bursaria cayzerae.* A. branchlet showing flowers and young fruit, Tucabia, N.S.W., *Copeland 2513 & Edwards*; B. habit showing dehisced capsules, Rocky Creek, N.S.W., Copeland 3780.

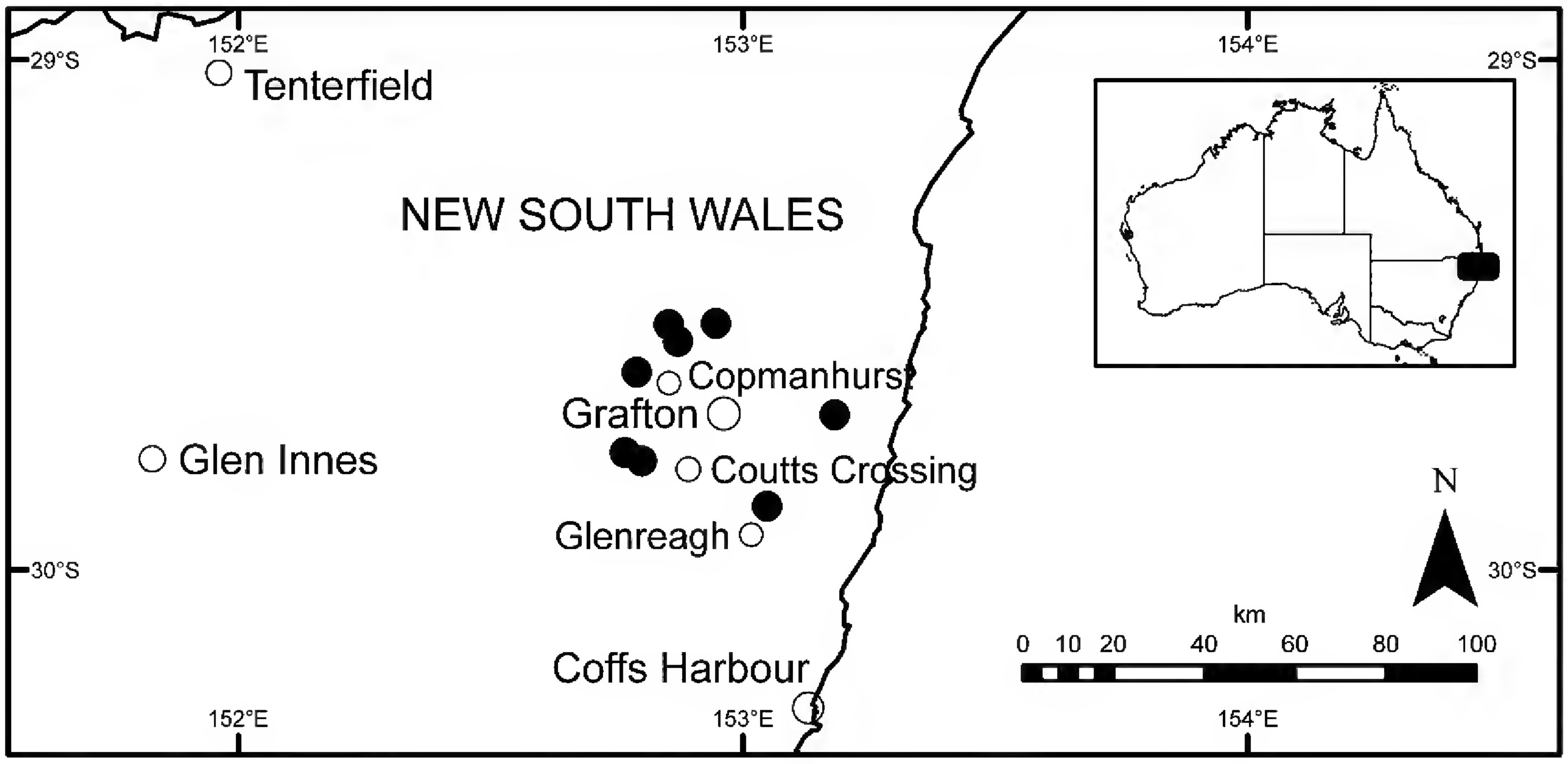


Fig. 3. Distribution of *Bursaria cayzerae.*

Table 1. Comparison of selected morphological attributes of *Bursaria cayzerae* with those of *B. longisepala* and *B. spinosa* subsp. *spinosa*.

Attribute	***B. cayzerae***	***B. longisepala***	***B. spinosa***
Juvenile leaf length (mm)	2.4–9.5	8–12	3–16
Adult leaf length (mm)	9.5–18.8	6–9	16–43
Adult leaf width (mm)	1.7–3	1–3	5–12
Spine length (mm)	2.8–8.2	5–10	6–23
Sepal length (mm)	2.4–3.6	3.5–4	0.7–1.2
Petal length (mm)	7.2–9	6–8	3.8–4.5
Capsule length (mm)	6–10.2	5–6	5–7
Capsule width (mm)	6.5–11.2	5–8	6–9

Key to species of *Bursaria* occurring in New South Wales

1a. Sepals < 2 mm long, caducous 2

1b. Sepals > 2 mm long, persistent 3

2a. Leaves glabrous .... *Bursaria spinosa* subsp. *spinosa*

2b. Leaves abaxially white hairy .... *Bursaria spinosa* subsp. *lasiophylla*

3a. Young branchlets densely covered with persistent, appressed hairs;
occurs on limestone-derived soils; restricted to Wombeyan Caves area .... *Bursaria calcicola*

3b. Young branchlets usually with spreading hairs; occurs on sandstone-derived soils 4

4a. Sepals 3.5–6 mm long; capsules 5–6 mm long; restricted to Blue Mountains .... *Bursaria longisepala*

4b. Sepals 2.4–3.6 mm long; capsules 6–10 mm long; restricted to
Grafton–Coffs Harbour area .... *Bursaria cayzerae*

Acknowledgments

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Morphometric analysis of caryopses in nine species of *Eragrostis* (Poaceae) from India using SEM and light microscopy

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Abstract

Seed exomorphic characters of nine different species of *Eragrostis* were investigated by Light and Scanning electron microscopy. In the present study the micro-morphological characteristic features of caryopses such as shape, dimension, colour, epidermal cell surface structure and features of anticlinal and periclinal walls were examined. Light microscopy revealed that most of the studied caryopses varied in shape from obloid to ovoid. The caryopses in most of the species of *Eragrostis* are sticky in nature due to the presence of surface slime cells, which makes them appear shiny and transparent. This morphological feature was able to be observed under SEM but not light microscopy. The nine different species could be differentiated on the basis of shape and position of the hilum and embryo.

Introduction

Seeds provide numerous morphological characters and can be used for taxonomic purposes. Heywood and Davis (1963) emphasized that the use of seed characters can be reliable and constant within taxa. Grass seed morphological features and surface patterns have been used in many studies to identify and compare taxa and genera (Hillman 1916; Jensen 1957; Bogdan 1965; Banerjee *et al.* 1981; Colledge 1988; Lazarides 1997; Matsutani 1986; Nesbitt 2006; Terrel and Peterson 1993; Peterson and Sánchez Vega 2007).

External features of seeds and small fruits tend to be neglected in Floras, and even in detailed taxonomic studies, which is surprising in view of the stability and high systematic value of external characters (Lawrence 1951; Barthlott 1981, 1984).

Seed characteristics, particularly exomorphic features, revealed through scanning electron microscopy have been used in resolving problems of systematics (Karihaloo and Malik 1994; Koul et al. 2000) and evolutionary relationships (Segarra and Mateu 2002). Micromorphological seed characters using a scanning electron microscope (SEM) are relatively consistent across plant species and may thus prove useful in distinguishing different species as well as their grouping under definitive categories (Agrawal 1984; Hoagland and Paul 1978). Few SEM studies have been concerned with the fine structural differences in taxonomic and morphological features of closely related species, especially within groups of plants of the same species (Liu et al. 2005; Joshi et al. 2008).

The Tribe Eragrostideae (Poaceae) contains 80 genera and 1000 species (*sensu* Clayton and Renoize 1986; Conert 1992). Amongst all the grass species currently recognized in the tribe, about 67% are contained in the three largest genera *Eragrostis* (350 species), *Muhlenbergia* (160 species) and *Sporobolus* (160 species) (Peterson et al. 1997). A newer classification based on DNA phylogenies includes about 20 genera in Eragrostideae, with three subtribes (Peterson et al. 2010, 2010a, 2011, 2012) and excludes *Muhlenbergia* and *Sporobolus* that have been moved to Cynodonteae and Zoysieae, respectively (Peterson et al. 2010b).

Eragrostis is used as livestock fodder and the caryopses appear to be of extremely high nutritional value (Ingram and Doyle 2003). For example, *Eragrostis tef* (Zucc.) Trotter (Zuccagni) is used for the production of the traditional breads across the Horn of Africa: Ethiopian *injera* and Somalian *laxoox*, are grown as a crop of commercial importance; *E. clelandii* S.T.Blake and *E. tremula* Hochst. ex Steud. are used as famine foods in Australia and Chad, respectively. Other species, such as *E. tenellus*, are used as ornamental plants, while *E. cynosuroides* (Retz.) P.Beauv. is used in the puja rites in the Hindu temple at Karighatta. Bahia lovegrass (*E. bahiensis* Schrad. ex Schult.) is known as a hyperaccumulator of Caesium-137 and can be grown to remove these highly toxic and radioactive atoms from the environment. Weeping lovegrass (*E. curvula* (Schrad.) Nees) has been planted extensively to combat soil erosion. Tef (*E. tef*) and several other *Eragrostis* species have been introduced to many other African countries, India, the United States of America, and Australia, mainly as specialty foods and forage crops (Ayele et al. 1996; Zeller 2003; Yu et al. 2000, 2006). In *Eragrostis*, typically caryopses have a thin pericarp consisting of a single cell layer, which completely adheres to the seed coat (Jackman 1999; Boechat et al. 2000, 2003). In the grasslands of the northwestern Indian state of Gujarat there are 14 species of *Eragrostis* that have been previously recorded (Shah 1978). These grasslands consist an area of ~1400 km^2 across the Kachh, Saurashtra and Panchmahal districts. The current study examines the macro- and micromorphological characters of caryopses and provides a taxonomic key for the identification of the nine *Eragrostis* species of the Saurashtra and Panchmahal districts.

Materials and Methods

Voucher specimens of the nine species of *Eragrostis* used in our analyses were collected from grassland and forest areas of Gujarat (Blatter and McCann 1936) (Table 1). Specimens are deposited in BARO Herbarium (Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, India). Specimens were identified to species level with comparison to know specimens at The Blatter Herbarium (BLAT) (Table 1). Mature dried caryopses were manually separated from spikelets (15–20 per species) and prepared for light microscopy and SEM study. Light microscopy measurements were made on the mature, dry seeds and diagnostic features photographed using a Stereo Microscope (Olympus microscope-SZ2-ILST).

All the morphometric measurements are averages (n=15–20) and were carried out as per Nesbitt (2006). Length of caryopses (L) was measured (in mm) parallel to the middle vertical axis included embryo tip, either in dorsal or ventral view. Breadth of caryopses (B) was the maximum width (in mm) on the horizontal axis measured either in dorsal or ventral view. Thickness of caryopses (T) was the maximum width (in mm) measured at right angles to the breadth and in the same horizontal plane, such that T≤B. The length to breadth ratio (L:B) was calculated as the length of caryopses divided by breadth and multiplied by 10. The thickness to breadth ratio (T:B) was calculated as the thickness of caryopses divided by breadth and multiplied by 100. The length of the embryo (from embryo tip to scutellum/endosperm boundary) was calculated as a % of caryopses length (Embryo %). Hilum % was calculated as the length of the hilum for linear hila (measured from base to tip) and for basal and subbasal hila (from base of caryopses to end of hilum) and calculated as a % of

Table: 1 List of *Eragrostis* species studied.

Botanical name	**Blatter Herbaria No.**
Eragrostis cilianensis (All.) Vignolo ex Janch	84583
Eragrostis ciliaris (L.) R.Br.	84506
Eragrostis japonica (Thunb.) Trin.	84802
Eragrostis nutans (Retz.) Nees.	84889
Eragrostis pilosa (L.) P.Beauv	84895
Eragrostis tenella (L.) P.Beauv. ex Roem & Schult.	85044
Eragrostis tremula (Lam.) Hochst. ex Steud.	85060
Eragrostis unioloides Nees ex Steud.	85079
Eragrostis viscosa (Retz.) Trin.	85205

caryopses length. All the dimensions details are presented in Table 2 and a summary of diagnostic characters are presented in Table 3.

To obtain SEM images, samples were attached to carbon conducting tape and mounted onto brass stubs. Seeds were washed with absolute alcohol or acetone for 1–2 mins to remove any debris, dried and placed on the stub with dorsal, ventral and lateral side facing upwards, and photographed on JEOL JEM – 5610 SEM with a voltage of 15KV. The observed features are presented in Table 4.

Results and Discussion

Across the nine species studied caryopses exhibited great variation in micromorphological surface patterns. *Eragrostis pilosa* had the largest caryopses 0.7 mm long (L), breadth (B) 0.3 mm and thickness (T) 0.4 mm whereas *E. ciliaris*, *E. tremula* and *E. viscosa* had the smallest length of 0.4 mm. *Eragrostis unioloides* has a maximum L:B ratio (35.51) and T:B ratio (204.66), while *E. cilianensis* has a minimum L:B ratio (12.25) and *E. tenella* has a minimum T:B ratio (96.33). *Eragrostis viscosa* exhibits the maximum embryo (64.08%) and hilum (24.46%) percentage in the caryopses, whereas *E. japonica* has a minimum embryo percentage (31.91%), and *E. tenella* has a minimum hilum percentage (11.69%).

The colour of mature caryopses varied from light to dark brown with a smooth shining surface. Shape of the caryopses in *E. japonica*, *E. nutans*, *E. tenella*, *E. unioloides* and *E. viscosa* varied from obloid to ovoid. When viewed dorsally *Eragrostis tenella* and *E. viscosa* had a slightly rounded apex compared to *E. japonica* and *E. nutans*. Caryopses of *E. tenella* have an almost equal breadth and thickness hence the minimum T:B ratio (96.33). A common feature noted was the absence of the ventral groove/sulcus on the caryopses. Apart from this, dorsal/lateral striations were present only in *E. cilianensis*, *E. tremula* and *E. unioloides* (Fig. 1), whereas other species had no striations. Of the nine species studied, the caryopses of *E. pilosa*, *E. tremula* and *E. unioloides* (Fig. 1c, u, x) were compressed laterally while caryopses of the others were ±terete. Peterson and Sanchez (2007) reported *E. japonica*, *E. pilosa* and *E. ciliaris* as ±dorsally compressed; however, we found that *E. ciliaris* and *E. japonica* were terete but *E. pilosa* was laterally compressed.

Caryopses in most of the nine species were sticky (Kreitschitz et al. 2009) because of the presence of surface slime cells, giving the surfaces a shiny and translucent appearance that was difficult to observe under a light microscope but very apparent under SEM.

Table: 2 Dimensional details of caryopses of species of *Eragrostis*

L = Length; B = Breadth; T = Thickness; L:B = (Length/Breadth)×10; T:B = (Thickness/Breadth)×100; Embryo% = length of embryo as a percentage of total length of caryopsis; Hilum% = length of hilum as a percentage of total length of caryopsis

Species Name	Size (mm)						
	L	B	T	L:B ratio	T:B ratio	Embryo %	Hilum %
E. cilianensis	0.5±0.01	0.4±0.02	0.4±0.02	12.25±0.55	102.32±2.83	35.58±6.24	17.73±1.11
E. ciliaris	0.4±0.01	0.2±0.02	0.2±0.01	18.45±0.72	100.70±5.32	38.88±5.43	17.83± 1.50
E. japonica	0.5±0.01	0.2±0.01	0.2±0.01	20.46±0.79	106.89±4.45	31.91±6.38	15.30±2.82
E. nutans	0.5±0.01	0.2±0.02	0.2±0.02	22.34±2.16	98.64±11.58	45.64±5.28	14.57±0.64
E.pilosa	0.7±0.05	0.3±0.01	0.4±0.01	21.50±1.70	120.89±5.05	61.75±5.77	13.33±1.60
E. tenella	0.5±0.02	0.2±0.02	0.2±0.02	18.19±1.39	96.33±9.81	47.82±3.34	11.69±2.03
E. tremula	0.4±0.03	0.3±0.02	0.4±0.02	14.48±1.42	131.36±9.38	49.82±5.76	13.46±0.78
E. unioloides	0.7±0.04	0.2±0.01	0.4±0.03	35.51±3.67	204.66±17.35	48.76±4.35	12.55±1.86
E. viscosa	0.4±0.01	0.2±0.01	0.2±0.01	17.33±0.86	117.20±6.85	64.08±15.37	24.46±3.38

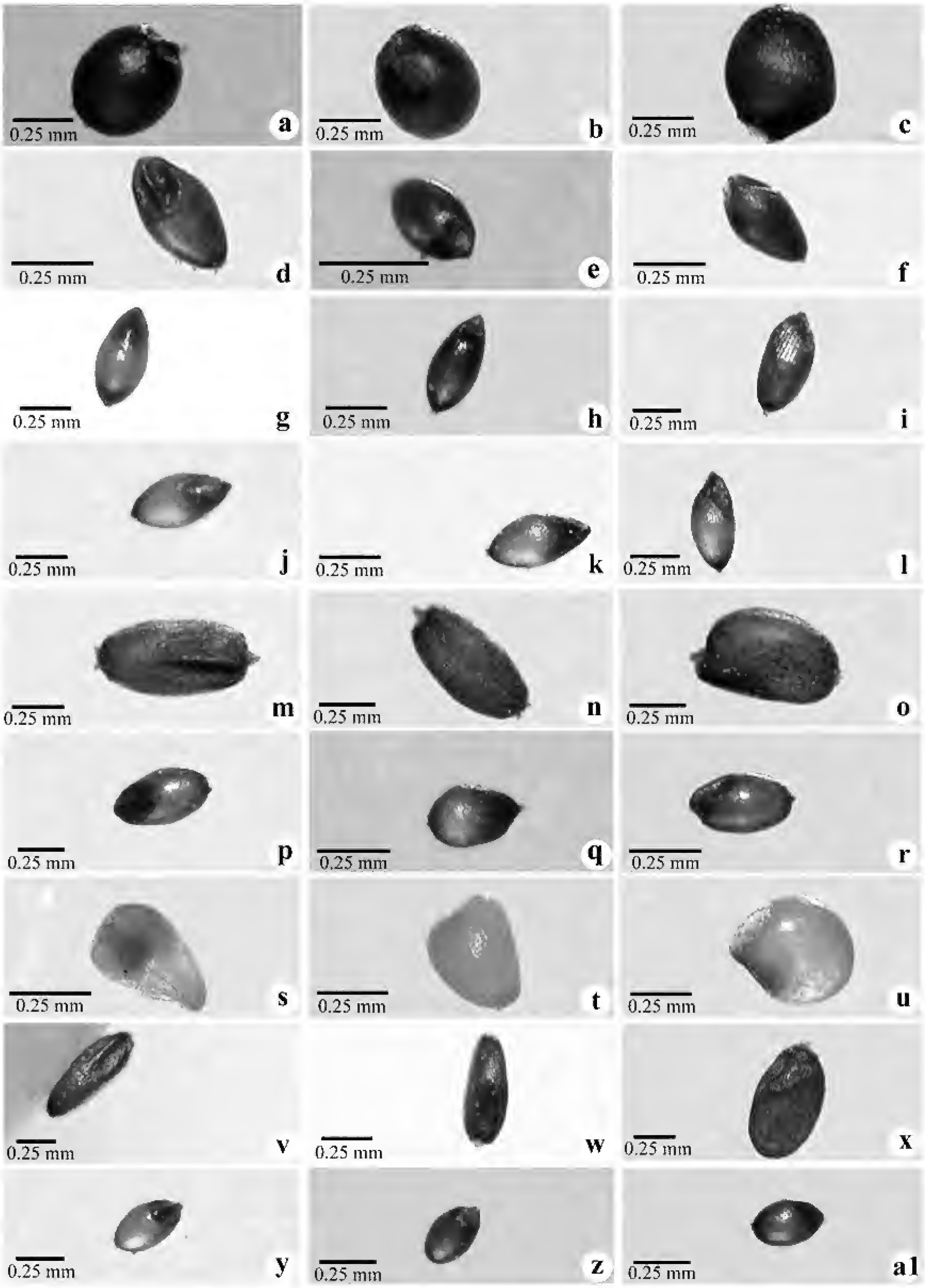

Fig.1. Light Microscopic features of caryopses of Eragrostis **a–c**, *Eragrostis cilianensis*. **d–f**, *E. ciliaris*. **g–i**, *E. japonica*. **j–l**, *Eragrostis nutans*. **m–o**, *Eragrostis pilosa*. **p–r**, *E. tenella*. **s–u**, *E. tremula*. **v–x**, *E. unioloides*. **y–a1**: *E. viscosa*. Column views: **a, d, g, j, m, p, s, v, y**, dorsal surface; **b, e, h, k, n, q, t, w, z**, ventral surface; **c, f, i, l, o, r, u, x, a1**, lateral surface.

Table 3: Light microscopic features of caryopses of species of *Eragrostis*

Embryo class: Large ≥ 46%, Short ≤ 45%

Species Name	Shape	Colour	Texture	Compressions	Dorsal/ Lateral striations	Scutellum shape	Embryo Class	Distinct features observed
E. cilianensis	Orbicular	Dark brown to black	Smooth, shiny	Not compressed	Present	Sickle-shape	Short	Embryo occupies very small portion of caryopses.
E. ciliaris	Obloid to obovoid	Dark brown	Smooth, shiny	Not compressed	Absent	V-shaped	Short	Towards the proximal end white color spot is seen, near the hilum
E. japonica	Obloid	Dark brown	Smooth, shiny	Not compressed	Absent	V-shaped	Short	On ventral surface longitudinal lines are seen which are prominent below the hilum.
E. nutans	Obloid to ovoid	Dark brown	Smooth, shiny	Not compressed	Absent	V-shaped	Short	Scutellum is more concave than *Eragrostis japonica.*
E. pilosa	Ovoid to obloid	Dark brown	Smooth	Laterally compressed	Present	V-shaped	Large	On ventral side longitudinal lines are present
E. tenella	Obloid to obovoid	Dark brown	Smooth, shiny	Not compressed	Absent	V-shaped	Large	Caryopses are translucent.
E. tremula	Globular to obloid	Creamish to light brown	Smooth, shiny	Laterally compressed	Present	Sickle-shape	Large	Towards the proximal end minute dotted slimy glands are present
E. unioloides	Ovoid	Brown to dark brown	Smooth, shiny	Laterally compressed	Present	V-shaped	Large	Scutellum is divided into two parts by embryo axis, which is continuous with the surface.
E. viscosa	Obloid to ovoid	Dark brown	Smooth, shiny	Not compressed	Absent	V-shaped	Large	Surface is more shiny than for other species of *Eragrostis.*

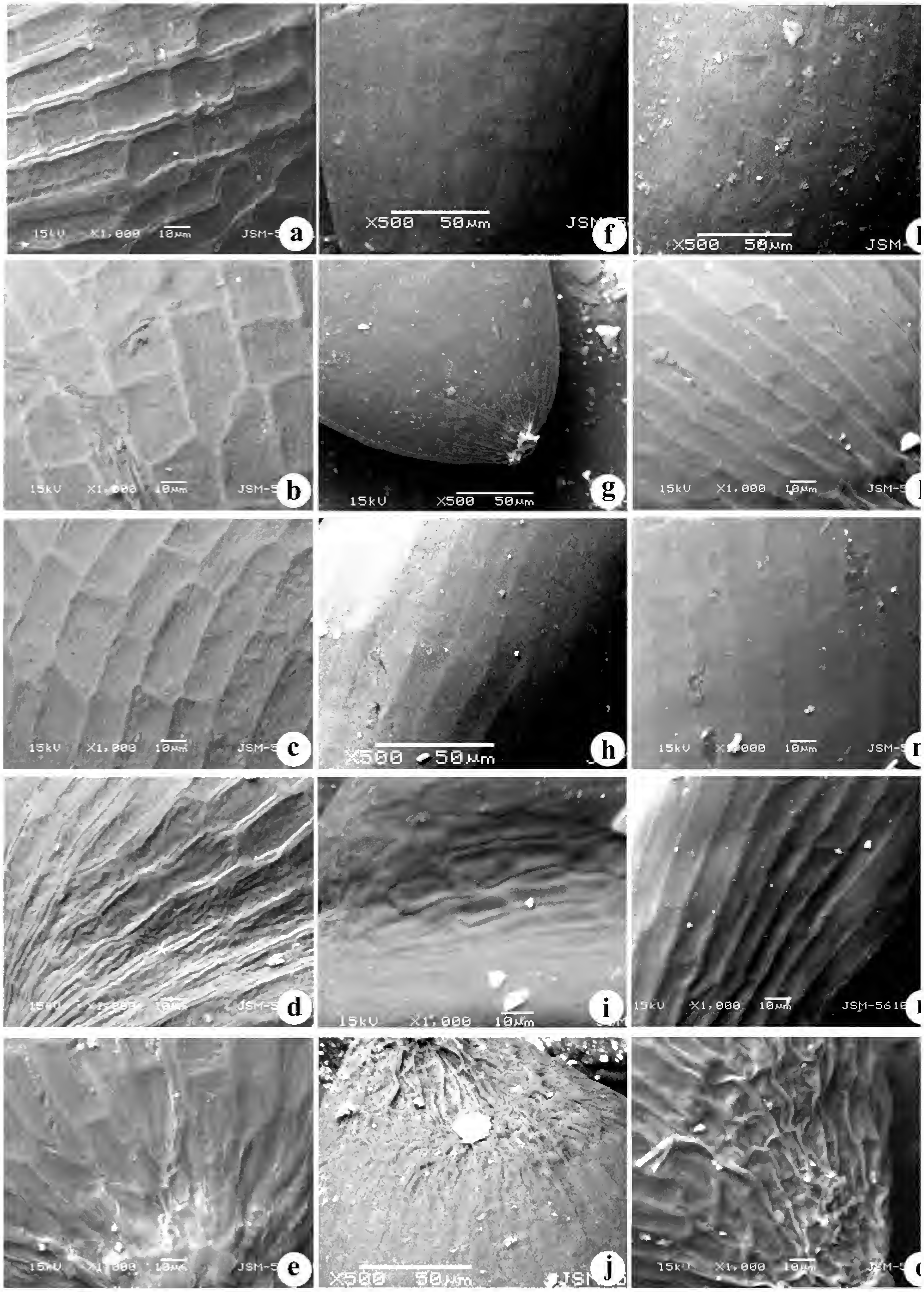

Fig 2: Scanning Electron Microscopic features of caryopses of *Eragrostis* **a–e,** *Eragrostis cilianensis.* **f–j,** *E. ciliaris.* **k–o,** *E. japonica.* Column views: **a, f, k,** dorsal surface; **b, g, l,** ventral surface; **c, h, m,** lateral surface; **d, i, n,** embryo surface; **e, j, o,** hilum surface.

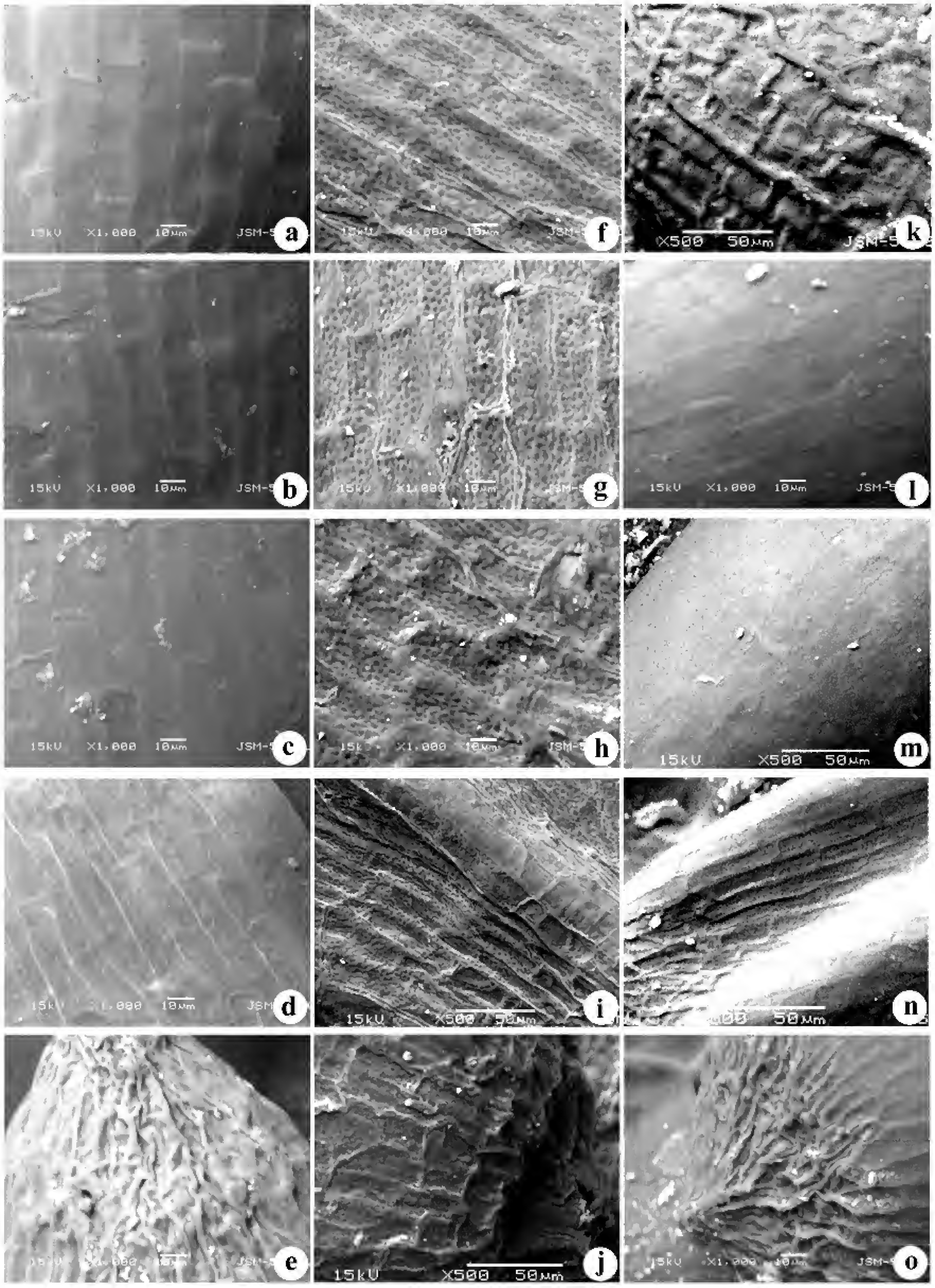

Fig 3. Scanning Electron Microscopic features of caryopses of *Eragrostis* **a–e**, *Eragrostis nutans*. **f–j**, *E. pilosa*. **k–o**, *E. tenella*. Column views: **a, f, k**, dorsal surface; **b, g, l**, ventral surface; **c, h, m**, lateral surface; **d, i, n**, embryo surface; **e, j, o**, hilum surface.

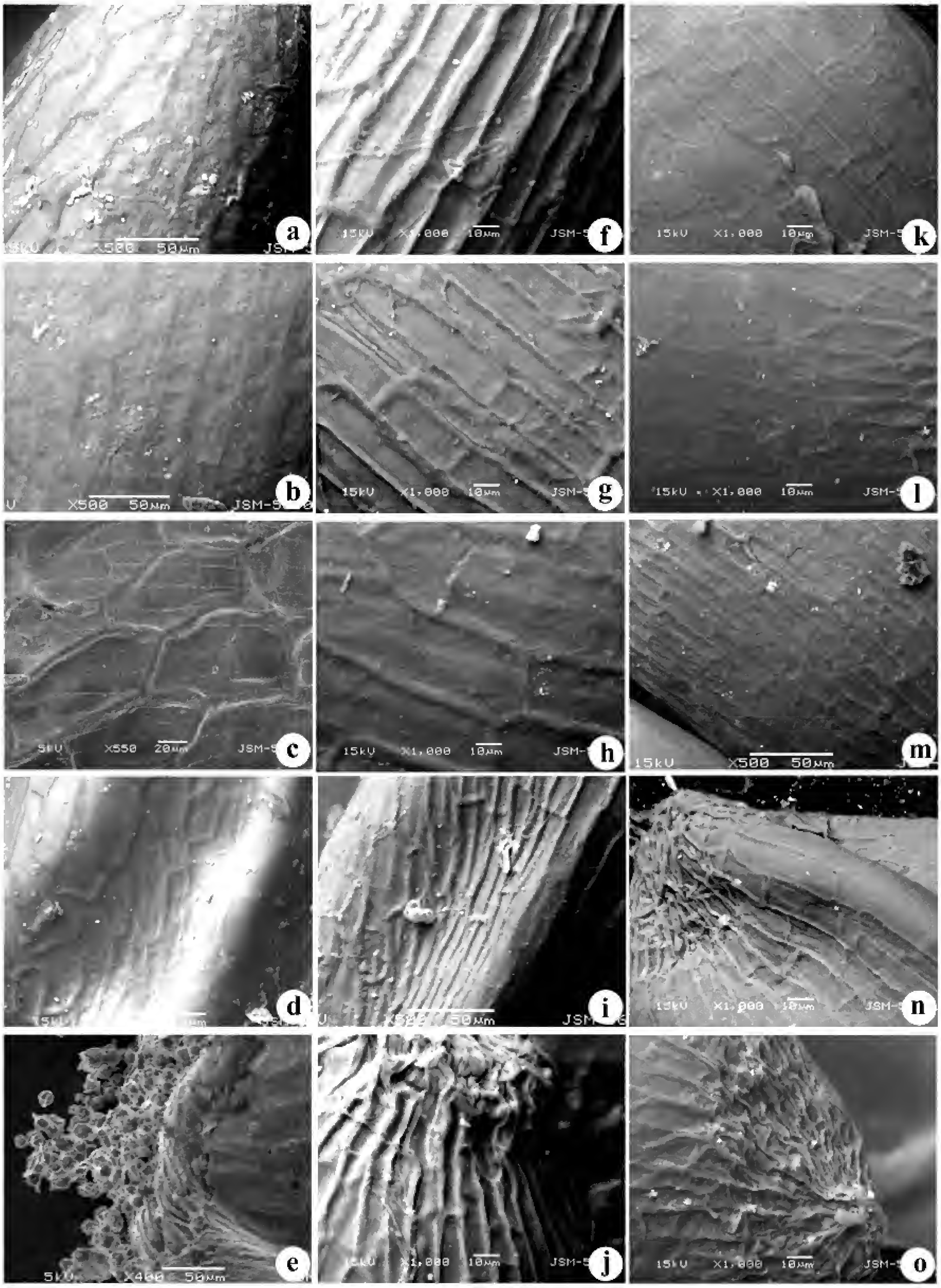

Fig 4. Scanning Electron Microscopic features of caryopses of *Eragrostis* **a–e**, *Eragrostis tremula*. **f–j**, *E. unioloides*. **k–o**, *E. viscosa*. Column views: **a, f, k,** dorsal surface; **b, g, l,** ventral surface; **c, h, m,** lateral surface; **d, i, n,** embryo surface; **e, j, o,** hilum surface.

The shape and surface features of the axis and scutellum separated the embryo into two different types. *Eragrostis cilianensis* and *E. tremula* both had a sickle-shaped scutellum (Fig. 1a, s) whereas all other species had a 'V'-shaped scutellum. The axis surface of *E. ciliaris* and *E. tremula* was glabrous, whereas in *E. cilianensis, E. japonica, E. nutans, E. tenella, E. unioloides* and *E. viscosa* the axis and scutellum surface showed reticulate architecture.

The ventral surface of *E. ciliaris, E. tremula* and *E. unioloides* showed rectangular to polygonal areas whereas in *E. ciliaris* (Fig. 2g) and *E. tenella* (Fig. 3m) it was smooth and homogeneous. *Eragrostis japonica, E. nutans* and *E. viscosa* had superficial architecture which was shallow and prominent. Dimensional details of the observed features are presented in Table 5. Tissue towards the proximal end of the hilum appears highly convoluted. *Eragrostis pilosa* showed a contrasting feature in having a reticulate-foveate surface with thick rugae (Fig. 3f, g). Two unique diagnostic features were observed in *E. tremula*, namely superimposed rows of reticulum were present on the lateral surface (Fig. 4c) and globular slimy glands were present at the proximal end on ventral surfaces (Fig. 4e). The upper reticulum was pentagonal to hexagonal with a smooth, thick, and elevated tangential wall in *E. tremula*, while the reticulum was elongated rectangular with smooth thin undulating walls in *E. pilosa*. The striations on the dorsal surface of *E. pilosa* had a maximum length (79.56 µm) among all studied specimens while the striations on the ventral surface of *E. nutans* had a maximum length (71.78 µm) and on the lateral surface *E. tremula* had a maximum length (92.45 µm). Other dimensional details are represented in Table 5.

Our study of epidermal surfaces reveals a number of important micromorphological characters exhibiting interspecific variation that are useful for identification.

Table 5. Dimensional features of striations (under SEM) on surface of caryopses of *Eragrostis*

Species Name	**Dorsal surface**		**Ventral surface**		**Lateral surface**	
	L (µm)	**B (µm)**	**L (µm)**	**B (µm)**	**L (µm)**	**B (µm)**
E. cilianensis	26.73±2.85	16.54±1.50	34.46±7.56	21.27±1.38	41.27±4.39	16.54±0.76
E. ciliaris	–	–	–	–	–	–
E. japonica	–	–	60.54±3.50	14.56±1.45	56±1.04	13.10±0.35
E. nutans	71.81±7.86	14.23±0.93	71.78±4.62	15.12±0.61	66.23±2.89	11.56±1.27
E. pilosa	79.56±1.86	19.11±0.93	51.92±1.30	17.56±0.93	42.45±6.25	18.45±1.27
E. tenella	42.48±1.79	20.05±1.63	–	–	–	–
E. tremula	73.48±8.47	30.86±1.82	–	–	92.45±6.59	46.23±1.86
E. unioloides	70.95±3.12	13.26±1.76	58.74±6.51	14.94±0.88	78.50±3.24	25.75±2.59
E. viscosa	55.69±1.85	12.16±0.99	–	–	47.80±7.33	8.52±1.70

Key to species of Eragrostis based on seed characteristics

1a. Caryopses not compressed 2
1b. Caryopses laterally compressed 7

2a. Scutellum sickle-shaped .... *E. cilianensis*
2b. Scutellum V-shaped 3

3a. Caryopses strictly obloid .... *E. japonica*
3b. Caryopses obloid to obovoid to ovoid 4

4a. Dorsal surface smooth (under SEM) .... *E. ciliaris*
4b. Dorsal surface with reticulate pattern (under SEM) 5

5a. Lateral surface smooth (under SEM) .... *E. tenella*
5b. Lateral surface with reticulate pattern (under SEM) 6

6a. Embryo short (embryo length ≤45% of caryopsis) .... *E. nutans*
6b. Embryo large (embryo length ≥46% of caryopsis) .... *E. viscosa*

7a. Scutellum sickle-shaped .... *E. tremula*
7b. Scutellum V-shaped 8

8a. Caryopses surface rectangular-foveate with pits (under SEM) .... *E. pilosa*
8b. Caryopses surface rectangular and smooth (under SEM) .... *E. unioloides*

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Drosera bulbosa subsp. *coronata* (Droseraceae) from the northern goldfields region of Western Australia

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Abstract

Drosera bulbosa Hook.f. subsp. *coronata* R.P.Gibson from Western Australia is here described as new. It differs from *D. bulbosa* subsp *bulbosa* and *D. bulbosa* subsp. *major* (Diels) N.G.Marchant primarily by having yellow pollen, and styles that form an annulus (crown) around the exposed apex of the ovary. It is currently known from two locations; however it is not considered to be under imminent threat of extinction.

Introduction

Analysis of variation in *Drosera bulbosa* across its distributional range revealed an unusual variant in the northern Wheatbelt of south Western Australia that is readily distinguishable, when in flower, from other known subspecies of this species. This subspecies is a flat-rosetted tuberous *Drosera* (*Drosera* subgenus *Erythrorhiza*), with leaves that are obovate to rectangular with a conspicuously raised mid-rib on the adaxial surface; flowers borne on individual pedicels arising directly from the centre of the rosette; and styles capitate similar to those of *D. bulbosa* (Fig. 1). However, the flower structure and pollen colour suggest that it is a new subspecies of *D. bulbosa*.

Taxonomy

Drosera bulbosa subsp. *coronata* R.P.Gibson, *subsp. nov.*

Holotype: *R.J. Cranfield 5075*, 18 Jun 1986, 63 km NE of Mullewa on Wanina Station, Western Australia (PERTH642746)

A tuberous perennial flat-rosetted carnivorous herb to 8 cm diameter. Mature rosettes comprises 10–16 leaves, olive-green; petiole red, up to 10 mm long; lamina oblong to slightly obovate, up to 4 cm long, c. 12 mm wide, apex obtuse; midrib red, raised for c. 90% of lamina length on adaxial surface, secondary veins also raised on abaxial surface; glands on adaxial surface of lamina red, stalked. Inflorescence usually 12–20-flowered; flowers with pedicels red, erect, 25–30 mm long at anthesis (that lengthen to 40 mm and become recurved in fruit). Sepals, 5, red, elliptic, 4 mm long, 1.2 mm wide, apex acute, apical margin often dentate, glabrous, recurved at anthesis. Petals, 5, white (sometimes light pink in bud), 9 mm long, 6 mm wide, faintly nectar-scented; apex obtuse, often weakly emarginate to dentate. Stamens 5, erect, up to 2 mm long; filaments white (or pale pink), linear; anthers pale red; pollen yellow. Ovary ellipsoid, weakly 3-locular, green, 1 mm long, up to 1 mm diam. Styles 3, up to 0.6 mm long, white to pale pink, multiply divided from base into 20–30 style segments;

capitate. Style segments arranged in an annulus below the apex of the ovary. Seeds black, ovoid, 0.7–0.8 mm diam. Figs 2 & 3.

Other specimen examined: *R.P.Gibson 319*, 17 Aug 2011, cultivated plants ex Mingenew Hill, Western Australia (NSW).

Distribution: This subspecies is only known from two locations in Western Australia, one near Pinegrove (27°47'13"S, 115°40'15"E) and the other near Mingenew (29°11'38"S, 115°26'28"E); about 130 km apart (Fig. 4). It is likely that this subspecies occurs in suitable habitat elsewhere in this region, in soils that are reliably moist each winter, such as the headwaters of streams in open shrublands and woodlands.

Habitat: Plants from Pinegrove are reported to grow in red clay-loam in *Acacia* woodland (*Cranfield 5075*). Plants that I have observed at Mingenew grew on the footslopes of a steep slope in an open *Acacia* shrubland growing with annual daisies and *Drosera macrantha* Endl. subsp. *macrantha*.

Flowering Period. Based on *Cranfield 5075* and observations of plants in cultivation, this species flowers in May and June. Flowers open for only a few hours during a single day and petals have a moderately strong nectar-sweet scent during anthesis. Plants appear to be self-incompatible and rely of cross-pollination for fertilization. Ripe seed is produced in July.

Conservation Status: This subspecies is currently known from two records 130 km apart; Mingenew Nature Reserve, and the other on a grazing property where the population does not appear to be under imminent threat. Thus this subspecies appears to meet the 'Priority three' conservation code for Western Australian Flora (Chapman 2013); that is, poorly known taxa that are known from a few locations, some of which may be at risk of threatening processes (the risk of land clearing at the Pinegrove site). Further survey for this subspecies is recommended, which would need to be conducted in May or June when plants are flowering in order to differentiate it from the other subspecies of *D. bulbosa*.

Etymology: The subspecific epithet ('coronata') is based on the annular, or crown-like arrangement of style segments around the apex of the ovary.

Affinities: Based on leaf shape, leaves with a prominent raised midrib, flowers held singularly on their own pedicles and capitate stigmas, and preliminary molecular data this taxon is most closely allied to *Drosera bulbosa* subsp. *bulbosa* and *D. bulbosa* subsp. *major*. It is intermediate in size between these two subspecies and due to its pollen colour and the absence of style segments from the apex of the ovary it is hereby considered to be another subspecies of *D. bulbosa*. Subspecific rank appears appropriate due to the similar leaf morphology of the three subspecies, all with their prominent raised midrib on the adaxial surface, and also the similarity of molecular sequences (unpublished data, not present here). Characteristic features of these subspecies are provided in Table 1 below. The type collection for *D. bulbosa* subsp. *major* was made near the town of Mingenew

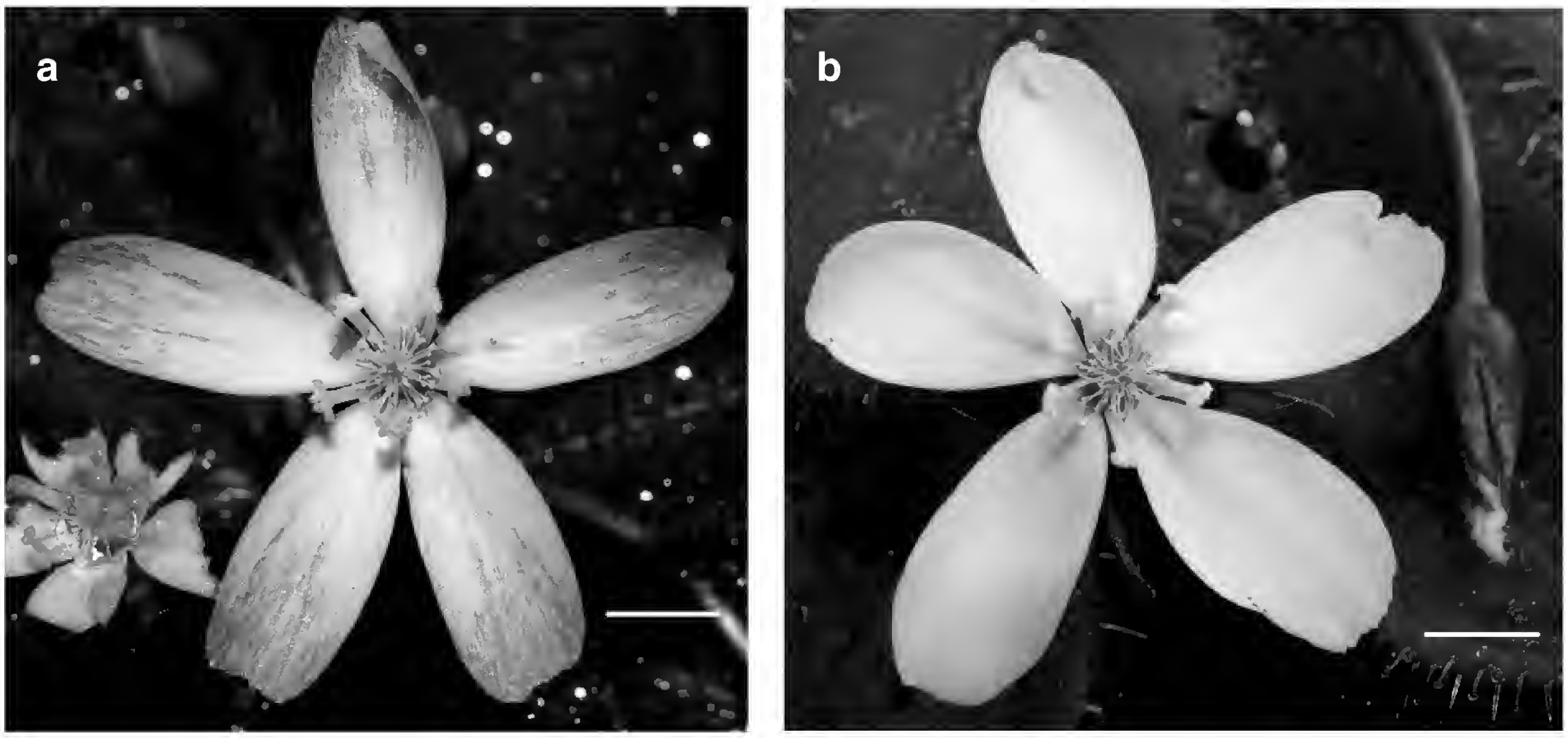

Fig. 1. Open flowers of **a,** *D. bulbosa* subsp. *bulbosa* and, **b,** *D. bulbosa* subsp. *major* that show the flowers have white pollen and capitate styles that form a hemispherical dome around the apex of the ovary. Scale bar: a & b = 5mm. Photographs by R. Gibson.

(Diels 1906: p. 126). A digital scan of this collection (Röpert 2013) was examined and found to match the taxon concept of *D. bulbosa* subsp. *major* (e.g. Lowrie 1987) and thereby confirm that *D. bulbosa* subsp. *coronata* is distinct from the former subspecies.

The recognition of this taxon provides an opportunity to update the key to species and subspecies of *Drosera* in the 'Flora of Australia' (Marchant *et al.* 1982). Suggested changes from couplet 53 (Marchant *et al.* 1982) to accommodate the 20 taxa of rosette tuberous *Drosera* here recognized are provided below. The tuberous rosetted sundew in Marchant et al. (1982, fig. 3) labeled as *D. bulbosa* is instead *D. rosulata* Lehm. based on its yellow pollen and leaves with a depressed midrib.

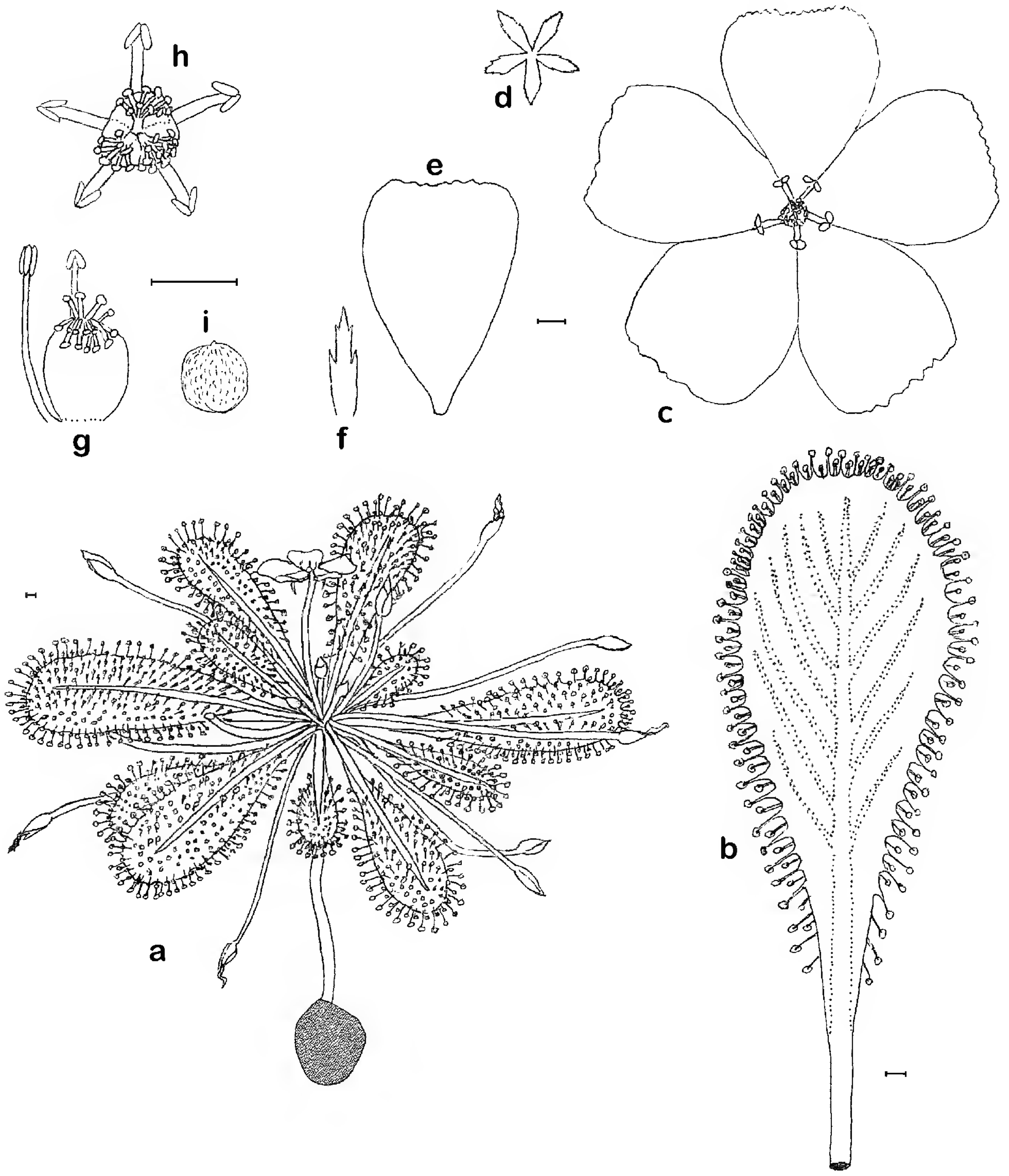

Fig. 2. Illustration of *Drosera bulbosa* subsp. *coronata*: **a,** whole plant in flower, **b,** mature leaf, abaxial surface; **c,** open flower; **d,** calyx; **e,** petal; **f,** sepal; **g,** gynoecium with two stamens from side; **h,** gynoecium and all stamens, from above; and **i,** ripe seed. Scale bar = 1 mm.

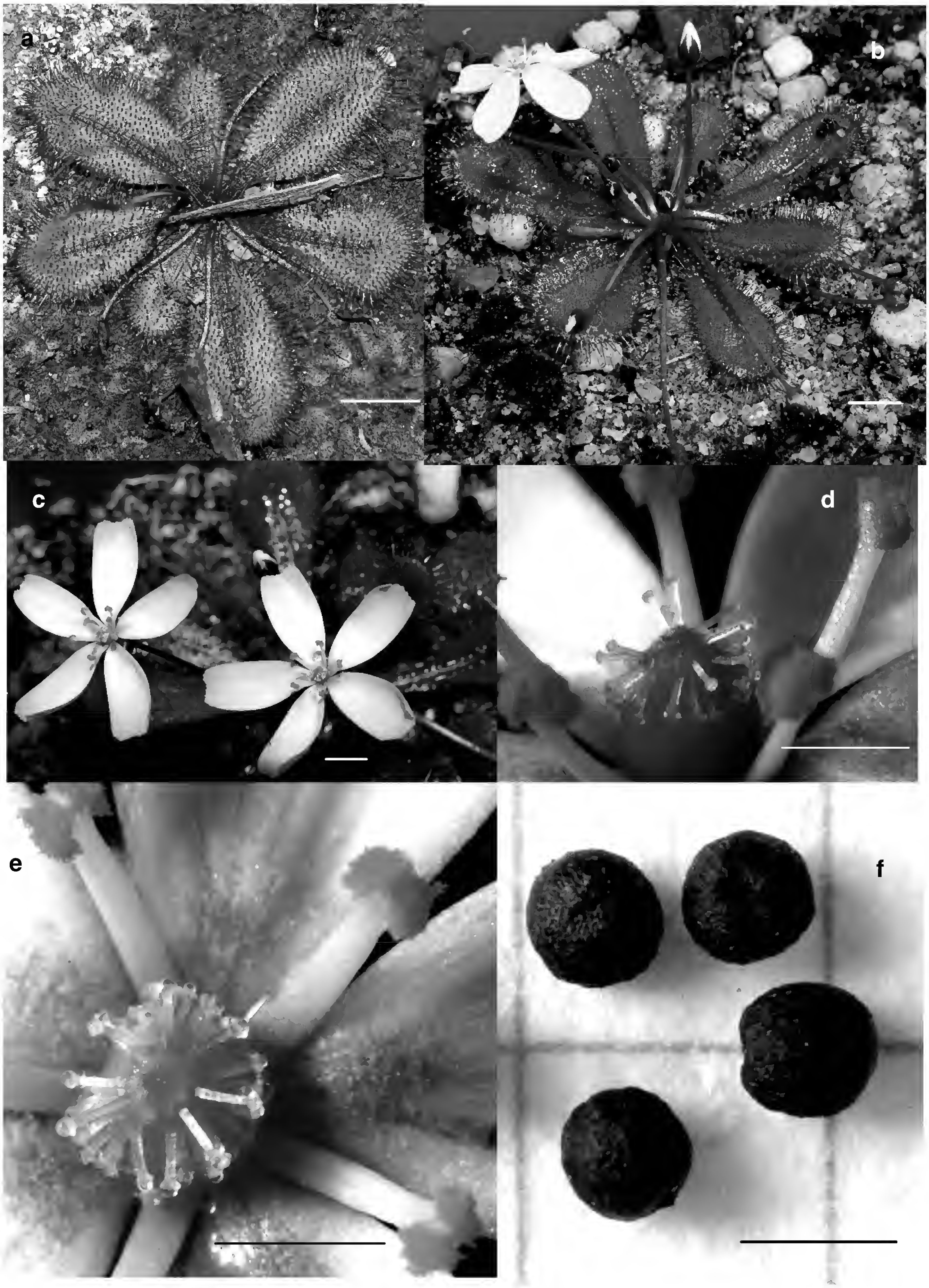

Fig. 3. *Drosera bulbosa* subsp. *coronata*: **a,** sterile rosette of leaves in situ; **b,** flowering plant (in cultivation); **c,** details of two flowers; **d,** details of stamens and ovary angled ventral view, showing naked apex of ovary above the annulus of styles and stamens with yellow pollen; **e,** details of centre of flower, ventral view; **f,** mature seeds (grid lines are 2 mm apart). Scale bar: **a, b**= 5 mm; **c** =5 mm; **d, e, & f** = 1mm. Photographs by R. Gibson

53 Inflorescence cymose, 2–many-flowered
  54 Rosettes of up to 12 leaves; leaves obovate
    55 Plants with one scape per rosette
      56 Leaves broadly obovate to 30 mm long 3–5 leaves per rosette; strongly stoloniferous .... *D. erythrorhiza* subsp. *erythrorhiza*
      56 Leaves broadly obovate to 60 mm long, 4–6 leaves per rosette; weakly stoloniferous .... *D. erythrorhiza* subsp. *magna*
        57 Leaves narrow obovate to 60 mm long, at least 8 leaves per rosette .... *D. erythrorhiza* subsp. *collina*
        57 Leaves obovate to 30 mm long; conspicuously variegated .... *D. erythrorhiza* subsp. *squamosa*
    55 Plants with several scapes per rosette
      58 Scapes 1–4, prostrate in scape .... *D. prostratoscaposa*
      58 Scapes up to 40, erect in fruit .... *D. macrophylla* subsp. *macrophylla*
  54 Rosettes of up to 30 leaves; leaves flabellate .... *D. zonaria*
53 Flowers on individual scapes
  59 Plants hysteranthous; tubers white .... *D. praefolia*
  59 Scapes produced after leaves; tubers orange or red
    60 Leaves with a prominently raised midrib on the adaxial surface
      61 Scapes erect in fruit
        62 Scapes 1–20; leaves to 18 mm long, shortly petiolate; petals pink ± white on adaxial surface .... *D. browniana*
        62 Scapes 20–50 (occasionally 2-flowered), leaves to 40 mm long, sessile; petals white, rarely pale pink .... *D. macrophylla* subsp. *monantha*
      61 Scapes prostrate in fruit
        63 Pollen white
          64 Leaves to 30 mm long, sepal margins entire .... *D. bulbosa* subsp. *bulbosa*
          64 Leaves to 55 mm long; sepal margins serrate .... *D. bulbosa* subsp. *major*
        63 Pollen yellow
          65 Style segments arranged in a hemisphere on the ovary apex; styles tubaeiform .... *D. tubaestylis*
          65 Style segments capitate; arra.nged in an annulus around apex of ovary .... *D. bulbosa* subsp. *coronata*
    60 Leaves without a prominently raised midrib on the adaxial surface
      66 Style segments erect with a recurved base
        67 Leaves obovate; shortly petiolate .... *D. rosulata*
        67 Leaves orbicular; distinctly petiolate .... *D. orbiculata*
      66 Style segments radiating from style apex
        68 Inflorescence of up to 7 flowers
          69 Plants stoloniferous; leaves obovate with a broad flat petiole; all leaves appressed to ground .... *D. aberrans*
          69 Plants not stoloniferous, whorled cauline leaves present; leaves spatulate with a linear, canaliculated petiole........ D. schmutzii
        68 Inflorescence up to 20 flowers; leaves obovate
          70 Petiole linear, to 10 mm long; multiple leaf rosettes produced per growing season .... *D. lowriei*
          70 Petiole obovate, to 15 mm long; single leaf rosette produced per plant per season .... *D. whittakeri*

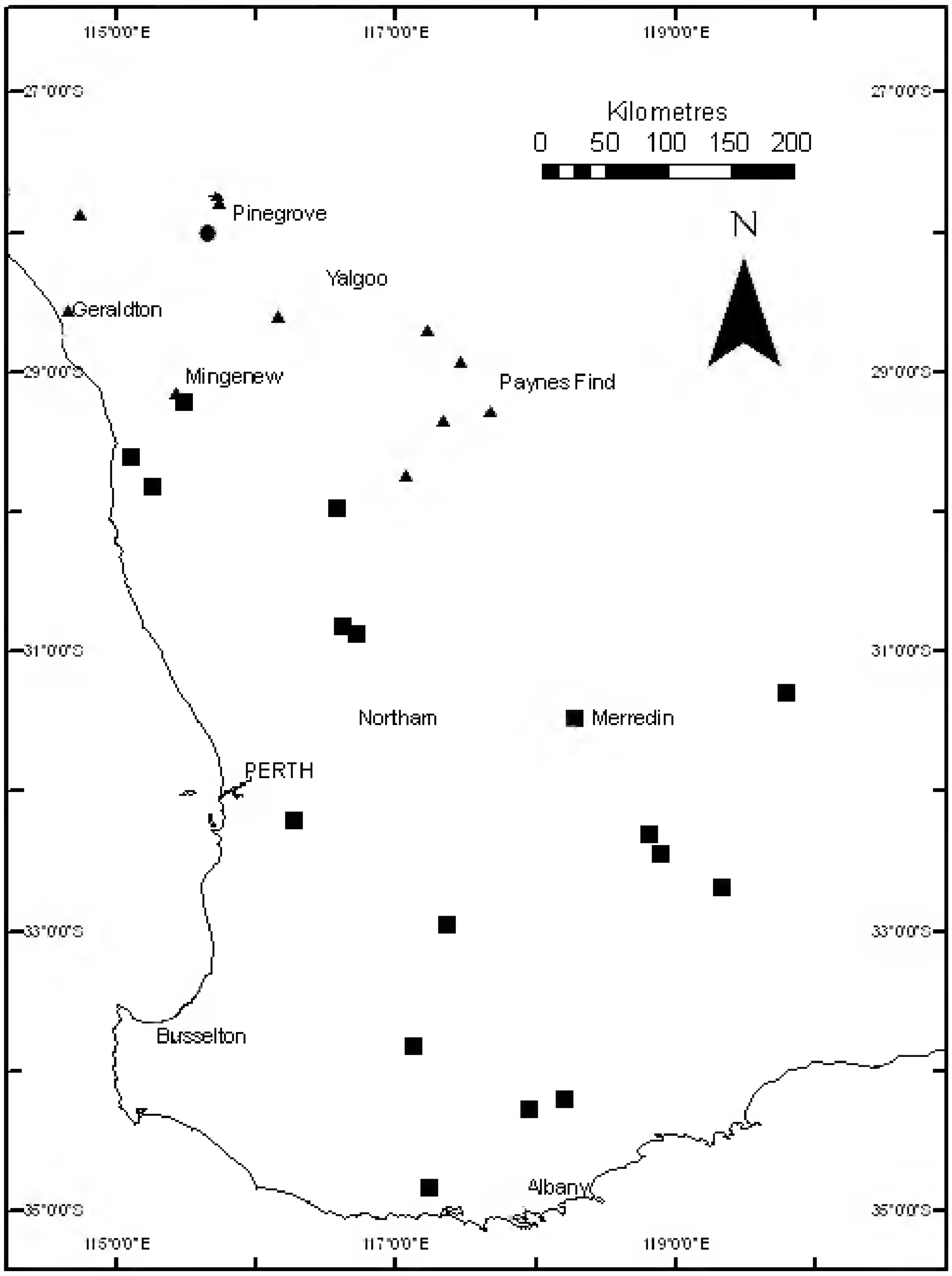

Fig. 4. Distribution map of *D. bulbosa* subsp. *coronata* (●), *D. bulbosa* subsp. *bulbosa* (■) and *D. bulbosa* subsp. *major* (▲) based on records at PERTH and the author's observations.

Table 1. Key morphological characters that distinguish *D. bulbosa* subsp. *coronata* from *D. bulbosa* subsp. *bulbosa* and *D. bulbosa* subsp. *major.*

Character:	***D. bulbosa* subsp. *coronata***	***D. bulbosa* subsp.*major***	***D. bulbosa* subsp. *bulbosa***
Pollen colour	yellow	white	white
Anther colour	pale red	white	white
Style length (mm)	3	1.5	1.5
Style segment arrangement	annulus around apex of ovary	hemispherical dome around apex of ovary	hemispherical dome around apex of ovary
Typical leaf size (mm)	40 × 12	55 × 25	25 × 10
Leaf colour	olive-green with red pigment on petiole and midrib	yellow-green	variably yellow green to olive green to partially to fully red
Leaf shape	oblong to weakly obovate	obovate	oblong to obovate

Conclusions

Drosera bulbosa subsp. *coronata* a new species based on leaf morphology and molecular sequences. It is part of the *Drosera bulbosa* complex, however this subspecies is differentiated from other taxa by its yellow pollen and the unique crown-like arrangement of its styles.

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Rediscovery of *Prostanthera albohirta* C.T.White (Lamiaceae)

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Abstract

The northern Queensland species, *Prostanthera albohirta* C.T.White (Lamiaceae) is very inadequately known and is officially regarded as extinct. The recent discovery of *P. albohirta* from the Mount Emerald area of Queensland (Australia) represents the first collections of this species since 1932. Habitat preferences, conservation notes and photographs of the species are here provided.

Introduction

Prostanthera albohirta C.T.White was described from a single collection by L.J. Brass in 1932 from Mount Demi, west of Mossman, Cook District, North Queensland (White 1936). Attempts to re-collect this species by several botanical collectors have been unsuccessful. Hence, both the Australian national authority (EPBC 2013) and the Queensland State authority (Nature Conservation (Wildlife) Regulation 2006) regard *P. albohirta* as being Extinct.

During discussions between the two authors regarding tropical species of *Prostanthera* in northern Queensland, it became apparent that unidentified collections from the Mount Emerald area, west of Tolga (Cook district, Queensland) were of *P. albohirta*.

Prostanthera albohirta C.T.White, *Proceedings of the Royal Society of Queensland* 47: 74 (1936). **Fig. 1**

Holotype: Queensland: Cook District: Mt Demi summit, *L.J. Brass 2102*, 6 Feb 1932 (BRI).

For detailed description of species – refer White (1936).

Distribution: Previously known by type collection from the summit area of Mount Demi, near Mossman, and now from the Mount Emerald area on the Great Dividing Range, west of Tolga. Both localities are from the Cook botanical district, Queensland, Australia. In addition, both localities are also within the Wet Tropics Bioregion, although the Mt Emerald population sits a little east of the Einasleigh Upland Bioregion (see http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/maps.html)

Fig.1. Photograph of flowering branchlets showing indumentum of branchlet, abaxial surface of leaves, prophylls and outer surface of calyx; oblique profile view of corolla (*Ford 6174*). Photographer: A. Ford

Habitat: The original collections from Mount Emerald (*Holmes 173*, *Ford 2360* and *Ford 5361*) occurred in one small area in a protected gully dominated by stunted *Syncarpia glomulifera* (Sm.) Nied, with a dense under story of mesic shrubs including: *Acrotriche aggregata* R.Br., *Bertya polystigma* Gruening, *Pittosporum revolutum* W.T.Aiton and *Pomaderris argyrophylla* N.A.Wakef. However, the latest collection (*Ford 6174*) came from a wet, low grassy woodland that is approximately 20 metres from the populations that were previously known. The habitat of the *Ford 6174* collection included the same understorey shrub species, but the ground-layer included more grass species such as *Entolasia* and *Panicum*. Little is known about the habitat preferences of this species on Mount Demi, except that it occurred 'on an exposed cliff face' (*Brass 2102*). The vegetation occurring on Mount Demi is predominantly tropical upland rainforest. The species is known to occur at elevations of 900–1100 metres, although the collections only represent two localities.

Notes: The discovery of *P. albohirta* from the Mount Emerald area is surprising given the extent of potential habitat between (and north of) Mount Demi and Mount Emerald. There are many areas above 900 m altitude that harbour scrubby gullies amongst rock outcrops which appear suitable but from which the species has not been found, this is despite several collectors being active in those areas.

It appears as though fire regimes play a significant role in determining the population structure and presence of *P. albohirta.* The Mount Emerald collections from the sheltered gully represent an area that has not been burnt for many years. In response to the lack of fire or other disturbances, the five plants of *P. albohirta* had become openly branched and poorly formed. As a result of a fire in a nearby gully in 2009, the plants that were at least 11 years old were killed. There was no sign of coppice growth at ground level from where the stems had originally been. It is assumed the stems were totally incinerated. However, nearby a healthy population now thrives in a much more open and sunny community. From these observations it is apparent that *P. albohirta* is an obligate seeder, but it is not known at what age plants become reproductive. Therefore, local fire regimes are critical if *P. albohirta* is to survive in the Mount Emerald area.

The affinities of this species are unclear. White (1935) regarded *P. albohirta* as closely related to *P. rugosa* A.Cunn. ex Benth from New South Wales. There are two other, morphologically unrelated, species of *Prostanthera* which occur within 10 km of Mt Emerald in north Queensland, viz. *P. clotteniana* (F.M.Bailey) A.R.Bean and *Prostanthera* sp. (Dinden *P.I. Forster 17342*). Both of these species have glabrous to glabrescent leaves with entire margins and a calyx which enlarges markedly during fruit maturation, however *P. albohirta* has densely hairy leaves with 1–4 bluntly pointed lobes on each side of the margin and a calyx which does not enlarge during fruit maturation.

Conservation status: We strongly urge reassessment of the extinction-risk listing status of *P. albohirta* under both Queensland and Commonwealth legislation, and incorporation of it in relevant conservation management plans and guidelines. There is a very strong prima facie case that it now satisfies the requirements for 'Critically Endangered' status *sensu* IUCN (2001), at least under Criterion D (population size <50 individuals). On Mount Emerald there are currently less than 50 plants known in an area no larger than 100 m^2. Searches of nearby areas have so far failed to discover additional occurrences.

This species has only been collected once from the summit area of Mount Demi and attempts to recollect this species from this area by the second author have failed and *P. albohirta* should be regarded as probably locally extinct at this location. Nearby areas which contain similar rock faces should be explored.

Other specimens examined: Queensland: Cook: Mt Emerald, Herberton Range: *Ford 2360*, 4 April 2000 (BRI, CNS); *Ford 5361*, 18 Aug 2008 (BRI, CNS, NSW); *Ford 6174*, 1 May 2013 (BRI, CNS, MEL, NSW); *Holmes 173*, 24 March 2000 (BRI, CNS).

Acknowledgments

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New species of *Pertusaria* (Pertusariaceae) from Australia and New Zealand

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Abstract

Four new species, ***Pertusaria ambigua*** (with lichesterinic acid), ***P. humilis*** (characterised by very flattened apothecia), ***P. queenslandica*** (with two-spored asci) and ***P. submalvinae*** (with confluentic acid), are reported from Australia and two new species, ***Pertusaria allosorodes*** (with two large, rough-walled ascospores per ascus) and ***P. wirthii*** (with barbatic acid), are reported from New Zealand.

Introduction

The lichen genus *Pertusaria* in Australia was the subject of a monograph in 1997 (Archer 1997) and since then additional taxa and distribution data have been published (Archer 2004); the latest account of the genus is available on line (Archer 2012). The genus was divided into 3 subgenera; *Monomurata*, *Pionospora* and *Pertusaria* (Archer 1997) but recent molecular work on the phylogeny of *Pertusaria* and allied taxa indicate that *Pertusaria* is polyphyletic, comprising three well-supported clades viz: (1) *Pertusaria* sensu stricto group (including the subgenera *Pertusaria* and *Pionospora*); (2) *Monomurata* group; and (3) *Varicellaria* group (Schmitt 2002; Schmitt & Lumbsch 2004). The two subgenera, *Pertusaria* and *Monomurata*, are distinguished by the morphology of the apothecia (verruciform in *Pertusaria* and disciform in *Monomurata*) and chemistry (chloroxanthones sometimes present in *Pertusaria, whereas* absent in *Momomurata*). In Australia, a total of 119 species of *Pertusaria* are described and of these, 25 are in subgenus *Monomurata* and the remainder in subgenus *Pertusaria.*

A comprehensive account of *Pertusaria* in New Zealand was given by Galloway (2007) who reported a total of 54 species, with 18 species in subgenus *Monomurata* (including Section *Digitatae*) and the remaining 36 species in subgenus *Pertusaria.*

As part of a continuing study of *Pertusaria*, some older collections of previously unidentified *Pertusaria* specimens from Australia and New Zealand were re-examined and found to include six new species. Four of these new species, *Pertusaria allosorodes P. humilis, P. queenslandica* and *P. submalvinae,* belong to subgenus *Pertusaria* and *P. ambigua,* with its unique chemistry, is also tentatively placed in the same subgenus. *Pertusaria wirthii*, with disciform apothecia, is placed in subgenus *Monomurata.*

In the present work chemical constituents were identified by thin-layer chromatography (Elix & Ernst-Russell 1993), high performance liquid chromatography (Elix et al. 2003) and comparison with authentic samples. MycoBank identifiers (MB) are given below the species names.

New species

Pertusaria allosorodes Elix & A.W.Archer, ***sp. nov.*** Fig.1.

MB 805235

Diagnosis: similar to *Pertusaria sorodes* Stirt., but containing norstictic and 2-*O*-methylstenosporic acids.

Type: New Zealand, North Island: Northland: 5 km NW of where Mangamuka River crosses Highway No. 1, at wayside stop labelled "Forest View", [35°12'S, 173°30'E], on twig, *W.E. Ewers 2700*, 6 April 1988; holotype CANB.

Thallus pale fawn, surface smooth and dull, somewhat cracked, lacking isidia and soredia, corticolous. Apothecia verruciform, flattened, sometimes becoming concave, scattered or confluent. 1.5–3 mm diam. Ostioles black, conspicuous, 1–3 per apothecia. Ascospores 2 per ascus, ellipsoid, hyaline with a rough inner wall, 175–210 µm long, 50–70 µm wide.

Chemistry: 2-*O*-methylstenosporic acid (major), 4,5-dichlorolichexanthone (minor), norstictic acid (minor) and 2-*O*-methylperlatolic acid (trace).

Pertusaria allosorodes resembles *P. sorodes* Stirt. in that both species are corticolous and have flattened, multi-ostiolate apothecia, asci with two large ascospores, c. 200 µm long, with rough inner walls. The two species differ chemically: *P. sorodes* contains stenosporic and perlatolic acids whereas *P. allosorodes* contains the *O*-methylated analogues, 2-*O*-methylstenosporic and 2-*O*-methylperlatolic acids. The somewhat similar species, *Pertusaria southlandica* A.Knight, Elix & A.W.Archer (Knight et al. 2011) (Fig. 2) also from New Zealand, contains conhypoprotocetraric acid and 2-chlorolichexanthone whereas another somewhat similar species, *P. subsorodes* Elix & A.W.Archer from Papua New Guinea, contains 2'-*O*-methylperlatolic acid (Elix et al. 1997).

The new species also resembles *P. wattiana* Müll.Arg., from India (Müller 1892). This species has flattened, multi-ostiolate apothecia, two rough-walled ascospores per ascus and contains norstictic and 2-*O*-methylstenosporic acids as major compounds but the ascospores are smaller (110–137 × 37–45 µm) than those of *P. allosorodes* (175–210 × 50–70 µm). At present the new species is known only from the type specimen.

The epithet is from the Greek *allo,* another, and the epithet *sorodes*, a reference to the similarity of the two species.

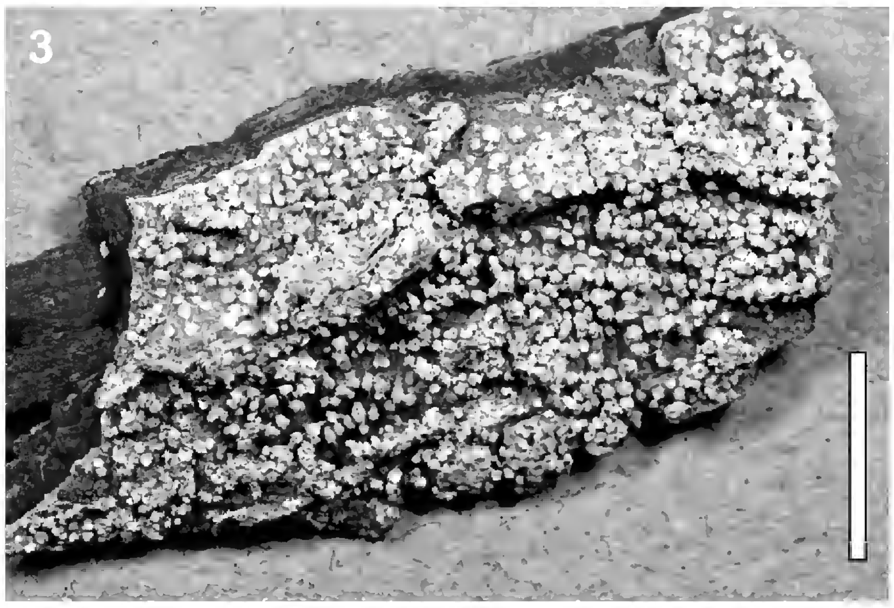
Pertusaria ambigua A.W.Archer & Elix, ***sp. nov.*** Figs 3 & 4

MB 805236

Diagnosis: similar to *Pertusaria montpittensis* A.W.Archer but differs in the isidia becoming ecorticate and in containing lichesterinic acid.

Type: Australia, New South Wales: Werrikimbe National Park: Brushy Mountain rest area, 31°09'S, 152°22'E, alt. c. 900 m, on tree, *A.W. Archer P630*, 21 Oct 1993; holotype: NSW.

Fig. 1. *Pertusaria allosorodes*, holotype. Scale bar = 2 mm
Fig. 2. *Pertusaria southlandica*, holotype. (OTA).



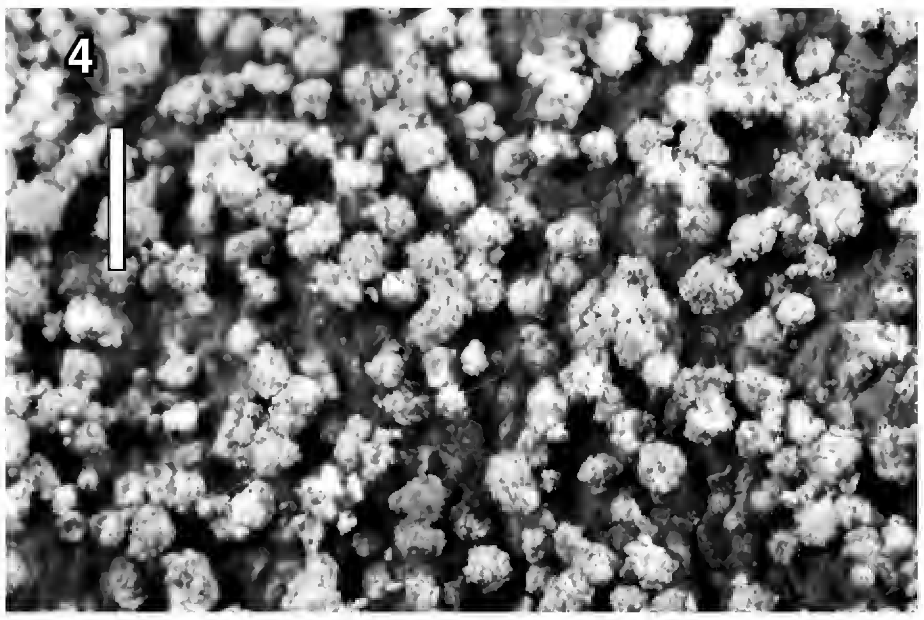


Fig. 3. *Pertusaria ambigua*, holotype. Scale bar = 5 mm
Fig. 4. *Pertusaria ambigua*, holotype. Scale bar = 1 mm

Thallus off-white to pale fawn (pale olive green when collected), surface smooth, somewhat shiny, cracked, isidiate, lacking soralia, corticolous. Isidia initially corticate, concolourous with the thallus, 0.5–0.6 mm tall, 0.2–0.3 mm wide, becoming ecorticate and resembling soredia. Apothecia not seen.

Chemistry: lichesterinic acid (major).

Pertusaria ambigua is characterised by the isidiate thallus, the lack of apothecia and the presence of lichesterinic acid. It is differentiated from other Australian isidiate *Pertusaria* species by the ecorticate surface of the isidia and the presence of lichesterinic acid. Relatively few corticate isidia were seen. The species is so far known only from the type specimen.

Lichesterinic acid is also found in *Pertusaria kinigiensis* A.W.Archer, Eb.Fischer, Killmann & Sérus., as a minor compound, and in *P. krogiae* A.W.Archer, Eb.Fischer, Killmann & Sérus. as a major compound (Archer et al. 2009). The substance is also found in the genus *Ochrolechia.* The epithet is from the Latin *ambiguus*, unclear, a reference to the unusual appearance and the presence of the aliphatic acid, lichesterinic acid.

Pertusaria humilis Elix & A.W.Archer ***sp. nov.*** Fig. 5

MB 805239

Diagnosis: similar to *Pertusaria plana* Vain., but with smooth walled ascospores, lacking norstictic acid and saxicolous.

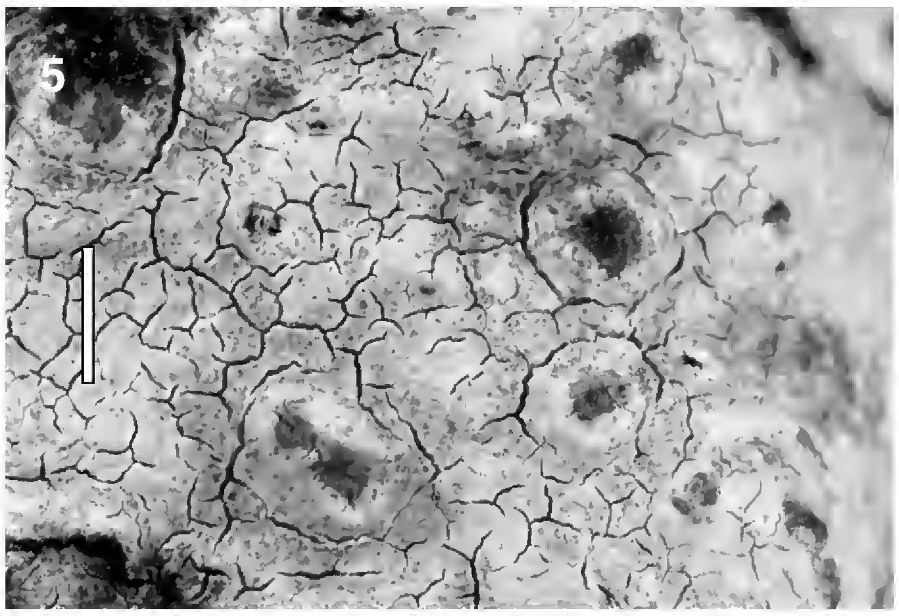
Type: Australia, Queensland: Conway State Forest: 16 km E of Proserpine, 20°21'S, 148°44'E, alt. 160 m, on rocks beside stream in lowland rainforest, *J.A. Elix 20805*, 29 June 1986; holotype CANB.

Thallus pale fawn, surface smooth and slightly cracked, lacking isidia and soralia, saxicolous. Apothecia verruciform, very flattened, scarcely rising above the thallus surface, scattered, rarely confluent, 0.8–1.5 mm diam., concolorous with the thallus. Ostioles conspicuous, pale brown, translucent, 0.4–0.6 mm diam. Ascospores 4 per ascus, hyaline, ellipsoid, with a smooth inner wall, 95–107 μm long, 30–37 μm wide.

Chemistry: 4.5-dichlorolichexanthone only (major).

Pertusaria humilis is characterised by the saxicolous habit, the markedly flattened apothecia, the conspicuous ostioles and the presence of 4,5-dichlorolichexanthone. The new species resembles the corticolous species *P. plana* Vain. (Wainio 1899) (Fig.6), from Guadeloupe, in that both have distinctly flattened apothecia (cf. Figs 5 and 6), and ascospores of similar size (90–120 × 25–34 μm in *P. plana* and 95–107 x 30–37 μm in *P. humilis*). However, the ascospores in *P. plana* have rough inner walls in contrast to the smooth inner walls present in *P. humilis.* The species also differ in distribution, substrate preference (corticolous versus saxicolous), and chemistry. *Pertusaria plana* contains norstictic acid and *P. humilis* contains 4,5-dichlorolichexanthone.

Flattened apothecia with conspicuous dark ostioles are also present in *P. platycarpiza* Zahlbr., from Taiwan (Zahlbruckner 1933) and in *P. brasiliana* Zahlbr. from Brazil (Zahlbruckner 1928) [= *P. laevigata* Müll. Arg., *nom inval.* non (Th.Fr.) Anzi], but these species can be distinguished from *P. humilis* by the number of ascospores per ascus and chemistry. Thus *P. platycarpiza* has two ascospores per ascus and contains divaricatic



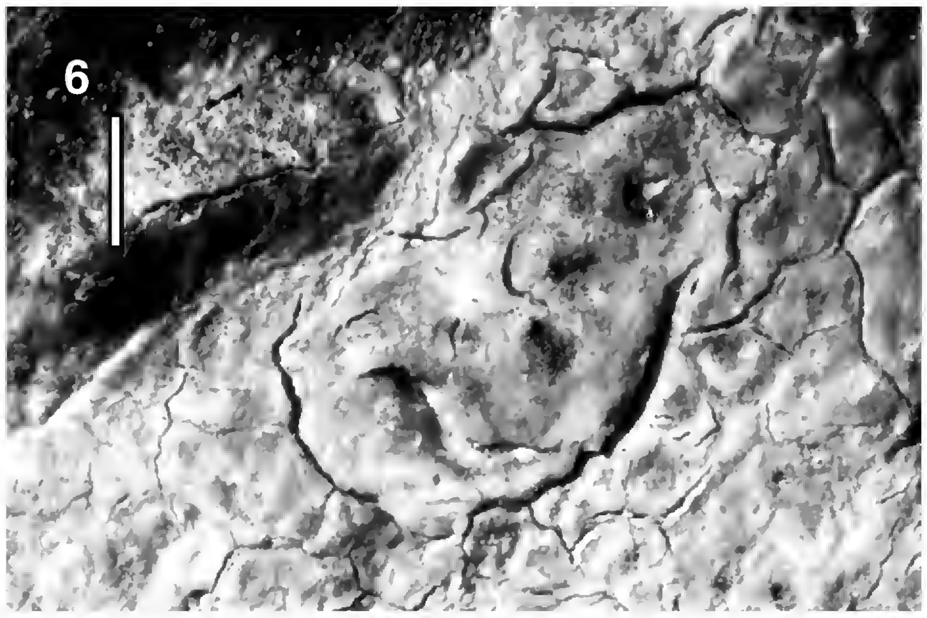


Fig. 5. *Pertusaria humilis.* Scale bar = 1 mm
Fig. 6. *Pertusaria plana* Vain. holotype (TUR-V 6902). Scale bar = 1 mm

acid, whereas *P. brasiliana* has eight ascospores per ascus and lacks lichen substances.

The saxicolous species *P. aleianta* Nyl. (Nylander 1877) from Cape Verde also has asci containing 4 ascospores and produces 4,5-dichlorolichexanthone as the sole lichen compound present, but the ascospores in *P. humilis* are longer than those in *P. aleianta* (95–107 µm compared to 70–90 µm in *P. aleianta*) and the apothecia are flattened in *P. humilis* in contrast to the raised, almost disciform, apothecia present in *P. aleianta.* Nylander (1877) reported the apothecia to be 'more or less protruding and separate, sometimes subconfluent'.

At present this species is known only from the type specimen.

The epithet is derived from the Latin *humilis*, low, a reference to the markedly flattened apothecia.

Note: Edvard Vainio (1852–1929), originally E. Lang until 1877, after that he used the spelling 'Wainio' until 1919, and then changed it to 'Vainio' (Stafleu and Cowan 1986, p. 636)

Pertusaria queenslandica Elix & A.W.Archer ***sp. nov.*** Fig. 7.

MB 805240

Diagnosis: chemically similar to *Pertusaria striolata* Räsänen, but with larger ascospores and paler ostioles.

Type: Australia, Queensland; on mangroves near walkway, Cairns airport, 16°53'S, 145°46'E, *W.H. Ewers 8708*, 2 Oct 1991; holotype: CANB.

Thallus pale fawn, surface smooth and somewhat shiny, cracked, lacking isidia and soralia, corticolous. Apothecia verruciform, conspicuous, scattered, subhemispherical, concolorous with the thallus, 0.7–1.6 mm diam. Ostioles inconspicuous, pale or more rarely black, punctiform, in a pale translucent zone, c. 0.1 mm diam. or slightly mammiform. Ascospores elongate ellipsoid, hyaline, 2 or rarely 3 per ascus, with a smooth inner wall, (112–)137–160 µm long, 30–37(–50) µm wide.

Chemistry: 4,5-dichlorolichexanthone (minor), 2'-*O*-methylperlatolic acid (major), stictic acid (major) and constictic acid (minor).

Specimen examined; Fiji: Viti Levu: Nasori Highlands, Nadi–Sigatoro Road, 13 km E of Vanturu Dam turn-off, *J.A. Elix 15233*, 27 Aug 1983 (CANB).

Spores 2(or 3) ascus, 125–165 × 37–50 µm.

Pertusaria queenslandica is characterised by the corticolous habit, the asci with two smooth-walled ascospores and the chemistry. It resembles the corticolous species *P. striolata* Räsänen (Fig. 8.) from Mindanao in the Philippines (Räsänen 1949), which also has asci with two smooth-walled ascospores and an identical chemistry, but differs in having significantly shorter ascospores, in having conspicuous dark ostioles and in containing traces of peristictic acid. The ascospores in the Philippine species were reported to be 65–80 µm long but on re-examination of the holotype they were found to be slightly longer, to 90 µm long but still significantly shorter than those of *P. queenslandica.*

The new species is chemically identical to the sterile, isidiate, Australian species, *P. pilosula* A.W.Archer & Elix (Archer 1997), and the tropical species *P. microstoma* Müll.Arg. (Müller 1882), but the latter have four rough-walled ascospores per ascus.

At present this species is known from the type locality in northern Queensland, and Fiji.

The epithet *queenslandica* refers to the type locality.

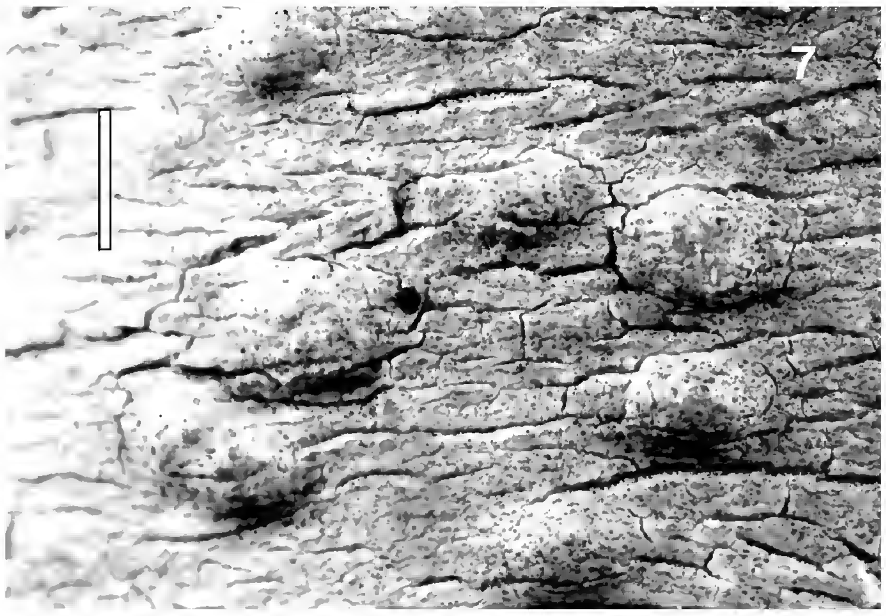


Fig. 7. *Pertusaria queenslandica* holotype. Scale bar = 1 mm
Fig. 8. *Pertusaria striolata* Räs. holotype (H). Scale bar = 1 mm

Pertusaria submalvinae A.W.Archer & Elix, ***sp. nov.*** Fig. 9.

MB 805241

Diagnosis: similar to *Pertusaria malvinae* Messuti & A.W. Archer but differs in having smaller ascospores and in containing norstictic acid.

Type: Australia: New South Wales: by side of Mill Creek, c. 55 km NW of Sydney, 33°23'S, 151°02'E, alt. c. 100 m, on exposed sandstone rock, *A.W. Archer P157*, 11 May 1991; holotype: NSW.

Thallus pale fawn, thin, surface smooth, lacking isidia and soralia, saxicolous. Apothecia verruciform, subhemispherical, scattered or crowded, sometimes confluent, 0.5–1.5 mm diam. Ostioles black, c. 0.05 mm diam, in a grey translucent zone, 0.2 mm diam. Ascospores ellipsoid, hyaline, with a smooth inner wall, 4 per ascus, 70–92 µm long, 30–40 µm wide.

Chemistry: confluentic acid (major), norstictic acid (minor), 2'-*O*-methylperlatolic acid (minor), stictic acid (trace) and 2'-*O*-methylstenosporic acid (trace).

Pertusaria submalvinae is characterised by the saxicolous habit, the asci with 4 ascospores and the presence of confluentic and norstictic acids. Superficially the species resembles the saxicolous *P. petrophyes* C.Knight (Knight 1881) which also occurs in eastern Australia but that species has asci with 8 ascospores and contains thiophaninic and 2-*O*-methylperlatolic acids. *Pertusaria malvinae* Messuti & A.W.Archer from the Falkland Islands (Islas Malvinas) (Messuti & Archer 1999) resembles *P. subvalvinae* in that both species are saxicolous, have asci with 4 ascospores and contain confluentic acid but the ascospores in *P. malvinae* are significantly longer (108–130 µm). In addition, *P. malvinae* lacks norstictic acid, present in P. *submalvinae.* At present this new species is known only from the type locality.

The epithet is derived from the Latin *sub*, somewhat and the epithet *malvinae*, indicative of the similarity of the two species.

Fig. 9. *Pertusaria submalvinae*. holotype. Scale bar = 1 mm

Pertusaria wirthii Elix & A.W.Archer, ***sp. nov.*** Figs 10 & 11

MB 805242

Diagnosis: similar to *Pertusaria novaezelandiae* Szatala but differs in having larger ascospores and in containing barbatic acid rather than hypothamnolic acid.

Type: New Zealand: South Island: Fiordland National Park: Milford Sound, near Visitor Centre, close to shore, on *Nothofagus*, 44°40'S, 167°56'E, alt. 1 m, *V. Wirth 27836*, 15 Nov 1995; holotype STU.

Thallus off-white, surface smooth and dull, lacking isidia and soralia, corticolous. Apothecia numerous, crowded, sometimes confluent, concolourous with the thallus, initially hemispherical, opening to become disciform, 0.5–0.8 mm diam, disc black, white pruinose. Ascospores 1 per ascus, rounded cylindrical, hyaline, 200–240 µm long, 56–70 µm wide, spore wall 4–5 µm thick. (Fig.12).

Chemistry: barbatic acid (major).

Pertusaria wirthii is characterised by the disciform apothecia, asci with a single, large ascospore with a single wall, and the presence of barbatic acid. It is distinguished from the morphologically similar *P. novaezelandiae* Szatala by the larger ascsopsores (200–240 µm long compared to 120–170 µm long in *P. novaezelandiae*) and the presence of barbatic acid; *P. novaezelandiae* contains hypothamnolic acid. Barbatic acid is an uncommon compound in the genus *Pertusaria* being known from *P. barbatica* A.W.Archer & Elix, a sterile, isidiate corticolous species from Eastern Australia and New Zealand (Archer 1997). At present the new species is known only from the type specimen.

The epithet honours Professor Volkmar Wirth (STU) who collected the type specimen.

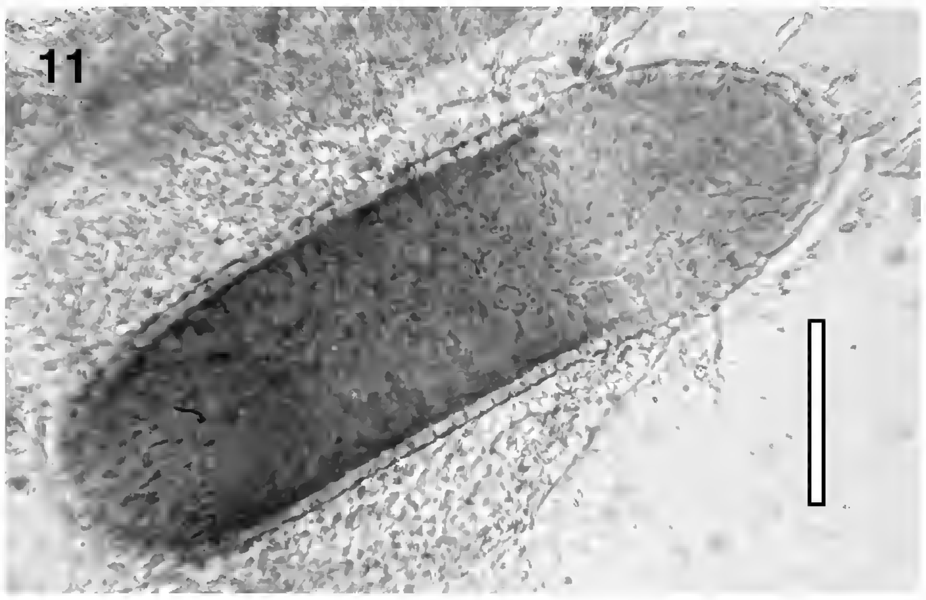


Fig. 10. *Pertusaria wirthii*. holotype. Scale bar = 1 mm
Fig. 11. *Pertusaria wirthii*, ascospore. Scale bar = 50 µm

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Acacia alaticaulis and *A. kulnurensis* (Fabaceae, Mimosoideae), rare new species from New South Wales, Australia

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Abstract

Two new species, ***Acacia alaticaulis*** Kodela & Tindale and ***A. kulnurensis*** Kodela & Tindale, belonging to *Acacia* section *Botrycephalae* and allied to *A. terminalis* (Salisb.) J.F.Macbr., are described and illustrated. Both species are rare with restricted distributions north of Sydney, from the Howes and Mangrove Mountain areas, into the Hunter Valley region of New South Wales, Australia.

Introduction

The bipinnate *Acacia* species of section *Botrycephalae* occur naturally in south-eastern Australia. This paper formalises the names of two new species belonging to this section that were previously referred to and described under various manuscript or phrase names in floras, reports and census lists (eg Maryott-Brown and Wilks 1993, Briggs and Leigh 1996, Kodela and Harden 2002, APC 2013, APNI 2013). Although superficially similar to *Acacia terminalis* (Salisb.) J.F.Macbr., *A. alaticaulis* and *A. kulnurensis* can most readily be distinguished from this allied species and each other based on vegetative characters (see key below). They are morphologically distinct from the remaining taxa in the *A. terminalis* complex, particularly in having sessile or near-sessile leaves and markedly recurved pinnules. A revision of the *A. terminalis* complex is ongoing, with several taxa currently treated as subspecies with manuscript and phrase names (see Kodela and Harden 2002, APNI 2013).

Methods

This study is largely based on detailed morphological observations of herbarium specimens held at NSW (including many duplicate specimens yet to be distributed), as well as field investigations. The morphological feature 'young foliage-tips' in the descriptions is often used in *Acacia* section *Botrycephalae* and refers to the apex of leaves that are at an early stage of development.

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†Deceased 2011.

Taxonomy

Acacia alaticaulis Kodela & Tindale, ***sp. nov.***

Acacia terminalis subsp. E (Maslin et al. 1990: 290)

Acacia terminalis s. lat. (winged form) (Maryott-Brown and Wilks 1993: 16)

Acacia sp. 35 (Howes Mountain; *R.G.Coveny 4108 & R.Bisby*) (Briggs and Leigh 1996: 194)

Acacia sp. A (Kodela and Tindale 2001a: 221 & 222, fig. 6A–E)

Acacia sp. Howes Mountain (*R.G. Coveny 4108*) NSW Herbarium (APC 2013, APNI 2013)

[*Acacia terminalis auct. non* (Salisb.) J.F.Macbr.: Maslin et al. 1990: 290, *p.p.*, fide NSW48881]

Diagnosis: *Acacia alaticaulis* Kodela et Tindale, species nova, differt ab *A. terminali* (Salisb.) J.F.Macbr. ramulis, petiolis et rhachidibus alatis, foliis fere sessilibus, petiolis ad 0.5 cm longis, pinnulis valde recurvatis et petioli glandula parviore 1–2 mm longa.

Type: New South Wales: Central Coast: Howes Mountain, 80 miles (128 km) N of Windsor on the Windsor–Singleton road, alt. 300 m, *R.G. Coveny 4108 & R. Bisby*, 26 Mar 1972 (holo: NSW106991; iso: BRI, CANB, K, MEL, NSW826817, US).

Spindly, straggly or slender shrub to small tree to 4 m high, with longer branches often weeping; *bark* smooth, grey. *Branchlets* angled, green, brown, reddish brown, purplish brown or bluish, glabrous or with very few scattered hairs to 0.2 mm long, conspicuously winged by c. 5 narrow, convoluted, pale brown to red or green (with reddish margin) ridges 1–3 mm high, with low (< 0.1 mm high) striations between. *Young foliage-tips* reddish brown, almost glabrous or slightly puberulous, resinous. *Leaves* bipinnate; *pulvinus* to 3.5 mm long, glabrous or with a few short, white hairs; *petiole* (above pulvinus) to 5 mm long but often less than 1 mm with leaves appearing almost sessile, ornamented by winged ridges, glabrous (or almost so), bearing a gland just below the basal pair of pinnae (or rarely just above the pulvinus), the gland oblong to broadly oblong or broadly elliptic, yellow-rimmed or red, glabrous, 1–2 mm long, 0.8–1.1 mm wide, with orifice depressed, 0.5–0.9 mm long and 0.2–0.3 mm wide; *rachis* (14–)25–85 mm long (sometimes absent), with winged ridges, almost glabrous with very sparse, short hairs, adaxial surface distinctly grooved, with a narrow longitudinal ridge often bearing a jugary gland just below terminal pair of pinnae (gland circular to broadly elliptic, very broadly obovate or sometimes ± rotund, glabrous, 0.7–1.8 mm long, 0.5–1.3 mm wide, with orifice 0.2–0.9 mm long and 0.1–0.4 mm wide), sometimes with similar jugary glands just below other pairs of pinnae towards apex of rachis, interjugary glands absent; *terminal seta* narrowly deltate, to 3 mm long, ± glabrous; *pinnae* (1–)3–10 pairs, (12–)25–45(–60) mm long, 7–15 mm wide, mostly ± perpendicular to rachis; *pinna-rachis* with very sparse short hairs, usually bearing a small, glabrous gland at base of terminal pair of pinnules (gland ± circular and 0.3–0.6 mm diam., with orifice to 0.2 mm diam.), rarely with similar small glands at base of other pairs of pinnules; *pinnules* 7–17 pairs, opposite or alternately arranged on pinna-rachis, well-spaced, not touching, oblong to narrowly oblong (sometimes almost cultrate), narrowly ovate to lanceolate, narrowly obovate or sometimes elliptic to narrowly elliptic, 2.6–9(–11) mm long, 0.9–3(–3.6) mm wide, glabrous or rarely with a few hairs, adaxial surface dark to mid-green, often slightly raised or keeled along midvein, abaxial surface paler, margin recurved, base asymmetric, apex acuminate or sometimes acute, 0.1–0.5 mm long. *Heads* globular, (6–)8–16-flowered, (5–)7–11 mm diam., pale yellow or pale cream-coloured, borne in axillary and terminal racemes or panicles to 33.5 cm long (arrangement often becoming panicle-like towards ends of the branches), the raceme axes winged, ± glabrous or sparsely puberulous/pubescent, with 8–41 heads; *peduncles* 5–17 mm long, sparsely to moderately puberulous; *bract* at base of peduncles broadly deltate, 1–1.5(–1.7) mm long, red-brown, becoming dark brown when dry, ciliolate, persistent; *bracteoles* dark brown, glossy, (0.7–)0.9–1.2 mm long, ± arrow-shaped or rhombic (similar to those in *A. kulnurensis*) (claw 0.1–0.5 mm long, usually broad and ciliolate; lamina 0.5–0.8 mm long, ciliate and with hairs similar to those on margin occurring at base of the outer surface). *Flowers* 5-merous; *calyx* 0.7–1.1 mm long, cupular, dissected for 1/8–1/3(–1/2) into very broad lobes, ciliolate with pale yellow or white hairs, with similar hairs at base and partly along midribs, with apex of lobes obtuse; *corolla* 2.1–2.5(–2.9) mm long, dissected for (1/2–)2/3 or to base, lobes narrowly ovate to lanceolate or sometimes ± narrowly elliptic, midrib prominent, apices of lobes acute, thickened, incurved, granulate or with a small tuft of minute white hairs on inside surface near tip; *ovary* glabrous. *Legumes* cultrate to linear, usually 60–120 mm long, 11–13(–15) mm wide, mostly straight-sided but sometimes irregularly constricted between seeds, usually curved, ± flat, slightly raised and sometimes rough over seeds, coriaceous, dull or slightly shiny, reddish brown or blackish brown, with fine, often obscure transverse veins (usually radiating from margin and incomplete), glabrous; margin pale, prominent. *Seeds* 6–11 arranged longitudinally or slightly oblique in the legume, 4.5–6 mm long, 3.3–3.9 mm wide, broad to very broadly ellipsoid or oblongoid, black; *areole* closed, same colour as rest of the seed, 2.5–3.8 mm long, 1.5–1.7 mm wide; *funicle* cream-coloured to fawn-coloured, filiform, expanded into a cap-like aril, prolonged along one side of seed. Fig. 1.

Distinguishing features: branchlets conspicuously winged by convoluted, narrow ridges 1–3 mm high; petioles and rachises also winged; bipinnate leaves almost sessile; interjugary glands absent; pinnules with margin recurved and apex acuminate or acute; flower-heads pale yellow or pale cream-coloured.

Flowering: December to May, possibly also later since old flowers occur in late August on *Constable s.n. NSW48881*. **Legumes:** developing from April, with mature legumes occurring around November. Old legumes without seed have been retained on plants in December, March and April.

Distribution: occurs in the vicinity of Howes Mountain (6–7 km NE of Howes Valley, E of Putty Road) and along Old Convict Road to Mount Murwin (c. 10 km ESE of Howes Valley), Hunter Range, Yengo National Park. Also recorded further north around Mount Isobel (Maryott-Brown and Wilks 1993). Locally occasional to scattered.

Habitat: grows on ridges and hillslopes, in sandy and sandy clay soils, on sandstone or at the junction of shale and sandstone, in woodland to open forest, with *Corymbia eximia*, *Eucalyptus piperita*, *E. punctata* and *Angophora costata*, with shrub understorey.

Etymology: the specific epithet refers to the winged branchlets, derived from Latin *alatus* (meaning 'winged') and *caulis* (meaning 'stem').

Conservation status: although the known populations of *Acacia alaticaulis* are protected in the Yengo National Park, the restricted distribution of the species will have management implications (see Maryott-Brown and Wilks 1993). *Acacia alaticaulis* is not listed as threatened under state or federal legislation but it has been recognised as a ROTAP taxon with the code 2RC-t, indicating it is 'rare', has a geographic range of less than 100 km, and the total known population occurs in a proclaimed reserved (Briggs and Leigh 1996).

Selected specimens examined: (c. 18 collections examined)**: New South Wales: Central Coast**: Howes Mountain, c. 6 miles [9.6 km] NE of Howes Valley, *Constable s.n.*, 26 Aug 1959 (AD, CANB, MEL, NSW48881, PERTH); Howes Mountain, 17 miles [27.4 km] S of Bulga, *Coveny s.n.*, 11 Feb 1968 (B, CBG, MO, NSW98531, PERTH); Howes Mountain, *Coveny 10209 & Seur*, 9 Sep 1978 (A, AD, BRI, CANB, HO, L, NSW, PERTH, US, Z); Putty Road, 27.5 km N of turnoff to Putty, *D'Aubert 425, Hind & Jones*, 5 Dec 1988 (NSW); 20.5 km S of intersection with Milbrodale Road on the Putty Road, *Johnstone 2300 & Orme*, 7 Dec 2007 (K, NSW, PERTH); Putty Road, 17.3 km N of the Macdonald River crossing, c. 6.5 km due NE of Howes Valley, western side of Howes Mountain, *Kodela 268 & James*, 16 Apr 1993 (CANB, NSW, PERTH), *Kodela 270 & James*, 16 Apr 1993 (CANB, MEL, NSW); W side of Howes Mountain, *Tame 2852*, 24 Nov 1990 (NSW).

Notes: *Acacia alaticaulis* differs from *A. terminalis* by the markedly winged branchlets, petioles and rachises (less pronounced winged ridges may occur in *A. terminalis*), shorter petioles to 5 mm long, markedly recurved pinnules (pinnules may be slightly recurved in *A. terminalis*) and usually smaller petiolar gland 1–2 mm long (1.2–12 mm long in *A. terminalis*). The possibility of intergrades or hybrids between these species requires further investigation. *Acacia alaticaulis* can be distinguished from *A. kulnurensis* by the winged branchlets, petioles and rachises, and almost glabrous branchlets and foliage, as well as often having shorter bracts at the base of the peduncles and slightly narrower legumes.

Some specimens are annotated with the earlier manuscript names *Acacia terminalis* subsp. *howensis* Tindale & Kodela and *A. howensis* Tindale & Kodela (both *in sched.*), where 'howensis' referred to the type locality Howes Mountain. Before publication the specific epithet was changed to the more suitable epithet 'alaticaulis' (referring to the distinct morphological feature of the winged branchlets) to avoid possible confusion with similarly named localities such as Lord Howe Island. *Acacia alaticaulis* has previously been cited as a manuscript name (eg in Maslin 2001, Kodela and Harden 2002: 467, Kodela 2013a; as *A. alaticaulis* Kodela & Tindale *ms.* (*Coveny 4108*) in the latter two references). The name was included in Pellow et al. (2009: 259) but not validly published there.

The collections, *Coveny 4108 & Bisby* (type) and *Constable s.n.*, 26 Aug 1959, are vouchers for a cyanogenesis survey undertaken by Maslin et al. (1990).

Acacia kulnurensis Kodela & Tindale, ***sp. nov.***

Acacia terminalis subsp. C (Maslin et al. 1990: 290), *p.p.* (excluding *M. Fox 7907028* and NSW55281)

Acacia terminalis s. lat. (Kulnura form) (Maryott-Brown and Wilks 1993: 14)

Acacia sp. 34 (Kulnura; *R.G. Coveny 4142 & R. Bisby*) (Briggs and Leigh 1996: 194)

Acacia sp. B (Kodela and Tindale 2001b: 222 & 223, fig. 6F–I)

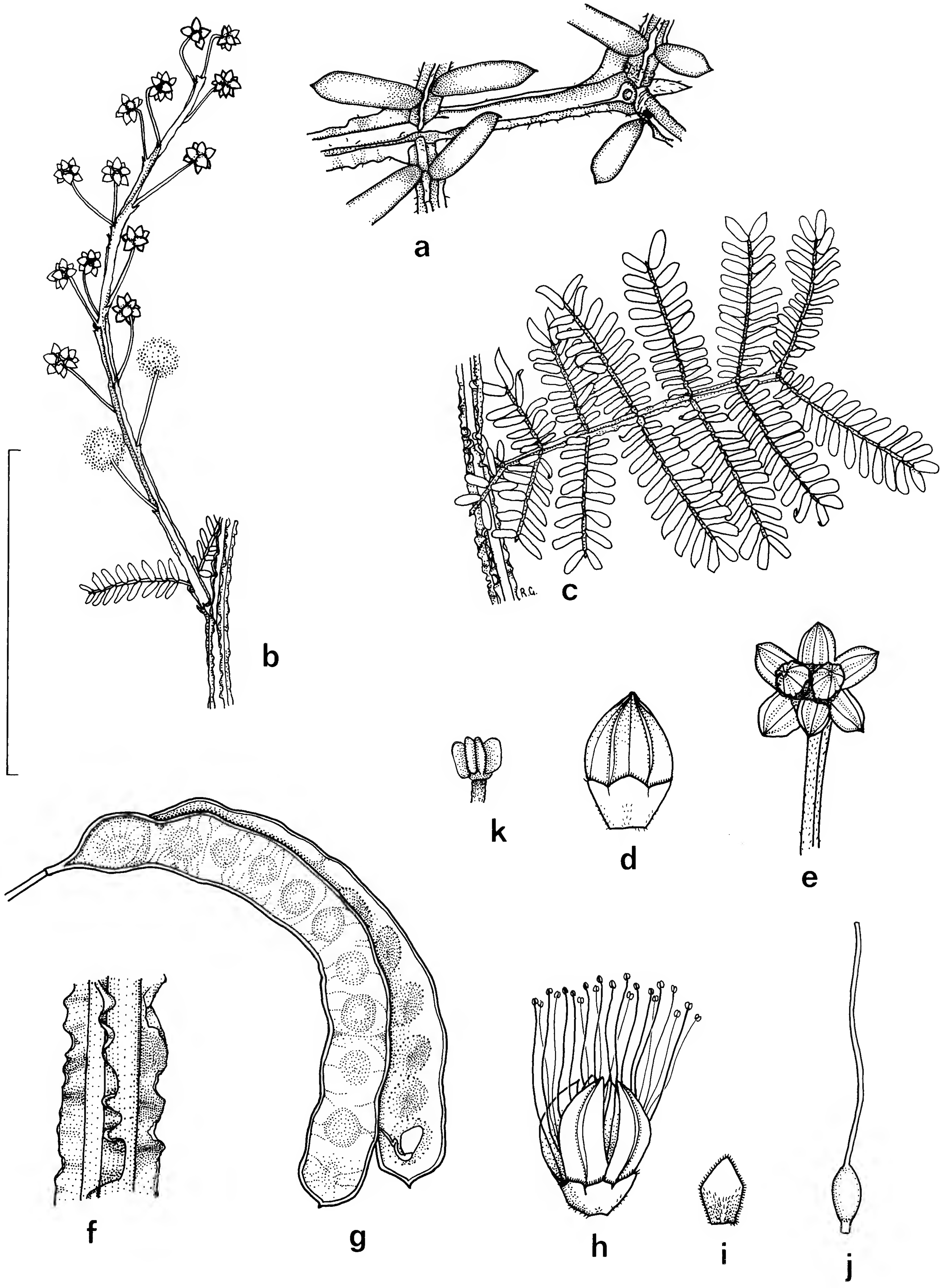

Fig. 1. *Acacia alaticaulis*: **a**, distal part of rachis; **b**, pseudo-raceme; **c**, leaf; **d**, bud; **e**, capitulum in bud; **f**, part of stem; **g**, legume; **h**, flower; **i**, bracteole; **j**, gynoecium; **k**, anther. Vouchers: a, c, f, g, *Constable s.n., NSW48881*; b, d, e, h–k, *Coveny s.n., NSW98531*. Scale bar: a, e = 12 mm; b, c, g = 60 mm; d, h–j = 6 mm; f = 20 mm; k = 1 mm.

Acacia sp. Kulnura (R.G. Coveny 4142) NSW Herbarium (APC 2013, APNI 2013)

Diagnosis: *Acacia kulnurensis* Kodela et Tindale, species nova, differt ab *A. terminali* (Salisb.) J.F.Macbr. foliis fere sessilibus, petiolis ad 0.5 cm longis, pinnulis valde recurvatis et petioli glandula parviore 0.7–1.6(–1.8) mm longa sed ab *A. alaticauli* ramulis, petiolis et rhachidibus non alatis et foliorum apicis juvenilibus dense pubescentibus pilis albis vel flavis statim diagnoscenda.

Type: New South Wales: Central Coast: 32.9 miles (53 km) c. S of Broke on the road to Kulnura, 1 mile (1.6 km) c. N of Bucketty, *R.G. Coveny 4142 & R. Bisby*, 27 Mar 1972 (holo: NSW106994; iso: A, AD, B, BRI, CANB, DNA, HO, K, L, MEL, MO, NSW826814, NSW826816, NSW977897, PERTH, RSA, U, UC, US).

Slender, spindly, bushy or spreading shrub or occasionally small tree to 4 m high, with branches often numerous and pendulous; *bark* smooth, grey or light brown. *Branchlets* angled, brown, grey-brown, reddish brown, reddish, pale green or blackish, sparsely to densely clothed with ± erect to spreading, white, fawn or yellowish hairs (often appearing in tufts) to 0.4(–0.6) mm long, with longitudinal ridges to 0.3(–0.4) mm high that are often red, red-brown or paler brown than rest of branchlet, not winged. *Young foliage-tips* densely pubescent with hairs yellow or sometimes white. *Leaves* bipinnate; *pulvinus* inconspicuous, to 2.5 mm long, pubescent; *petiole* (above pulvinus) to 5 mm long, often inconspicuous with the leaves appearing sessile or almost so, pubescent, bearing a gland just below the basal pair of pinnae or just above the pulvinus, the gland broadly oblong to circular, yellow, tan, orange-brown or red, glabrous, 0.7–1.6(–1.8) mm long, 0.5–1(–1.2) mm wide, with orifice depressed, 0.2–0.6 mm long and 0.15–0.4 mm wide; *rachis* (6–)25–85 mm long, pubescent with hairs similar to those on branchlets, adaxial surface grooved and with a longitudinal ridge often bearing a jugary gland at or near base of terminal pair of pinnae (gland to 1 mm below terminal pinnae, similar to petiolar gland but usually smaller, broadly elliptic, broadly oblong or circular, glabrous, 0.7–1(–1.2) mm long, 0.5–0.8 mm wide, with orifice 0.15–0.5 mm long and to 0.2 mm wide), rarely with a similar jugary gland at base of second pair of pinnae from apex, interjugary glands absent; *terminal seta* often recurved, narrowly deltate, to 3.2 mm long, glabrous or with sparse hairs; *pinnae* 3–13 pairs, 5–45 mm long, 6–14 mm wide (basal pair of pinnae sometimes much smaller than others), mostly ± perpendicular to rachis; *pinna-rachis* pubescent, often with a minute, circular to elliptic gland (to 0.4 mm long) at the base of the terminal pair of pinnules and rarely a similar gland at base of second pair of pinnules below the apex; *pinnules* (4–)6–15 pairs (opposite or sometimes alternately arranged on pinna-rachis), well-spaced, mostly not overlapping or touching, oblong to narrowly oblong, broadly elliptic to narrowly elliptic, lanceolate or ± narrowly obovate to oblanceolate, 2.5–8.5 mm long, 0.8–4 mm wide, midvein often faint or inconspicuous, adaxial surface dark to mid-green, often slightly raised or keeled along midvein (particularly towards base), abaxial surface paler, margin recurved, ciliate, base asymmetric to slightly asymmetrically cordate, apex conspicuously acuminate. *Heads* globular, 5–11-flowered, (5–)6–12 mm diam., cream-coloured to pale yellow, borne in axillary and terminal racemes (1–)2–6 times the length of the leaves or in panicle-like arrangements (usually at ends of branches), the raceme axes to 29 cm long, pubescent, with 3–45 heads (axes generally shorter and with fewer heads towards apex of branchlet); *peduncles* 4–15 mm long, pubescent; *bract* at base of peduncles broadly deltate, 0.8–2.3 mm long, ciliate or rarely glabrous (eg *NSW107951*), with a distinct midrib, persistent; *bracteoles* ± conspicuous, dark brown, glossy, 0.9–1.5 mm long, arrow-shaped (claw 0.1–0.5 mm long, 0.15–0.55 mm wide, ciliate; lamina usually narrowly to broadly ovate, (0.5–)0.7–1.35 mm long, densely ciliate with yellow hairs to 0.3 mm long and with similar hairs at base of the outer surface) (bracteoles variable, generally having a very short, wide claw expanding into a broadly ovate lamina or having a longer and narrower claw expanding into a narrowly ovate to ovate lamina). *Flowers* 5-merous; *calyx* 0.7–1.1(–1.4) mm long, cupular, dissected for 1/7–1/2, ciliate with pale yellow or white hairs to 0.2 mm long, with similar hairs at base and often along midribs, with apex of lobes acute to obtuse; *corolla* 1.9–2.8 mm long, dissected for c. 1/2 length or to base, lobes narrowly ovate to ± lanceolate, midrib prominent, apices of lobes acute, thickened, incurved and granulate or with a tuft of minute, white hairs on inside surface near tip; *ovary* glabrous. *Legumes* long-stipitate, narrowly oblong to linear, (30–)50–130 mm long, 11–17 mm wide, mostly straight-sided but sometimes irregularly constricted between seeds, straight or curved, ± flat, slightly raised and sometimes corrugated over seeds, coriaceous, dull, brown, brownish black, purplish brown or purplish black, with fine, often obscure transverse veins (usually radiating from margin and incomplete), glabrous; margin pale, prominent. *Seeds* (3–)5–12 arranged longitudinally or slightly oblique within legume, 4.5–6.5 mm long, 3–4.2 mm wide, oblongoid to broadly oblongoid or ellipsoid (sometimes broadly ellipsoid to almost rotund), black, dull to slightly shiny; *areole* closed, same colour as rest of the seed, flat or slightly depressed, 2.4–3.8 mm long, 1.1–1.7 mm wide; *funicle* cream-coloured to fawn-coloured, filiform, expanded into a cap-like aril, prolonged along one side of seed. Fig. 2.

Distinguishing features: almost sessile bipinnate leaves with small glands; indumentum of erect, white or pale yellow hairs similar on branchlets and foliage; branches and foliage have a yellowish, dull appearance, sometimes ± powdery (old herbarium specimens); pinnules with margin recurved and apex acuminate; flower-heads pale yellow.

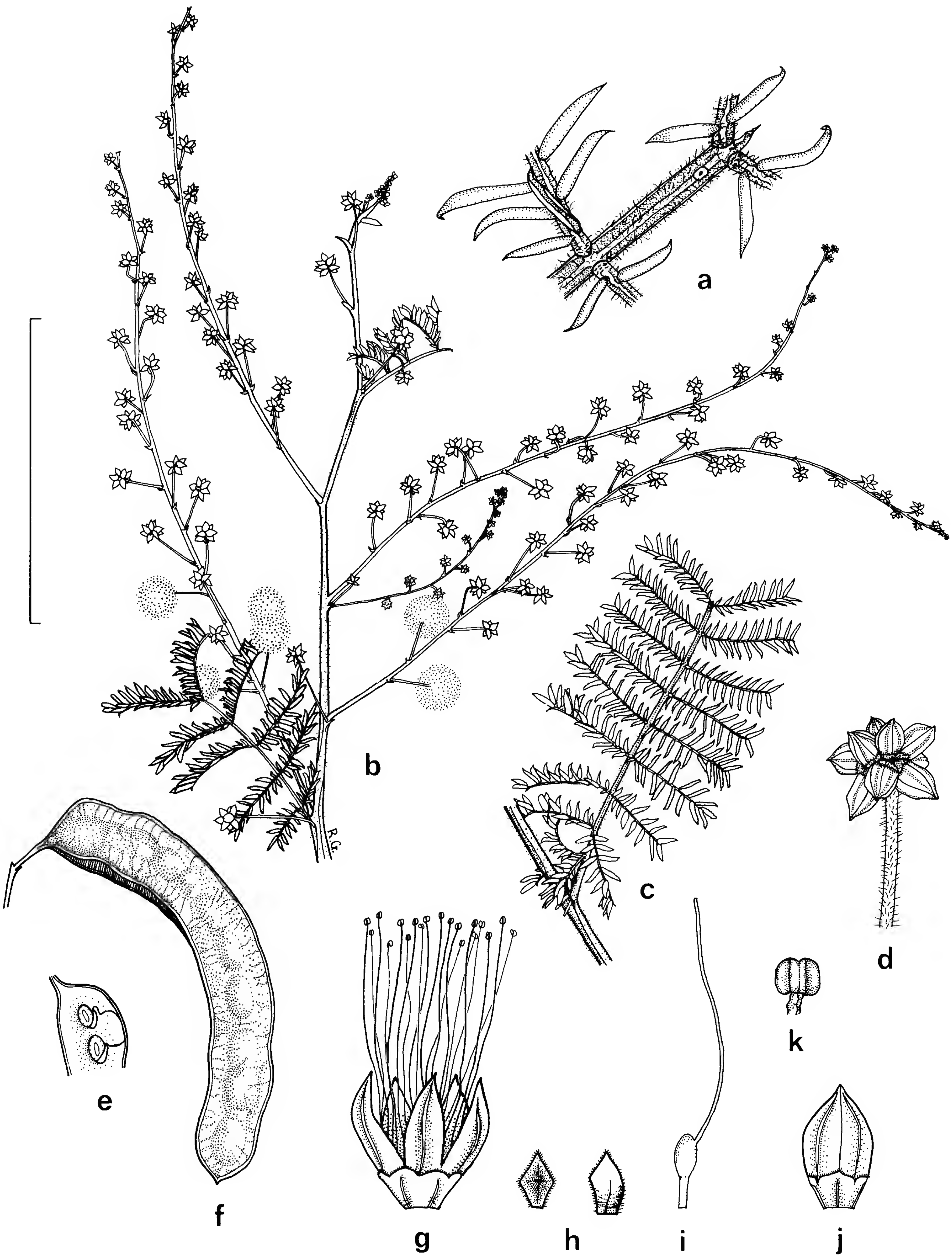

Fig. 2. *Acacia kulnurensis*: **a**, distal part of rachis; **b**, terminal part of branchlet with inflorescences; **c**, leaf ; **d**, capitulum in bud; **e**, seeds; **f**, legume; **g**, flower; **h**, bracteoles; **i**, gynoecium; **j**, bud; **k**, anther. Vouchers: a–d, g–k, *Coveny 4142 & Bisby*; e, f, *Ollerenshaw 143 & Muffett*. Scale bar: a, d = 12 mm; b, c, e, f = 60 mm; g–j = 6 mm; k = 1 mm.

Flowering: flowers from March to September with buds occurring from February. **Legumes:** starting to develop from April while plants still flowering; with mature seed occurring from September, but predominantly November to December.

Distribution: mainly in the Bucketty–Kulnura–Mangrove Mountain area in hilly country; common along the Wollombi and Settlers Roads between Mogo Creek and Bucketty (occurring c. 3 km N of Mogo Creek), and along roads (including George Downes Drive) between Bucketty, Kulnura and Mangrove Mountain (Central Mangrove area); occurring north to the Cessnock–Kurri Kurri area in the Hunter Valley. Locally occasional to frequent.

Habitat: grows in sandy soil on sandstone and sometimes in more loamy or clayey soil on softer rock lenses; often growing between sandstone boulders or on sandstone outcrops; prefers drier habitats on upper hillslopes and ridges above c. 200 m altitude; usually in dry sclerophyll forest or woodland, sometimes open woodland, with *Corymbia eximia*, *C. gummifera*, *C. maculata*, *Eucalyptus agglomerata*, *E. haemastoma*, *E. punctata*, *E. sieberi*, *E. squamosa*, *Angophora bakeri*, *A. euryphylla* and *A. costata*. Appears to colonise disturbed roadside areas in the Bucketty–Kulnura–Mangrove Mountain region. Grows in grey clay in *Eucalyptus crebra* forest near Kurri Kurri.

Etymology: the specific epithet refers to the occurrence of this species in the Kulnura area which includes the type locality.

Conservation status: *Acacia kulnurensis* has a restricted distribution (range < 100 km) and occurs in the Yengo National Park; most of the known distribution appears to be on the boundaries or outside the Park. Although not listed as threatened under state or federal legislation it has been recognised as a ROTAP taxon with the code 2RC, indicating it is 'rare' and has a geographic range of less than 100 km with at least one population occurring in a proclaimed reserved (Briggs and Leigh 1996).

Selected specimens (c. 28 collections examined)**: New South Wales: North Coast:** c. 1 km NE of Abernethy Pinnacle, Aberdare State Forest, *Bell s.n.*, 20 Feb 2001 (NSW472007); Elrington near Cessnock, *Harman s.n.*, 17 Nov 2009 (NSW797979); Ellalong (Maitland Pastoral Protection District), *Riley s.n.*, Sep 2012 (NSW974083); 3 km SE of Kurri Kurri, *Tame 78*, May 1978 (NSW); 2 miles [3.2 km] E of Kurri Kurri, *Tindale s.n.*, 30 Jun 1964 (CANB, NSW64670). **Central Coast:** near Old Northern Road turnoff on road to St Albans from Wollombi, *Bishop, Goodwin & James 678*, 15 Nov 1984 (NSW); Olney State Forest, 25 miles [40.3 km] SW of Newcastle, *Constable s.n.*, 26 May 1960 (AD, BRI, CANB, HO, NE, NSW56753, PERTH, UNSW, Z); Kulnura, 21 km WNW of Wyong, *Coveny 5846, Hind & Hancock*, 23 Nov 1974 (BRI, CANB, K, NSW, US), *Coveny 5852, Hind & Hancock*, 23 Nov 1974 (BRI, MEL, P, PERTH, Z); Kulnura, *Coveny 10200 & Seur*, 9 Sep 1978 (AD, BM, BRI, CANB, K, MEL, NSW, PERTH, Z); 3.1 km N of Greta Road intersection at Kulnura on George Downes Drive, *Johnstone 2264 & Orme*, 27 Nov 2007 (K, NSW); ridge N of Mogo Hill, c. 7.5 km due NE of Fernances, Yengo National Park, *Kodela 264 & James*, 16 Apr 1993 (CANB, MO, NSW, PERTH); Fernances–Mogo Creek–Bucketty road, c. 3 km N of Mogo Creek, Yengo National Park, *Kodela 265 & James*, 16 Apr 1993 (CANB, MEL, NSW); Mangrove Mountain, c. 3 km W of Central Mangrove, *Kodela 266 & James*, 16 Apr 1993 (CANB, NSW, UNSW); Walkers Ridge Forest Drive, Olney State Forest, *Kodela 267 & James*, 16 Apr 1993 (CANB, MEL, NSW, PERTH, Z); 2.5 miles [4 km] N of Fernances, toward Bucketty, *Ollerenshaw 143 & Muffett*, 5 Dec 1972 (CBG046029, NSW).

Notes: specimens of *Acacia kulnurensis* have sometimes been confused with *A. jonesii* F.Muell. & Maiden, which occurs further south in the vicinity of Bargo, Nowra and Goulburn. *Acacia jonseii* differs from *A. kulnurensis* by having small jugary glands at the base of all pairs of pinnae, pinnules ± concolorous with apex less acuminate, racemes flexuose to 6 cm long, flower-heads yellow to golden-yellow, ovary densely hairy and legumes smaller.

Acacia kulnurensis differs from *A. terminalis* by having almost sessile leaves with petioles up to 5 mm long, pinnules markedly recurved, and petiolar gland usually smaller, being 0.7–1.6(–1.8) mm long. Occasionally there are intermediate forms (eg in the areas of Boree, Fernances and Howes Range), which possibly represent intergrades or hybrids between these species. For example in the Yengo National Park: small tributary of Wellums Creek, between the Great North Road and Mogo Creek Road, *Bell & Vollmer s.n.*, 14 Apr 1993 (NSW270203); Devils Rock, Boree Track, Bala Range, *Wilks & Maryott-Brown s.n.*, 6 Mar 1993 (NSW270698). *Acacia kulnurensis* is most readily distinguished from *A. alaticaulis* by the unwinged branchlets, petioles and rachises, and the apex of the developing leaves being densely pubescent with white or yellow hairs.

The collections *Constable s.n.*, 26 May 1960, *Tindale s.n.*, 30 Jun 1964, and *Ollerenshaw 143 & Muffett* are vouchers for a cyanogenesis survey by Maslin et al. (1990).

Some specimens are annotated with the earlier name '*Acacia terminalis* subsp. *kulnurensis* Tindale & Kodela', *in sched.*, while '*A. kulnurensis*' has previously been cited as a manuscript name (eg in Maslin 2001, Kodela and Harden 2002: 467, Kodela 2013b; as *A. kulnurensis* Tindale & Kodela *ms.* (*Coveny 4142*) in the latter two references). The name was included in Pellow et al. (2009: 259) but not validly published there.

Key to distinguish *Acacia alaticaulis*, *A. kulnurensis* and *A. terminalis*

1a. Leaves with petiole mostly 5–43 mm long; pinnae (1 or)2–6(–8) pairs; pinnules ± flat or with margin slightly recurved; petiolar gland 1.2–12 mm long .... ***A. terminalis***

1b. Leaves almost sessile with petioles to 5 mm long; pinnae (1–)3–13 pairs; pinnules with margin markedly recurved; petiolar gland 0.7–1.6(–1.8) mm long 2

2a. Branchlets glabrous or very sparsely puberulous, conspicuously winged by convoluted, narrow ridges to 3 mm high; young tips of foliage reddish brown, almost glabrous or slightly puberulous, resinous; pinnules mostly glabrous; petioles and rachises winged; raceme axes ± glabrous or sparsely puberulous, winged .... ***A. alaticaulis***

2b. Branchlets sparsely to densely pubescent, with indistinct longitudinal ridges to 0.4 mm high (not winged); young tips of foliage densely pubescent with yellow or white hairs; pinnules ciliate; petioles and rachises not winged; raceme axes pubescent, not winged .... ***A. kulnurensis***

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Kylie Maryott-Brown, David Wilks, Jacqui Vollmer and Stephen Bell, formerly of the Bulga Sub-District of the New South Wales National Parks and Wildlife Service, kindly provided specimens and information on the distribution and ecology of these two species while undertaking rare plant and vegetation survey work in Yengo National Park. Field assistance and helpful comments were provided by Teresa James. Line drawings were produced by Robyn Griffiths. This work was supported by T.C. Chambers and B.G. Briggs (both NSW), and largely funded by the Australian Biological Resources Study (ABRS) and the Royal Botanic Gardens and Domain Trust Research Fund. I thank Peter Wilson and the referees for providing useful comments on the manuscript.

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Five new species of *Utricularia* (Lentibulariaceae) from Australia

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Abstract

Utricularia fenshamii R.W.Jobson, *U. ameliae* R.W.Jobson, *U. barkeri* R.W.Jobson, *U. grampiana* R.W.Jobson, and *U. lowriei* R.W.Jobson (Lentibulariaceae) are described as new and are considered members of *Utricularia* subg. *Polypompholyx* section *Pleiochasia*. The distribution and habitat preferences of these species are discussed. The morphological differences between all five species and species to which they are allied are here discussed and identification keys provided.

Introduction

The five species of the current study possess a two parted calyx, lack scales on their peduncles, and have bladder-traps with a single unbranched dorsal appendage. Therefore they are considered members of sect. *Pleiochasia* (subgen. *Polypompholyx*) (Jobson et al. 2003, Reut & Jobson 2010). All species described here (Figs 1–6, 8) are restricted to eastern Australia (Fig. 7).

Recognition as distinct species is supported by morphological data (this paper), and preliminary molecular phylogenetic results (Jobson et al., in prep.). All species, except for *U. lowriei* R.W.Jobson, were previously included in *U. dichotoma* Labill. (sensu lato), a species distributed across all Australian states except the Northern Territory (Taylor 1989). The main inflorescence characters differentiating these four new taxa from *U. dichotoma* are shape and size of the ridges located near the base of the corolla lower lip, and the consistently gibbous shape of the base of bracts and bracteoles in *U. dichotoma* (refer to 'Key to species of *Utricularia dichotoma* complex')

The fifth new species, *U. lowriei* (Figs 6, 8), was recently collected by the author north of Cooktown, Queensland (Fig. 7a). This new species shows close affinities to *U. antennifera* P.Taylor and *U. dunstaniae* F.E.Lloyd, both occurring in the Kimberley region of Western Australia, with the latter also collected near Darwin and on the Arnhem Land Escarpment, Northern Territory (Taylor 1989). All three species possess a single flowered inflorescence, apricot-coloured corolla with scrotiform spur, and a corolla lower lip consisting of five lobes (Reut and Jobson 2010). Of these five lobes, the lateral pair is erect and filiform, with the three central lobes either minutely deltoid or highly reduced and less than half the length of the spur in *U. antennifera* and *U. dunstaniae* (Taylor 1989); whereas in *U. lowriei* they are deeply lobed, capillary, and longer than the spur (Fig 6h). Two other Northern Territory species, *U. capilliflora* F.Muell. and *U. dunlopii* P.Taylor, have erect filiform corolla lobes, but in both cases these lobes arise from the corolla upper lip (Taylor 1989), and have evolved independently from one another (Reut and Jobson 2010) (refer to 'Key to Australian *Utricularia* species possessing an erect pair of capillary corolla lobes').

Herein five new taxa are named and compared with the morphology of related species, with notes on distinguishing characters, phenology, distribution and ecology, and conservation status. Taxonomic keys are provided for identification and terminology follows Taylor (1989).

Methods and Materials

Relevant dried and alcohol-preserved material representing synonymous taxa and related species, held at the National Herbarium of New South Wales (NSW), Queensland Herbarium (BRI), Australian National Herbarium (CANB), State Herbarium of South Australia (AD), and the National Herbarium of Victoria (MEL) were examined. Seed and pollen were examined using a standard compound microscope (magnification X40). Distribution maps used in Figure 7, and all associated data, were created and downloaded from the spatial portal of the Atlas of Living Australia web site (http://spatial.ala.org.au/). The specimens examined are summarised according to the following geographic regions: 'Pastoral Districts' of Queensland (Anonymous 1975), 'Botanical divisions' of New South Wales (Jacobs and Pickard 1981, modified from Anderson 1961), 'Natural regions' of Victoria (Conn 1993), 'Floristic regions' of South Australia (Jessop and Toelken 1986), and 'Natural regions' of Tasmania (Orchard 1988).

Taxonomy

1. *Utricularia fenshamii* R.W.Jobson *sp. nov.*

Diagnosis: This species differs from *U. dichotoma* with presence of bracts and bracteoles that are basally non-gibbous; corolla lower lip central ridge twice the length of neighbouring ridges.

Type: Australia: Queensland: Warrego: Yowah Creek Springs, Bundoona, NW of Eulo, (27.941°S,144.777°E), 30 Sep 2012, *R.W. Jobson 1523* (holo: NSW901605 iso: BRI, CANB).

Small to medium-sized perennial, terrestrial herb. Rhizoids capillary, simple, up to 20 mm long 0.1–0.3 mm thick, numerous from base of peduncle, with one or a few from nodes of stolon. Stolons few, filiform 0.2–0.3 mm thick, unbranched, up to 50 mm long, internode length c. 1 mm long, nodes slightly thickened. Leaves numerous, several from base of the peduncle and often in threes from stolon internodes, petiolate; lamina fleshy c. 0.15 mm thick, 0.2–0.5 mm wide, 3–8 mm long, linear to narrowly obovate, single nerve, apex rounded. Traps stalked, numerous at base of peduncle and up to three at nodes of stolon, ± uniform, ovoid, 1.5–2.5 mm long, mouth lateral, with an inward folding dorsal appendage simple 0.3–0.5 mm long, two lateral appendages somewhat flattened, laciniate on terminal margin, ventral wings laciniate. Inflorescence erect, solitary 80–250 mm long; peduncle terete, glabrous, hollow near base, 0.5–1 mm thick. Scales absent. Bracts and bracteoles c. 2 mm long, similar, basifixed, ovate-deltoid with apex acute. Flowers 2–4, often 3, rarely 1, in opposite pairs, occasionally on an elongated axis, pedicels erect, dorsiventrally flattened, 5–10 mm long. Calyx lobes unequal; upper lobe c. 3 mm long, 2.6 mm wide, ovate with apex rounded; lower lobe c. 2.5 mm long, 2.2 mm wide with apex emarginate. Corolla blue-violet; lower lip 6–10 mm long with three yellow raised ridges at base with central ridge twice the length of those immediately adjacent, bordered marginally by a whitish band, two white outer ridges c. equal in length to the adjacent yellow ridges. Lower lip with limb transversely elliptic, apex rounded, slightly 3-lobed, palate pubescent, with a marginal rim; spur whitish or violet, subulate, straight or weakly curved forwards near the apex, at 90° from, and slightly shorter than the lower-lip; upper lip c. 5 mm long, constricted at middle, at which point it is straight or reflexed to c. 30 degrees, superior part truncate with apex entire or slightly emarginate, inferior part ovate, ciliate on margin. Staminal filaments curved, c. 1.5 mm long, anther thecae subdistinct. Ovary ovoid, c. 1 mm long; style c. 0.8 mm long; stigma with lower lip semicircular, upper lip deltoid. Capsule globose, 2–4 mm diam.; walls thin, dehiscing by a single, ventral, longitudinal, weakly thickened slit. Seeds obovoid, c. 0.75 mm long, 0.3 mm wide. Pollen: 3-colporate, c. 30 × 30 µm (*Jobson 1523*, NSW901605) (Figs 1, 5a–b).

Specimens examined: Queensland: Warrego: Moorabinda, *Fensham 3510*, 28 Jan 1999 (BRI-AQ0665426); 'Bingara', W of Eulo, *Fensham 4070*, 28 Aug 2000 (BRI-AQ0491742); Tunga Spring, W of Eulo, *Jobson 1527*, 30 Sep 2012 (NSW901609); 'Werewilka', *Jobson 1668 & Cherry*, 14 Apr 2013 (NSW972811); **Mitchell**: Thomson River, *Birch s.n.*, anno c. 1875, (MEL90020A); **South Kennedy**: Carmichael River, NW of Clermont, *Fensham 3337*, 4 Feb 1998 (BRI-AQ0670427); Moses Spring Doongmabulla, *Fensham 3488*, 19 Aug 1998 (BRI-AQ0670264); 3 km S of Doongmabulla, *Thompson GAL9 & Simon*, 1 Apr 1992; **Cook**: Gamboola, N of Chillagoe, *Fensham 4435*, 26 May 2001 (BRI-AQ0498726); Soda spring on 'Gamboola', *Jobson 1946 & Quinn*, 7 Jul 2013 (NSW977122). **New South Wales: North Far Western Plains**: Peery Lake, *Holmes s.n.*, 16 Sep 1985 (NSW251159); Peery Lake, *Jacobs 4943*, 4 Nov 1986 (NSW251155); **North Western Plains**: Wee Waa, SW of Cuttabri on Cuttabri Road., *Jobson 1539*, 1 Oct 2012 (NSW901631). **South Australia: Lake Eyre**: Mt. Lyndhurst,

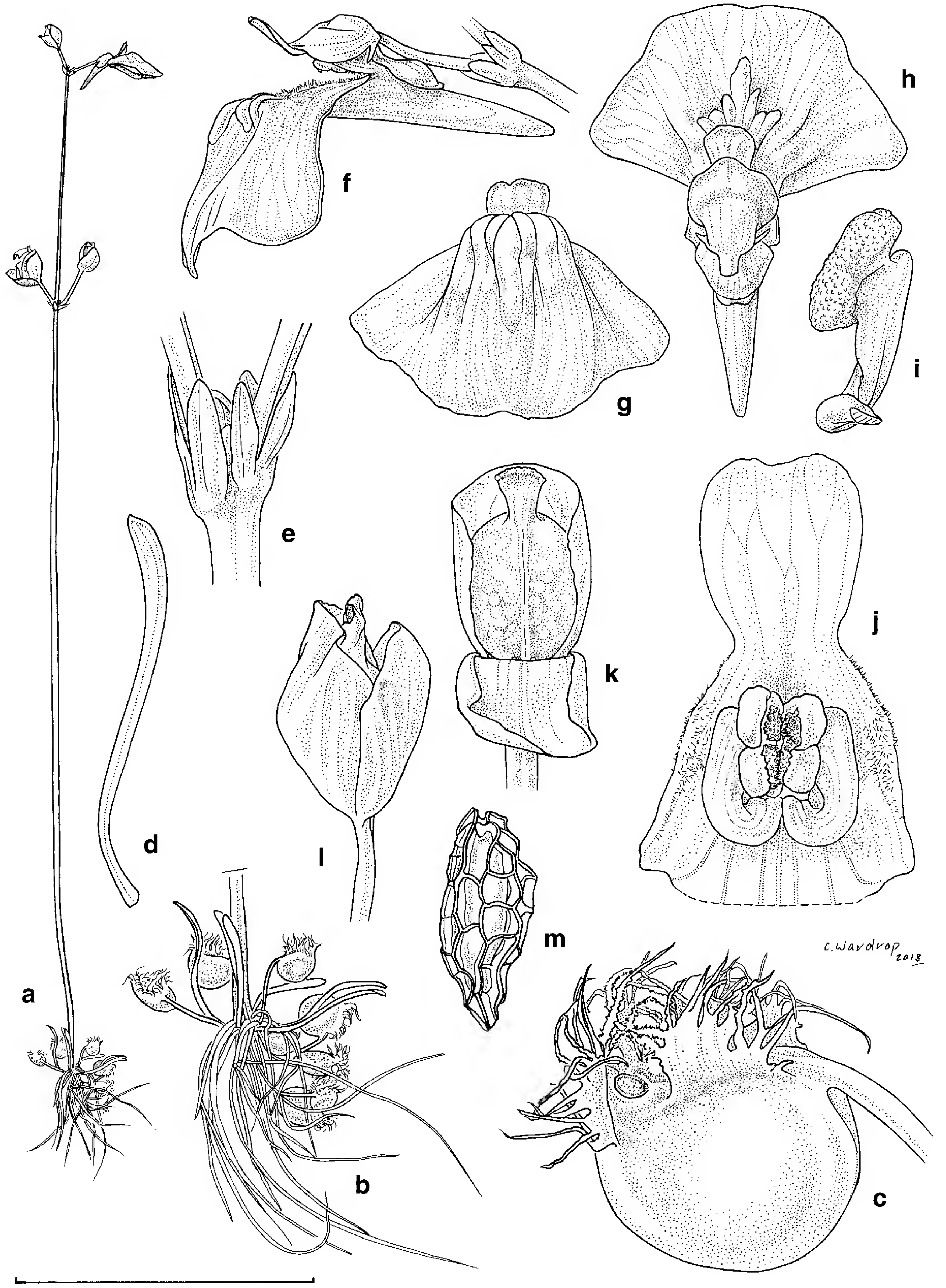

Fig. 1. *Utricularia fenshamii* **a**, habit; **b**, leaves and rhizoids at base of peduncle; **c**, bladder-trap in lateral view; **d**, leaf adaxial surface; **e**, bracts & bracteoles with pedicel base *in situ*; **f**, flower in lateral view; **g**, flower in frontal view; **h**, flower in dorsal view; **i**, stamen; **j**, upper lip with stamens; **k**, fruiting capsule showing suture ventral view; **l**, fruiting capsule and calyx lateral view; **m**, seed. Scale bar: a = 4.8 cm; b = 2 cm; c = 0.3 cm; d = 0.4 cm; f,g&h = 1 cm; i = 0.25 cm; j = 0.3 cm; k&l = 0.5 cm; m = 0.1 cm. Material used: a = R.W. Jobson 1523 (NSW901605); b-f,h-m = R.W. Jobson 1523 (spirit – NSW820786); g = photograph of type collection.

Koch s.n., Oct 1899 (AD97948389); Moolawatana Station, Twelve Springs, *Bell 1266*, 16 Sep1987 (BRI-AQ0467192); 10 km NW of Moolawatana, *Murfet 5807 & Duval*, 1 Oct 2007 (AD224111).

Etymology. The specific epithet refers to Associate Prof. Roderick Fensham of the School of Biological Sciences, The University of Queensland, and the Queensland Herbarium, who has contributed greatly to our knowledge of the biology and ecology of the mound springs distributed across the Great Artesian Basin.

Phenology. Flowers and fruits recorded from August until May. Seed-set has been observed in the following specimens: *Jobson 1523* (type), *Koch s.n, Bell 1266, Murfet 5807 & Duval, Jobson 1668 & Cherry, Fensham 4435.* Flowers do not seem to emit a detectable fragrance.

Distribution and Ecology. Australia: apart from a single non-mound spring collection (*Jobson 1539*) west of Wee Waa in New South Wales, this species is restricted to wetlands associated with discharge mound springs across the Great Artesian Basin. The most southerly locations are in South Australia near Mt Lyndhurst, halfway between Lakes Frome and Eyre at 30.1°S (Alt. 150 m), and in New South Wales at Lake Peery at 30.7°S (Alt. 90 m). The remaining distribution is scattered across the central Queensland districts of Warrego, Mitchell, South Kennedy, and a single site in Cook north of the Mitchell River at Gamboola 16.6°S (Fig. 7a). The first collecting locality was the Thompson River c. 100 km SW of Longreach within the Mitchell Grass Downs bioregion. A specimen from this locality was collected by C.W. Burgh de Birch (circa 1871) and was sent to Ferdinand von Mueller as "*Utricularia*" *sp.* until determined as *U. dichotoma* by Peter Taylor in 1985. The site description is vague – "Thomson River", and probably refers to an extinct or active mound spring site NE of Longreach on the upper reaches of the Thomson River.

This species is locally common, inhabiting permanent to semi-permanent wetlands fed by artesian discharge springs. Populations are often found in association with the sedges *Cyperus laevigatus* L. and *Fimbristylis* sp., and other spring endemics *Myriophyllum artesium* Halford & Fensham and *Eriocaulon carsonii* F.Muell. (Westbrooke *et al.* 2003; Fensham and Price 2004).

Conservation Status. *Utricularia fenshamii* has a large distribution across the seasonally arid regions of the Great Artesian Basin (Fig. 7a). This distribution is extremely scattered with the shortest distance between a set of sites c. 280 km (*Jacobs 4943* and *Jobson 1527*), while the furthest distance between two closest sites is c. 660 km (*Fensham 3337* to *Fensham 4435*). At the local level *U. fenshamii* is restricted to small clusters of artesian spring habitats (Fig. 7a). Most of the collections were made on leasehold land, but the spring wetlands are protected under EPBC legislation and Peery Lake is in the Paroo-Darling National Park. The population in the North Western Plains near Wee Waa NSW (*Jobson 1539*) exists in an ephemeral shallow swampy depression, in open *Casuarina cristata* Miq. dominated woodland. This non protected site is situated on private property approx. 4 km north of the Piliga East State Forest boundary.

There is a strong prima-facie case that this species satisfies IUCN Red List criteria (IUCN 2001) for listing as a Vulnerable species, under both Commonwealth legislation and that of the States of occurrence. To more definitively determine conservation status, future work should include a population assessment that examines levels of genetic isolation, also looking at relationships within and between the sites, and levels of divergence from closely related taxa.

2. *Utricularia ameliae* R.W.Jobson *sp. nov.*

Diagnosis: This species differs from *U. dichotoma* with presence of bracts and bracteoles that are basally non-gibbous; spur tapers to an acutely bifid apex; white corolla upper lip.

Type: Australia: Queensland: Gregory North: Elizabeth Springs, S of Boulia, (23.33°S, 140.58°E), 15 April 2013, *R.W. Jobson 1694 & W.A. Cherry* (holo: NSW972812; iso: CANB).

Small perennial, terrestrial herb. Rhizoids capillary, simple, often flattened, up to 20 mm long 0.1–0.3 mm thick, numerous from base of peduncle, with three or six from nodes of stolon. Stolons numerous, filiform, 0.3–0.5 mm thick, unbranched, up to 20 mm long, internode length c. 5 mm long. Leaves numerous, several from base of the peduncle and 4–6 from stolon internodes, petiolate; lamina fleshy c. 0.15 mm thick, 0.4–2.5 mm wide, 4–10 mm long, narrowly ovate to obovate, 1 or 3–6-nerved, apex rounded. Traps several at base of peduncle and up to three at nodes of stolon, stalked 1.5–2.5 mm long, ovoid, surface glandular, 1.6–4.5 mm long, mouth lateral, with dorsal appendage simple 0.7–1.5 mm long, two lateral appendages shorter, simple or flattened and laciniate, ventral wings usually absent, or if present, then laciniate. Inflorescence erect, solitary 50–110 mm long; peduncle terete, glabrous, hollow, 0.3–0.6 mm thick. Scales absent. Bracts c. 0.9 mm long, bracteoles c. 0.6 mm long, similar, basifixed, originating from a circumscissile bulge, deltoid with apex acute. Flowers 1, pedicels erect, often with a single twist, dorsiventrally flattened, 4–8 mm long. Calyx lobes unequal; upper lobe c. 3 mm long, 2.2 mm wide, obovate with apex rounded; lower lobe c. 2.5 mm long, 2.2 mm, ovate with apex emarginate. Corolla dark-violet; lower lip 5–9 mm long, reniform or transversely oblong, apex rounded with three yellow strongly raised ridges at base, bordered by two white/yellow outer ridges, sometimes equal length to the three central ridges, with the central ridge slightly shorter than those immediately adjacent, palate glandular, with a marginal rim; spur whitish, narrowly subulate from a short conical base, tapering to an acutely bifid apex, curved forwards near the middle, sharply so near the apex, shorter than the lower-lip; upper lip c. 9 mm long, constricted at middle, at which point it is reflexed outward to c. 45 degrees, superior part emarginate or bilobed, inferior part obovate, glandular on margin. Staminal filaments curved, c. 2 mm long, anther thecae confluent, surface glandular. Ovary ovoid, c. 1 mm long; style c. 1 mm long; stigma with lower lip semicircular, upper lip deltoid. Capsule globose, c. 4 mm diam.; walls thin, dehiscing by a single, ventral, longitudinal, marginally thickened slit. Seeds obovoid, c. 0.7 mm long, 0.3 mm wide. Pollen: 4-colporate, c. 27 × 27 µm (*Jobson 1694 & Cherry*, NSW972812) (Figs 2, 5c–d).

Specimens examined: Queensland: Gregory North: Elizabeth Springs, Springvale Homestead. *Wilson 103*, 20 May 1994 (BRI-AQ0628041); *Fensham 3671*, 24 Feb 1999 (BRI-AQ0679274).

Etymology. The specific epithet refers to Miss Amelia Pieternella Jobson, plant enthusiast and daughter of the author.

Phenology. Flowers and fruits recorded from February until May. Seed-set has been observed in the following specimens: *Jobson 1694* (type). Flowers emit a faint sweet fragrance.

Distribution and Ecology. Australia: situated in the Diamantina River Catchment on the flood-plain of Spring Creek. Elizabeth Springs forms part of the Springvale group of artesian discharge springs about 100 km SE of Boulia (Fig. 7a). The associated spring wetland is approximately 1600 m^2 in area (pers. observation), consisting of about 40 active springs (ANCA, undated; Fensham *et al.* 2010).

Although *U. ameliae* is locally common, it has only been collected from Elizabeth springs. A population of '*Utricularia dichotoma*' was previously recorded from a spring on Warra Station, c. 40 km N of the Elizabeth springs (R. Fensham pers. communication), although no collection was made. To determine whether this is an extension of range for *U. ameliae*, future fieldwork should attempt to collect a specimen from Warra Station, and locate additional populations in other nearby regions known to contain Artesian springs.

Colonies of *U. ameliae* are scattered throughout the permanently wet sedgeland bog habitat (Fensham *et al.* 2004, 2010). Colonies are found in association with *Cyperus laevigatus, Eragrostis fenshamii* B.K.Simon, *Fimbristylis sp., Myriophyllum artesium, Eriocaulon carsonii* subsp. *carsonii and Utricularia caerulea.*

Conservation Status. The Elizabeth Springs wetland is a Conservation Reserve and the community is protected under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (Australian Government [2010]; Fensham *et al.* 2010). *Utricularia ameliae* forms small flowering colonies that are scattered across the northern half of the springs. On the 15th April 2013 a survey estimated that at least 5% of the wetland vegetation was affected by fresh pig damage (pers. obs.). The species should be listed as endangered in Queensland. This species appears to satisfy the IUCN (2001) Red List criteria for listing as an Endangered species – criteria B1 (EOOa), B2 (AOOa) and C (population size EN, and C1). Further study is required to more definitively determine threats and conservation status.

3. *Utricularia barkeri* R.W.Jobson *sp. nov.*

Diagnosis: This species differs from *U. dichotoma* with presence of basiolute bracts with upper and lower lobes of ±equal length; corolla upper lip light mauve with purple flecks.

Type: Australia: Victoria: Wannon: Casterton, S on Casterton-Dartmoor Road, (37.713°S, 141.309°E), 26 Nov 2012, *R.W. Jobson 1621 & R.P. Gibson* (holo: NSW905026; iso: AD, MEL).

Small to medium-sized perennial, terrestrial herb. Rhizoids capillary, simple, up to 20 mm long 0.2–0.4 mm thick, numerous from base of peduncle, with usually two from stolon nodes. Stolons few, filiform 0.3–0.5 mm thick, unbranched, up to 100 mm long, internode length c. 4 mm long. Leaves few, rarely from base of the peduncle and often in one or two from stolon internodes, petiolate; lamina 0.2–0.6 mm wide, 3–12 mm long, linear to narrowly obovate, single nerve, apex rounded or sometimes subulate. Traps stalked, few at base of peduncle and one or two at nodes of stolon, uniform, ovoid, 1.5–2.0 mm long, mouth lateral, with a small dorsal appendage simple 0.2–0.4 mm long, two lateral appendages folded inward, flattened, laciniate, ventral wings large, margin entire or laciniate. Inflorescence erect, solitary 80–280 mm long; peduncle terete, glabrous, ± solid, 0.5–1.5 mm thick. Scales absent. Bracts and bracteoles c. 1.1 mm long, similar, basiolute, upper and lower bract parts c. equal length; upper part ovate-deltoid with apex rounded, lower truncate. Flowers usually 2 in opposite pair, sometimes 1 or 3, pedicels erect, dorsi-ventrally flattened, 3–7 mm long. Calyx lobes ± equal; upper lobe c. 2.5 mm long, 2.5 mm wide, ovate with apex rounded; lower lobe

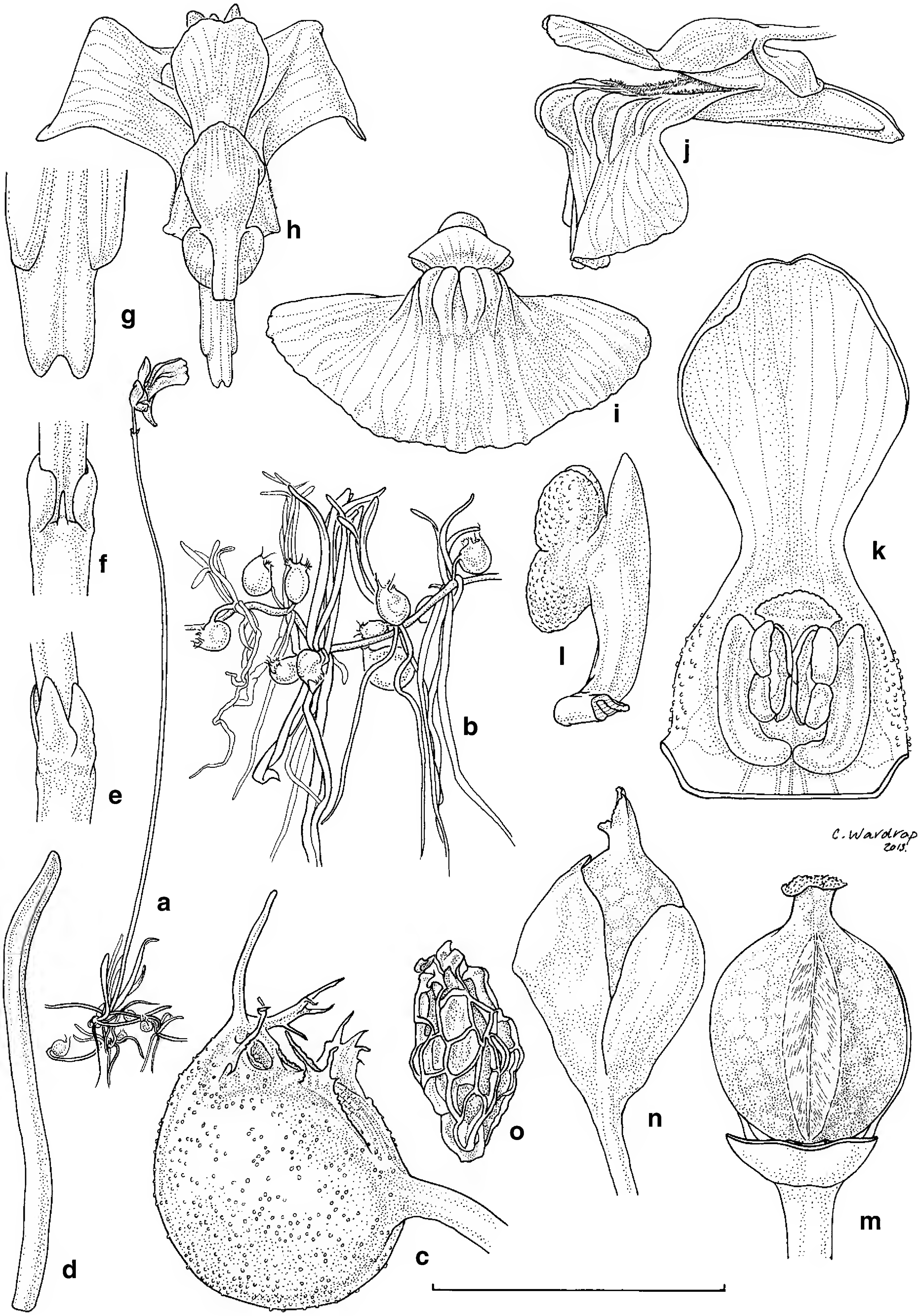

Fig. 2. *Utricularia ameliae* **a**, habit; **b**, stolon nodes - leaves, traps, rhizoids; **c**, bladder-trap in lateral view; **d**, leaf; **e**,**f**, bracts & bracteoles with pedicel base *in situ*; **g**, spur apex adaxial surface; **h**, flower in dorsal view; **i**, flower in frontal view; **j**, flower in lateral view; **k**, upper lip with stamens; **l**, stamen; **m**, fruiting capsule showing suture ventral view; **n**, fruiting capsule and calyx lateral view; **o**, seed. Scale bar: a = 4.8 cm; b = 2 cm; c&g = 0.3 cm; d = 0.6 cm; e,f&k = 0.4 cm; h, i & j = 1 cm; l,m&n = 0.25 cm; o = 0.1 cm. Material used: a-o = R.W. Jobson 1694 (spirit – NSW824653).

c. 2.5 mm long, 2.5 mm wide with apex emarginate. Corolla light mauve; lower lip limb transversely elliptic, apex rounded, 5–12 mm long with 2 raised yellow central ridges at base, not projecting apically beyond the purple ridge on either side, bordered marginally by a thick purple band; palate pubescent, with a marginal rim; spur cylindrical, straight, emarginate with broadly rounded lobes at the base, mauve, reddish nearer the base, about 90° from lower lip, 1/3 shorter than the lower-lip; upper lip very light mauve with purple flecks c. 3.5 mm long, constricted at middle, straight or slightly curved upward, superior part ovate with apex entire, inferior part ovate, ciliate on margin. Staminal filaments curved, c. 1.6 mm long, anther thecae confluent. Ovary ovoid, c. 1 mm long; style c. 0.6 mm long; stigma with lower lip semicircular, upper lip deltoid. Capsule globose, 3–3.5 mm diam.; walls thin, dehiscing by a single, ventral, longitudinal, none-thickened slit. Seeds obovoid, c. 0.5 mm long, 0.3 mm wide. Pollen: 4-colporate, c. 28 × 28 µm (*Jobson 1621*, NSW905026) (Figs 3, 5e–f).

Specimens examined: Victoria: Wannon: Casterton, *Cunningham 298*, 10 Dec 1990 (AD99108060); Cobboboonee State Forest, on Heath Rd, S of Fitzroy River, *Jobson 1623 & Gibson*, 26 Nov 2012 (NSW905044); Lower Glenelg National Park, Kentbruck heath, *Entwisle 2077*, 31 Oct 1991 (MEL2018742): **Lowan Mallee**: Little Desert, 26 km S of Nhill PO, *Beauglehole 66380*, 9 Nov 1979 (MEL1564768): **Grampians:** The Grampians, 34 km S of Hall Gap, *Nordenstam 1165 & Anderberg*, 9 Oct 1989 (AD99149025); Grampians (Gariwerd) National Park, *Murfet 4540*, 26 Nov 2003 (AD156542): **Gippsland Plain**: Melbourne suburb of Wantirna, Sheppard's Bush near Dandenong Creek, *Paget 184*, 19 Oct 1985 (MEL683614); Langwarrin Flora Reserve, *Beauglehole 71246 & Elmore*, 8 Nov 1982 (MEL1564696). **Tasmania: Furneaux Group**: Flinders Island, east of Ragged Peaks, in conservation area, *Whinray 12288*, 25 Nov 2004 (MEL2316276A); **North West**: Mouth of the Harcus River, *Buchanan 8909*, 26 Dec 1986 (HO405716); 18 km SE of Balfour, *Murfet 5895*, 30 Dec 2007 (AD216550); **West Coast**: SW of Reece Dam, *Gray 1621*, 11 Dec 2005 (HO 537157). **South Australia: Kangaroo Island**: Larrikin Lagoon, Flinders Chase, *Jackson 3197*, 29 Nov 1994 (AD99617231); **South-eastern**: Marsh's Swamp, c. 45 km NE of Mt Gambier, *Wilson 924*, 26 Oct 1968 (AD96936371); Berkins Forest Reserve, NE of Penola, *Murfet 4576*, 2 Dec 2003 (AD156382); Mount Lyon Perch Swamp, *Murfet 5123*, 28 Dec 2005 (AD190630); Island swamp heath, Native Forest Reserve via Nangwarry, *Bates 66786*, 2 Nov 2005 (AD192773).

Etymology. The specific epithet refers to Dr William (Bill) R. Barker, former Chief Botanist of the State Herbarium of South Australia (AD), who has made significant contributions to Australian botany with studies of Australasian Scrophulariaceae and various other families. In the mid 1980's Dr. Barker provided the framework for the description of the current species by way of annotating the substantial AD collection of *U. dichotoma*, differentiating *U. barkeri* from the latter based mainly on the presence of "medifixed" bracts.

Phenology. Flowers and fruits recorded from October until January. Seed-set has been observed in the following specimens: *Jobson 1621 & Gibson*, *Jobson 1623 & Gibson*, *Beauglehole 71246 & Elmore*, *Murfet 4576*, *Nordenstam 1165 & Anderberg*. Flowers do not seem to emit a detectable fragrance.

Distribution and Ecology. Australia: distributed on flat coastal areas of South Australia, Victoria, and west coast Tasmania usually at or near sea level. On Kangaroo Island (South Australia), Flinders Islands (Tasmania), and within the Grampians (Gariwerd) National Park (Victoria), it is found at higher elevations (alt. 150–250 m) (Fig 7b). *Utricularia barkeri* occupies coastal ephemeral sedge swampland and heath soakage on deep sand. Often found growing with *Utricularia dichotoma* sensu lato (pers. observation)

Conservation Status. *Utricularia barkeri* has a broad distribution across South Australia, Victoria and Flinders Island and the west coast of Tasmania. In South Australia populations are protected within the Flinders Chase National Park on Kangaroo Island (*Jackson 3197*), and north of Mt Gambier collections represent populations protected within the Penola Forest and Mt Burr Forest Reserves (*Murfet 4576*, *Bates 66786*). In Victoria a collection was made within the Grampians (Gariwerd) National Park near Glenisla Crossing (*Murfet 4540*), in addition to several collections representing protected populations within the Lower Glenelg National Park and adjacent Coboboonee State Forest (*Entwisle 2077*, *Jobson 1623*). In Tasmania a population is known to be protected within the Arthur Pieman Conservation Area, SE of Balfour (*Murfet 5895*).

4. *Utricularia grampiana* R.W.Jobson *sp. nov.*

Diagnosis: This species differs from *U. dichotoma* with presence of basiolute bracts with upper lobes about twice the length of lower; corolla upper lip cream with purple flecks.

Type: Australia: Victoria: Grampians: Mt William, Mt William Road, entrance to carpark, (37.287°S, 142.593°E), 27 Nov 2012, *R.W. Jobson 1630* & R.P. Gibson (holo: NSW; iso: AD, MEL).

Small to medium-sized probably annual, terrestrial herb. Rhizoids capillary/flattened, simple, up to 15 mm long 0.3–0.4 mm wide, numerous from base of peduncle, with one or two from nodes of stolon. Stolons few, flattened or cylindrical 0.1–0.2 mm wide, branched, up to 20 mm long, internode length c. 4 mm long. Leaves numerous, a rosette of leaves forming the base to the peduncle, and often one or occasionally two from stolon internodes, petiolate; lamina fleshy c. 0.8 mm thick, 1–1.4 mm wide, 1.5–6 mm long, obovate, ovate

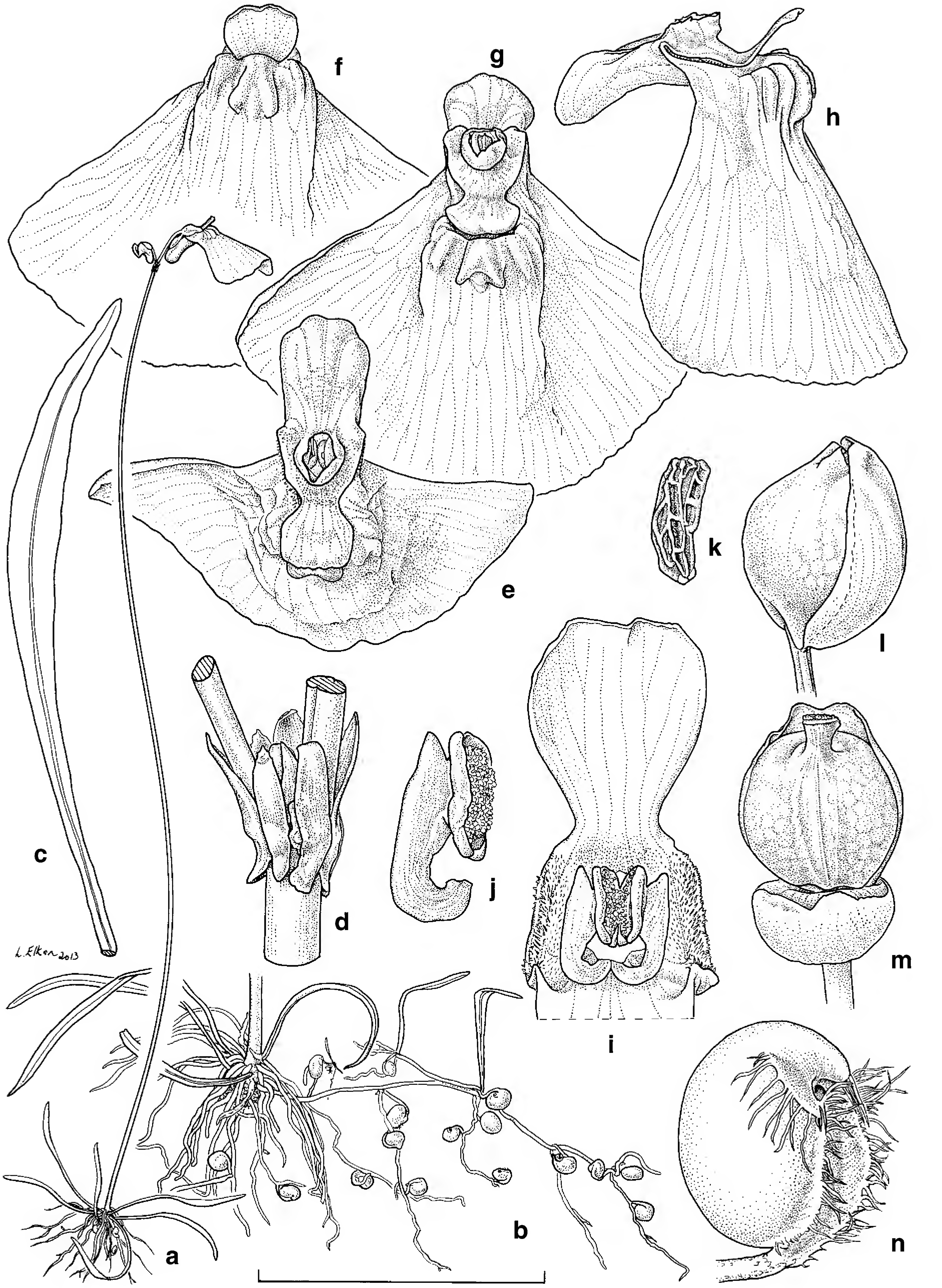

Fig. 3. *Utricularia barkeri* **a**, habit; **b**, peduncle base & stolon nodes - leaves, traps, rhizoids; **c**, leaf; **d**, bracts & bracteoles with pedicel base *in situ*; **e**, flower in dorsal view; **f**, flower in frontal view; **g**, flower in ¾ frontal view; **h**, flower in lateral view; **i**, upper lip with stamens; **j**, stamen; **k**, seed; **l**, fruiting capsule and calyx lateral view; **m**, fruiting capsule showing suture ventral view; bladder-trap in lateral view. Scale bar: a = 4 cm; b = 2 cm; c,l&m = 0.6 cm; c = 0.3 cm; d&i = 0.4 cm; e-h = 0.1 cm; j = 0.25 cm; k = 0.1 cm; n = 0.2 cm. Material used: a = R.W. Jobson 1621 (NSW905026); b-n = R.W. Jobson 1621 (spirit – NSW824604).

or spatulate, single nerve, apex rounded. Traps stalked, few at base of peduncle and two at nodes of stolon, ± uniform, ovoid, 1.1–1.7 mm long, mouth lateral, with a dorsal appendage simple 0.8–1.3 mm long, two lateral appendages truncate, flattened, laciniate on terminal margin, ventral wings splayed outwards, fimbriate margins. Inflorescence erect, solitary 60–190 mm long; peduncle terete, glabrous, 0.5–1 mm thick, often curved near apex. Scales absent. Bracts and bracteoles c. 6 mm long, similar, basiolute, upper bract part approximately twice the length of lower; upper part lanceolate-deltoid with apex subulate, lower part truncate. Flowers 1 or 2 (or 3), when 2 then in opposite pair, pedicels usually curved, sometimes erect, cylindrical, 5–15 mm long. Calyx lobes subequal; upper lobe c. 2.5 mm long, 1.5 mm wide, truncate; lower lobe ovate c. 2.5 mm long, 2.5 mm wide with apex emarginate. Corolla light mauve; lower lip limb transversely elliptic, apex rounded, 4–10 mm long with 2 strongly raised yellow central ridges at base, projecting apically beyond the purple ridge on either side, each hooked near the apex, bordered marginally by a thick purple band; palate pubescent, with a marginal rim; spur cylindrical, curved forward at middle, broadly rounded, reddish green, about 90° from lower lip, shorter than the lower-lip; upper lip cream-coloured with purple flecks, c. 3 mm long, constricted at middle, at which point it is reflexed to c. 30 degrees, superior part ovate with apex entire, inferior part ovate, ciliate on margin. Staminal filaments curved, c. 1 mm long, anther thecae confluent. Ovary ovoid, c. 1 mm long; style c. 0.5 mm long; stigma with lower lip semicircular, upper lip obtuse. Capsule globose, 4 mm diam.; walls thin, dehiscing by a single, ventral, longitudinal, marginally thickened slit. Seeds broadly obovoid, c. 0.25 mm long, 0.2 mm wide. Pollen: 4, 5-colporate, c. 30 × 30 µm (*Jobson 1630*, NSW905060) (Figs 4, 5g–h).

Specimens examined: Victoria: Grampians: Mt William, SSE of Halls Gap, *Streimann 3088*, 15 Dec 1975 (CBG63857); Grampians National Park, Devils Gap from Sundial carpark, *Murfet 4536 & Lowrie*, 26 Nov 2003 (AD156538); Western district, Black Range, *Bates 40042*, 25 Nov 1994 (AD9961317); Stoney Creek, between Wonderland carpark and Cascades, *Jobson 1633 & Gibson*, 27 Nov 2012 (NSW905088): **Midlands**: Mt Langi Ghiran; on flats at foot of steep north facing slopes, *Corrick 7505*, 31 Oct 1981 (MEL603620).

Etymology. The specific epithet refers to the Grampians National Park (Gariwerd) located in Victoria's western highland region.

Phenology. Flowers and fruits recorded from October to January. Material from the type location was cultivated in Sydney and flowered May–September 2013. Seed-set has been observed in the following specimens: *Bates 40042*, *Jobson 1630* and *1633*: Flowers emit a detectable sweet fragrance.

Distribution and Ecology. Australia: thus far restricted to high elevation (alt. 400 – 1170 m) on sandstone seepages in the Mt Difficult and Mt William Ranges within the Grampians National Park (Gariwerd), and in similar habitat at Mt Langi Ghiran c. 10 km E of Ararat (Fig. 7b). Usually forms small colonies among mosses and sedges in seepage areas on rock platforms.

Conservation Status. Within Victoria *Utricularia grampiana* has a restricted distribution, all recorded collections represent populations protected within the Grampians National Park, and Langi Ghiran State Park.

Key to species of *Utricularia dichotoma* complex.

1a. Bracts and bracteoles basiolute; corolla upper lip cream/light mauve with purple flecks **2**

1b. Bracts and bracteoles basifixed; corolla upper lip uniformly white or mauve/purple **3**

2a. Bract upper and lower lobes ±equal length; corolla lower lip 2 yellow central ridges not projecting apically beyond ridges on either side .... ***U. barkeri* (SA, Vic, Tas)**

2b. Bract upper lobes about 2× length of lower; corolla lower lip 2 yellow central ridges projecting apically beyond ridges on either side ....***U. grampiana* (Vic)**

3a. Spur subulate, conical at base, tapering to an acutely bifid apex, corolla upper lip white .... ***U. ameliae* (Qld)**

3b. Spur straight, cylindrical from the base, apex truncate to subulate, corolla upper lip purple/mauve **4**

4a. Corolla lower lip central palate ridge 2× longer than neighbouring ridges .... ***U. fenshamii* (SA, NSW, Qld)**

4b. Corolla lower lip central palate ridge equal or shorter than neighbouring ridges **5**

5a. Corolla lower lip with 4–11 conspicuous yellow central ridges, bracts and bracteoles non-gibbous at base .... ***U. beaugleholei* (SA, Vic, NSW)**

5b. Lower corolla lip with 2–3 conspicuous yellow central ridges; bracts and bracteoles gibbous at base .... ***U. dichotoma* s. lat. (All states except NT)**

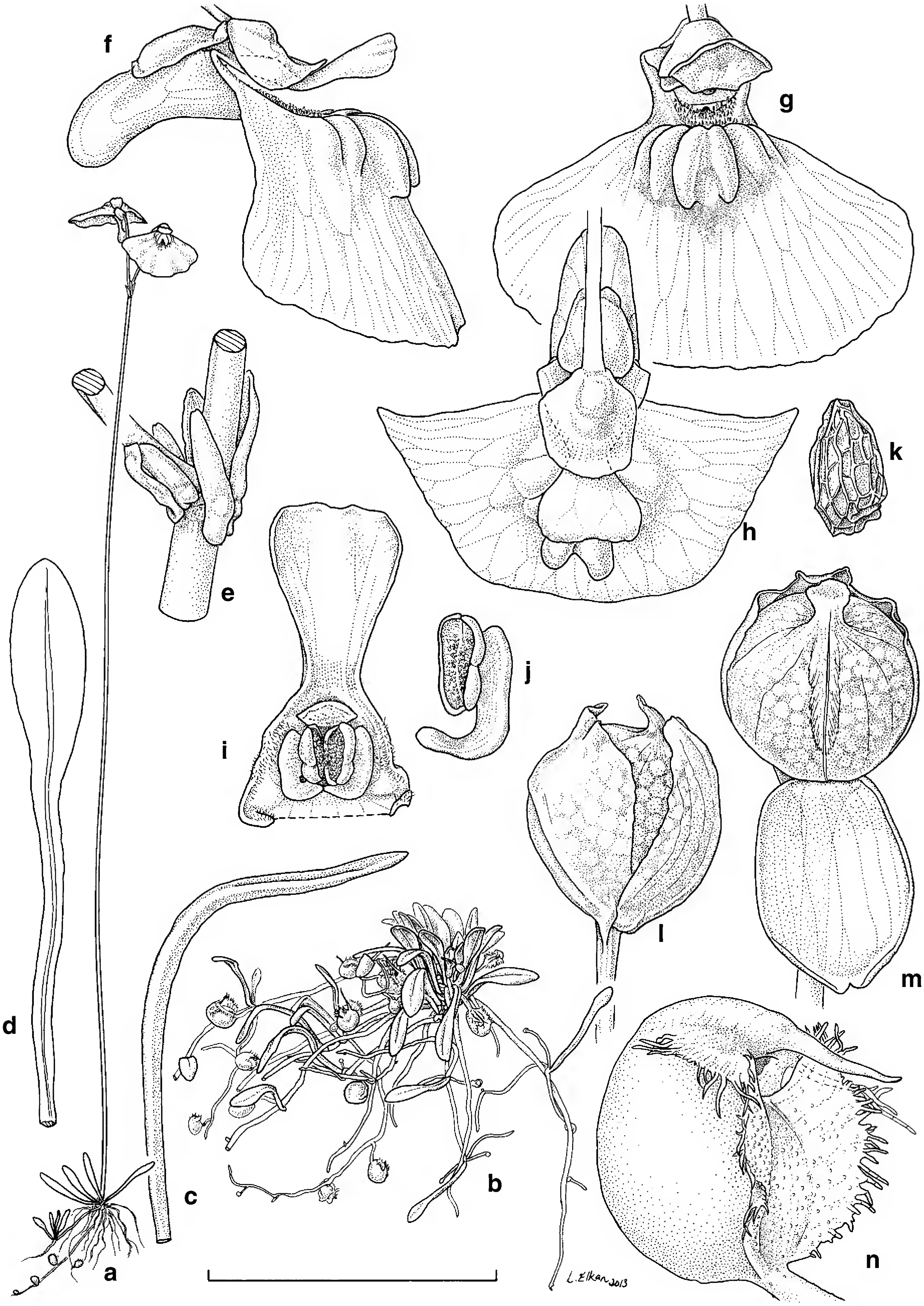

Fig. 4. *Utricularia grampiana* **a**, habit; **b**, stolon nodes - leaves, traps, rhizoids; **c**, leaf lateral view; **d**, leaf adaxial surface; **e**, bracts & bracteoles with pedicel base *in situ*; **f**, flower in lateral view; **g**, flower in frontal view; **h**, flower in dorsal view; **i**, upper lip with stamens; **j**, stamen; **k**, seed; **l**, fruiting capsule and calyx lateral view; **m**, fruiting capsule showing suture ventral view; **n**, bladder-trap in lateral view. Scale bar: a = 4 cm; b = 2 cm; c,d,f-h,l&m = 0.6 cm; e,i = 0.4 cm; j = 0.25 cm; k = 0.1 cm; n = 0.2 cm. Material used: a = R.W. Jobson 1630 (NSW905026); b-n = R.W. Jobson 1630 (spirit – NSW824604).

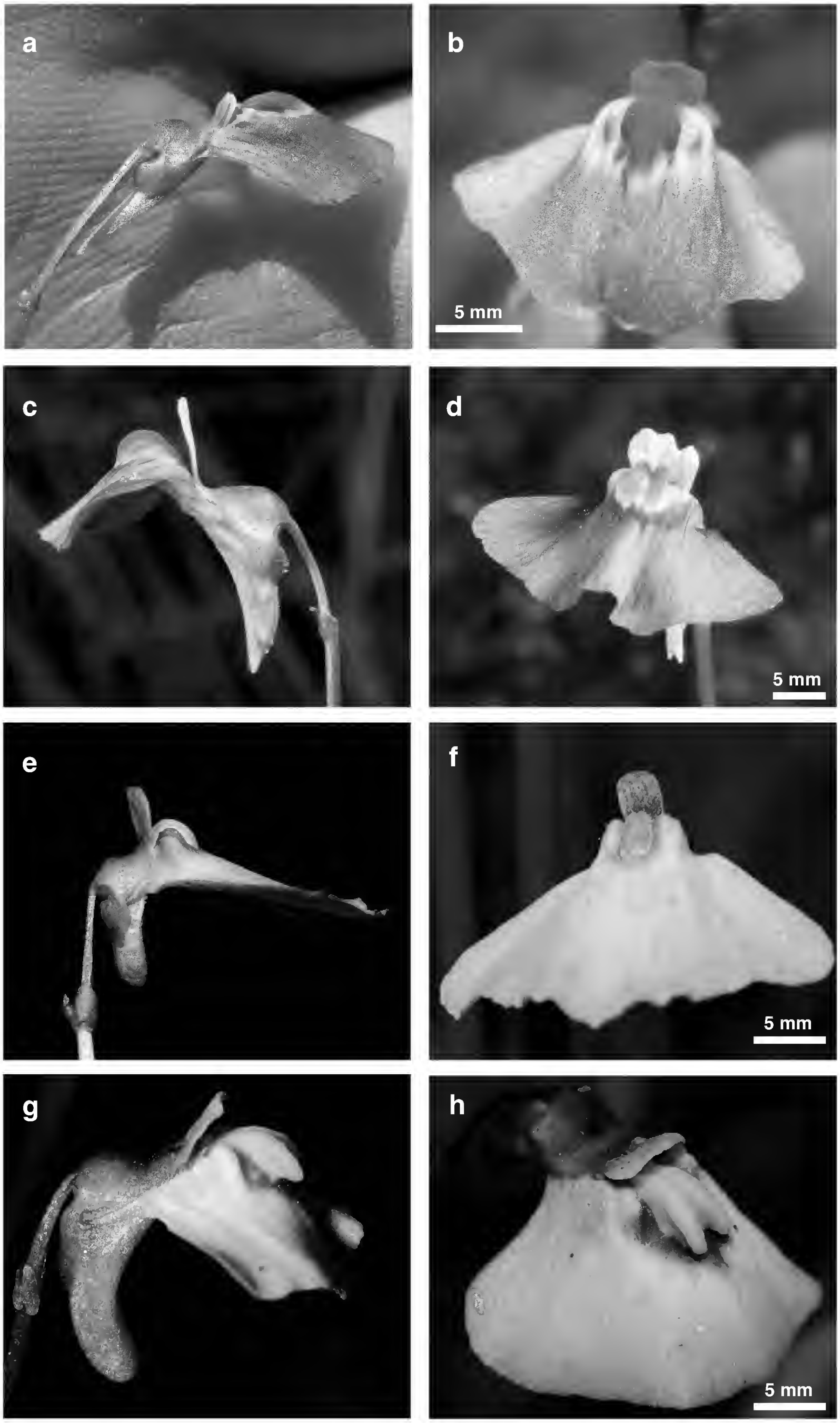

Fig. 5. Flowers in lateral and frontal view: **a–b,** *U. fenshamii* showing the long central yellow ridge at base of lower lip; **c–d,** *U. ameliae* showing bifid spur apex and white upper lip; **e–f,** *U. barkeri* showing two yellow ridges at the base of lower lip not exceeding those adjacent; **g–h,** *U. grampiana* showing two strongly raised yellow ridges at base of lower lip that exceed those adjacent. Scale bars represent both sides of the plate.

5. *Utricularia lowriei* R.W.Jobson *sp. nov.*

Diagnosis: This species differs from *U. dunstaniae* F.E.Lloyd with presence of three filiform central lower lip lobes that are longer than the spur.

Type: Australia: Queensland: Cook: North of Cooktown, (15.01°S, 145.13°E), 6 July 2013, *R.W. Jobson 1921* (holo: NSW976183; iso: BRI).

Small probably annual, terrestrial or affixed subaquatic herb. Rhizoids numerous, capillary, simple, up to 6 mm long, 0.1 mm thick, from base of peduncle, with one from nodes of stolon. Stolons few, filiform, 0.1–0.2 mm thick, unbranched, up to 30 mm long, internode length c. 5 mm long. Leaves few, two or three from base of peduncle and 1 from stolon internodes, petiolate; lamina narrowly obovate c. 0.3 mm wide, 2–3 mm long, single nerve, apex rounded. Traps several at base of peduncle and one at nodes of stolon, ovoid, 0.75 mm long, mouth lateral, with dorsal appendage reduced to a slight bump, lateral appendages long capillary or highly reduced, ventral wings absent, stalk 3–7 mm long. Inflorescence erect, solitary 40–70 mm long; peduncle terete, glabrous, ± hollow, 0.5 mm thick. Scales absent. Bracts and bracteoles similar, basifixed, ovate with rounded apex, c. 0.5 mm long. Flowers 1, pedicels erect or apically curved, slightly dorsiventrally flattened, 2–5 mm long. Calyx lobes unequal; upper lobe c. 1.7 mm long, 1.6 mm wide, oblong, convex with apex rounded; lower lobe c. 1 mm long, 1.2 mm wide, ovate with apex bifid. Corolla reddish-brown to apricot; lower lip 5–lobed with lateral pair filiform, erect, papillose on inner surface, 9–15 mm long, three central lobes descending, subulate/filiform, mostly equal length c. 3 mm long, usually twice the length of the spur; spur scrotiform, glabrous, from a cylindrical base, longer than the calyx lobe, apex bilobed with each lobe more-or-less rounded. Staminal filaments straight, c. 1 mm long, anther thecae distally confluent. Ovary ovoid, adnate to calyx lobe, c. 1 mm long; style c. 0.5 mm long; stigma with lower lip semicircular forming a flap concealing a slightly deltoid upper lip. Capsule ovoid, c. 1.5 mm diam.; walls thin, dehiscing by a single, ventral, longitudinal, marginally thickened slit. Seeds ovoid 0.15–0.2 mm long, major end subtruncate, testa cells slightly elongated, with raised anticlinal boundaries. Pollen: 3-colporate, c. 28 × 28 µm (*Jobson 1921*, NSW976183) (Figs 6, 8).

Etymology. The specific epithet honours botanist and colleague Allen Lowrie, who has greatly advanced the study of *Drosera*, *Stylidium,* and *Utricularia.*

Phenology. Flowers recorded in July. Seed-set has been observed in the type specimen. Flowers do not emit an obvious fragrance.

Distribution and Ecology. Australia: N of Cooktown (Fig. 7a), in shallow water at edge of depression on deep sand with *Utricularia albiflora* R.Br., *U. caerulea* L., *U. chrysantha* R.Br., *U. subulata* L., *U. quinquedentata* F.Muell. ex. P.Taylor, *U. gibba* L., *Dapsilanthus ramosus* (R.Br.) B.G.Briggs & L.A.S.Johnson, *Melaleuca arcana* S.T.Blake.

Probably endemic to a small area north of Cooktown, with a brief survey of the surrounding area (several adjacent swamps) finding no other populations. However, a single inflorescence collected by Ann G. Gunness, at Namaleta Creek, c. 90 km N of Weipa, (AG 2306, 11 Apr 1994; specimen held in Herbarium Lowrieanum, Perth), provides some evidence of a second population some 500 km to the NW of the type location. Although specimen AG-2306 was poorly preserved, an interpretation of the inflorescence by Allen Lowrie seems to match the floral morphology of *U. lowriei* (A. Lowrie, pers. comm.). A revisit of the Namaleta Creek site is required for formal identification, and if positive will provide a significant extension of the *U. lowriei* range, and might indicate that this species is more widespread and previously overlooked by collectors.

Conservation Status. Further study is required to determine threats and conservation status.

Key to Australian *Utricularia* species possessing an erect pair of capillary corolla lobes (modified from Taylor 1989).

1a. Corolla with 2 capillary lobes arising from the corolla upper lip 2
1b. Corolla with 2 capillary lobes arising from the corolla lower lip 3

2a. Corolla lower lip 5-lobed .... ***U. capilliflora***
2b. Corolla lower lip 3-lobed .... ***U. dunlopii***

3a. Three central lower lip lobes filiform, longer than the spur .... ***U. lowriei***
3b. Three central lower lip lobes reduced or deltoid, shorter than the spur 4

4a. Dorsal bladder-trap appendage always absent .... ***U. dunstaniae***
4b. Dorsal bladder-trap appendage long and filiform .... ***U. antennifera***

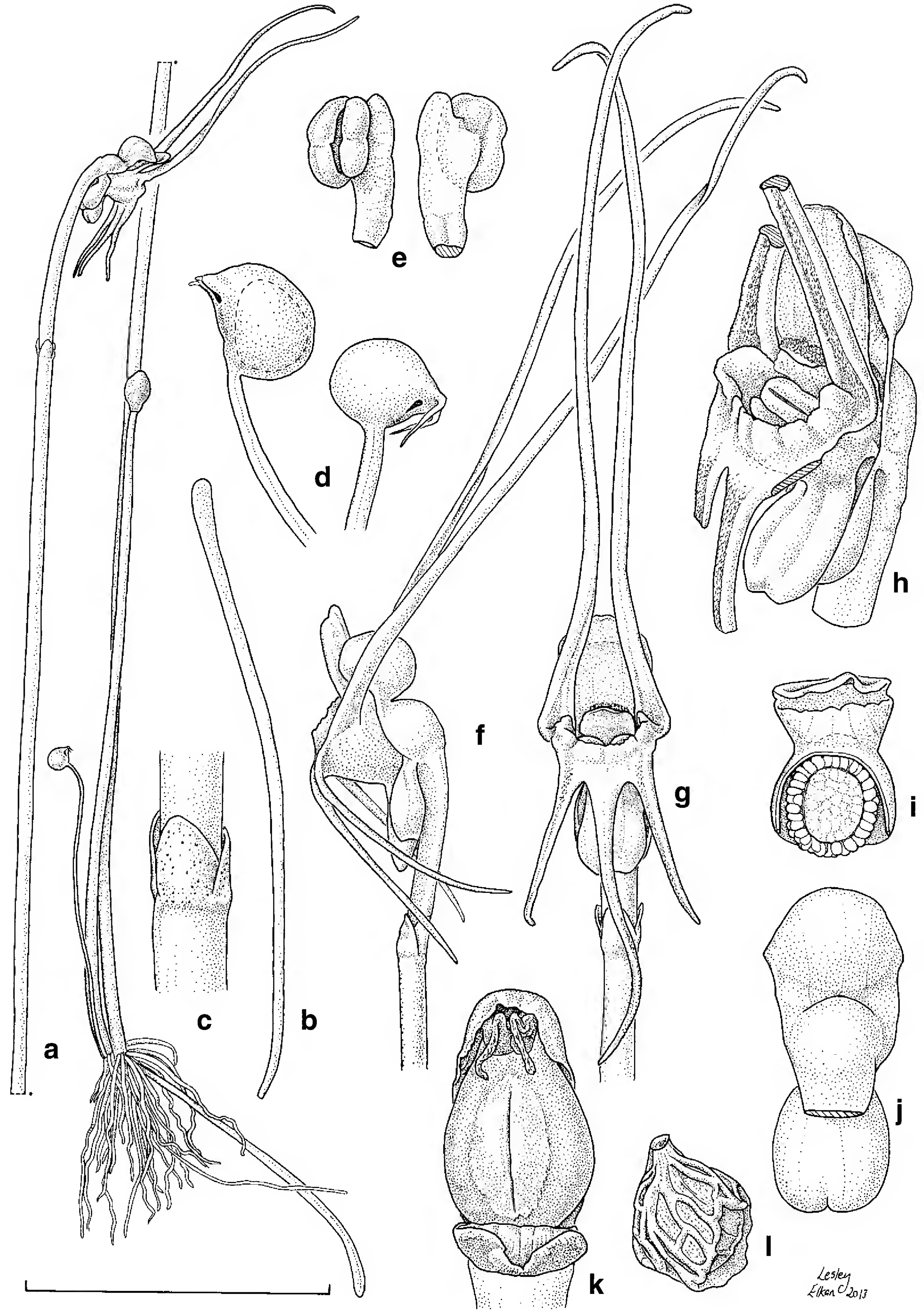

Fig. 6. *Utricularia lowriei* **a**, habit; **b**, leaf; **c**, bracts & bracteoles with pedicel base *in situ*; **d**, bladder-traps in lateral view; **e**, stamen ventral & dorsal view; **f**, flower in lateral view; **g**, flower in frontal view; **h**, corolla showing spur; **i**, pistil sectioned; **j**, calyx dorsal view; **k**, fruiting capsule with calyx; **l**, seed. Scale bar: a = 1 cm; b = 0.6 cm; c,d,e&i = 0.2 cm; f&g = 0.4 cm; h,j&k = 0.5 cm; l = 0.05 cm. Material used: a-l = R.W. Jobson 1921 (spirit – NSW922741).

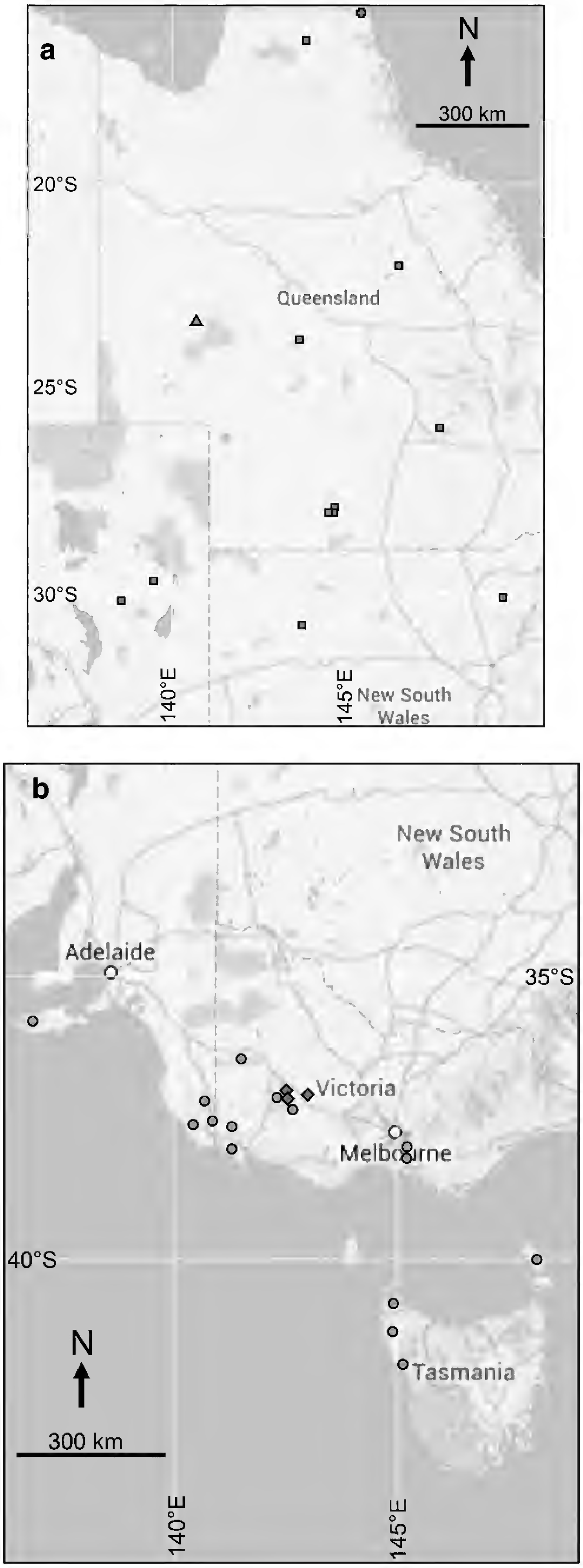

Fig. 7. a, North eastern Australia with known distribution of *U. fenshamii* (red squares); *U. ameliae* (blue triangle); and *U. lowriei* (yellow cross). **b**, South eastern Australia showing known distribution of *U. barkeri* (mauve circles), with *U. grampiana* shown with green diamonds.

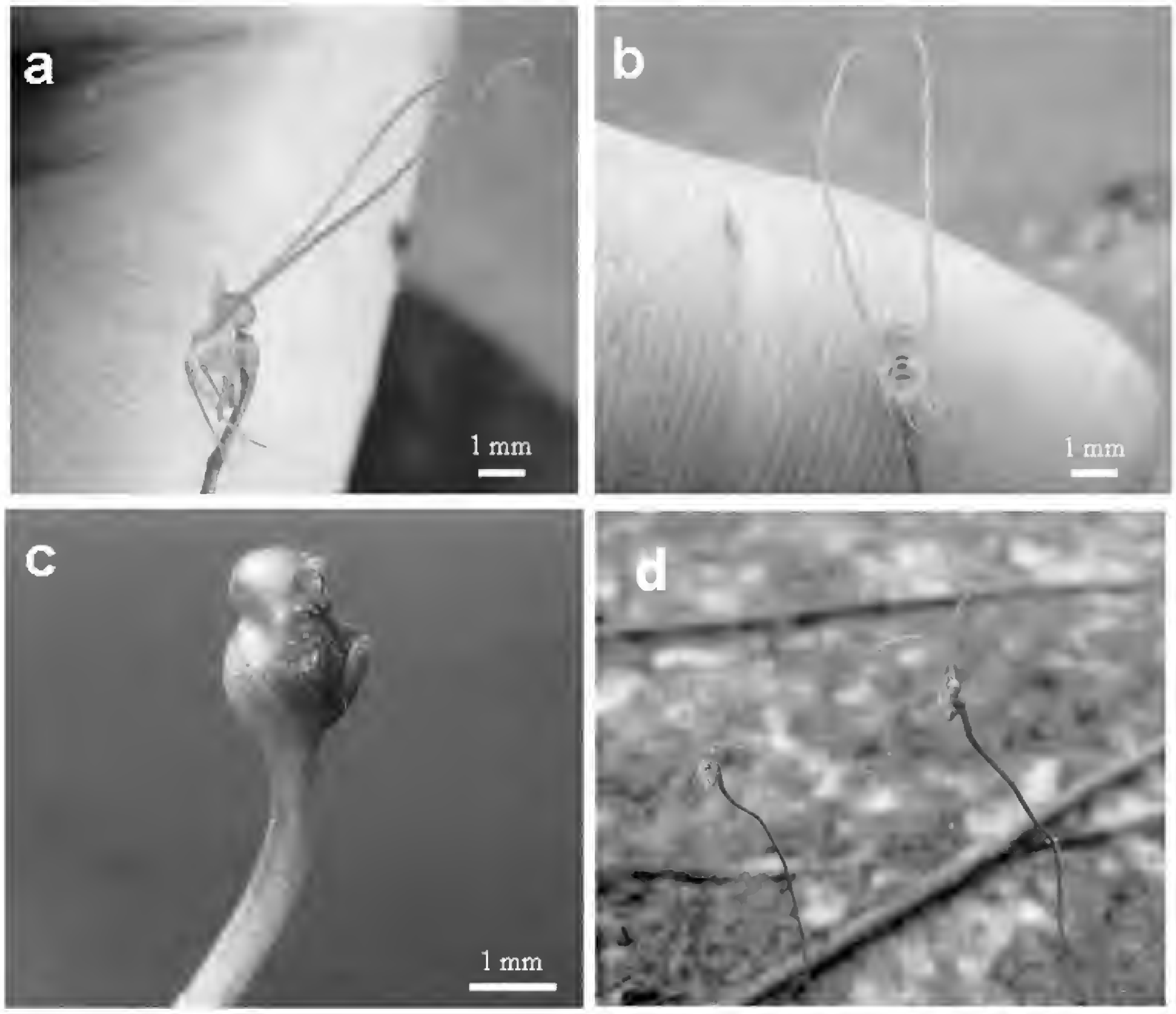

Fig. 8. *Utricularia lowriei* floral form **a**, lateral view; and **b**, frontal view; **c**, mature seed capsule (lateral view); **d**, emergent inflorescences *in situ* at type locality. Scale bars shown.

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Additions to and Nomenclatural Changes in the Bryaceae (Bryopsida) in Australia

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Abstract

The treatment of the family Bryaceae for Australia is updated based on recent taxonomic studies. Two species of *Ptychostomum*: *P. pallescens* (Scheicher ex Schwägr.) J.R.Spence from Tasmania and *P. bimum* (Schreb.) J.R.Spence from New South Wales, Tasmania and Western Australia are newly recorded. Reported for the first time is the tropical species *Gemmabryum erythropilum* (M.Fleisch.) J.R.Spence & H.P.Ramsay from northern Queensland. *Anomobryum* is re-instated in the Australian flora for the species *A. auratum* (Mitt.) A.Jaeger. Five Australian species of *Gemmabryum* are transferred to the newly described genus *Imbribryum* N.Pederson: *I. australe* (Hampe) J.R.Spence & H.P.Ramsay, *I. cheelii* (Broth.) J.R.Spence & H.P.Ramsay, *I. clavatum* (Schimp.) J.R.Spence & H.P.Ramsay, *I. crassum* (Hook.f. & Wilson) J.R.Spence & H.P.Ramsay, and *I. laevigatum* (Hook.f. & Wilson) J.R.Spence & H.P.Ramsay. *Bryum tuberosum* Mohamed & Damanhuri, previously placed in *Rosulabryum* by Spence and Ramsay (2006), is transferred to *Gemmabryum tuberosum* (Mohamed & Damanhuri) J.R.Spence & H.P.Ramsay. Several new nomenclatural transfers of Australian species, based on studies in North America taxa in *Plagiobryoides* (replacing *Plagiobryum cellulare)*, *Rosulabryum* and *Gemmabryum* are added to bring the Australian flora up to date.

Introduction

Since the publication of the family Bryaceae in the 'Flora of Australia' (Spence and Ramsay 2006; also see Spence and Ramsay 2012) significant new research on the family, not available at the time, has been published. This includes both morphological (Spence 2005, 2007, 2009; Spence and Ramsay 2005,) and molecular work (Pedersen and Hedenäs 2005; Pedersen et al. 2007; Holyoak and Pederson 2007). Nomenclatural transfers of several Australian species based on studies of North American taxa are presented here. Two genera new to Australasia: *Imbribryum* N.Pedersen and *Plagiobryoides* J.R.Spence, are recorded and appropriate combinations made. Other changes in taxonomic interpretations together with re-examination of the relevant herbarium specimens have added two additional *Ptychostomum* species. The first Australian report of *Gemmabryum erythropilum* (M.Fleisch.) J.R.Spence & H.P.Ramsay, a tropical Asian species, is also documented.

Species additions to *Gemmabryum* and *Ptychostomum*

Gemmabryum erythropilum (M.Fleisch.) J.R.Spence & H.P.Ramsay

Examination of some specimens from tropical Northeast Queensland has revealed the presence of *Gemmabryum erythropilum* (M.Fleisch.) J.R.Spence & H.P.Ramsay, a new record in the Bryaceae for Australia. In earlier studies *Bryum erythropilum* M. Fleisch. had been considered a synonym of *Bryum clavatum* (Schimp.) Müll. Hal. (Norris and Koponen 1984; Eddy 1996). Spence and Ramsay (2006) placed *B. clavatum* in the genus *Gemmabryum* as *G. clavatum.* In these studies the latter species has been re-interpreted as *Imbribryum clavatum* (Schimp.) J.R.Spence & H.P.Ramsay (see below).

Ochi (1985), Tan and Koponen (1989) and Tan and Iwatsuki (1991), maintained *Bryum clavatum* (here recognised as *Imbribryum clavatum*) and *B. erythropilum* (= *Gemmabryum erythropilum*) as distinct unrelated species, an interpretation we accept. Their observations together with additions from our studies separate the species as follows: the two taxa differ in sexuality – autoicous or sometimes dioicous in *G. erythropilum* (but dioicous in *I. clavatum*); in colour and length of costa – long-excurrent with strong red tints in *G. erythropilum*, (short-excurrent and lacking red tints in *I. clavatum);* in the degree of leaf border differentiation (1 or 2 rows of elongate border cells in *G. erythropilum* versus 2–5 rows of linear border cells in *I. clavatum*); and in cell size differences with relatively long distal and medial cells, > 6:1 in *G. erythropilum*, (short 3–4:1 in *I. clavatum*). Rhizoidal tubers are small, pyriform or clavate, < 60µm long in *G. erythropilum* (but large >100 µm and sphaerical in *I. clavatum*). Capsule morphology also differs - short and pyriform in *G. erythropilum* (very large and long clavate in *I. clavatum*).

Ecologically *G. erythropilum* is a species of riparian zones and running water whereas *I. clavatum* is primarily a species of calcareous seeps and springs. They also have different distributions, with *G. erythropilum* being palaeotropical and in Australia has been found so far only in far-north Queensland, whereas *I. clavatum* is largely subantarctic and southern temperate reaching only as far north as New South Wales in Australia.

Our studies have determined that *Bryum erythropilum* is related to *Gemmabryum apiculatum* (Schwägr.) J.R.Spence & H.P.Ramsay (see below) and have therefore, transferred it to the genus *Gemmabryum.*

Gemmabryum erythropilum (M.Fleisch.) J.R.Spence & H.P.Ramsay, *comb. nov.*

Basionym: *Bryum erythropilum* M.Fleisch., *Musci Flora Buitenzorg* 2: 553 fig. 102 (1904).

T: Indonesia, West Java 'bei Tjibodas auf Erde', VII 1898, *M. Fleischer s.n.* (syntype: H-BR).

Illustrations: Fleischer (1904: p. 559, fig. 102); Ochi (1964: p. 68, fig. 1; as *B. erythropilum*); Norris and Koponen (1984: p. 277, figs 4e–j; as *B. clavatum*); Ochi (1985: p. 70, figs 8A–F; as *B. erythropilum*; Eddy (1996: p. 127 fig. 414; as *B. clavatum*).

Autoicous or dioicous. Plants small, stems 1–2 cm, glossy green, usually with red tints or plants entirely red; leaves ovate-lanceolate, 1–2 mm long, acuminate, not much altered when dry, erect when wet; costa strong, red to red-purple, long excurrent in strong sometimes denticulate awn, distal and medial laminal cells very long, firm walled to distinctly incrassate, (60–) 80–100 um, 10–14 um wide, more or less elongate along costa to leaf base, alar cells abruptly short-rectangular to quadrate in corners, distal leaf margins finely serrulate, limbidium present, 1 or 2 layers wide; gemmae present as rhizoidal tubers, common, small, 40–60 µm long, red to orange, clavate to pyriform, 1 or 2 cells across, 2–5 cells along long axis. Capsule brown, 1–3 mm long, pyriform, apophysis thick, tapered, smooth, peristome well-developed. Spores not seen.

Norris and Koponen (1984) noted that a number of collections listed by Ochi (1970) under *B. clavatum* had rhizoidal gemmae. The gemmae, also present in Australian collections, are typical of *G. erythropilum* being deep red and clavate to pyriform and very similar to those of *G. apiculatum* which are pyriform to irregularly globose (Spence and Ramsay (2006).These two species can be distinguished by a variety of characters, including the strong red tints in *G. erythropilum* (green to pale pink-green in *G. apiculatum*), long excurrent awn (percurrent to short excurrent in *G. apiculatum*), the limbidium (absent in *G. apiculatum*), leaves ovate-lanceolate, acuminate (narrowly ovate and acute in *G. apiculatum*), and tubers deep red to orange (brown to red-brown in *G. apiculatum*).

The discovery of *G. erythropilum* in Queensland is not unexpected as it is a widespread paleotropical species and has a distribution similar to *G. tuberosum.* The species has been recorded previously on islands south of Japan, India, in south-east Asia, and Malesia (including New Guinea). The reference to the locality of the type collection as 'West Java bei Tjibodas auf Erde' refers to the collection being from Cibodas, dutch spelling 'Tjibodas' (West Java), now Kebun Raya Cibodas, growing on earth (hence terrestrial) (BJ Conn, pers. comm. 17 Oct 2013).

Specimens examined: Australia: Queensland: On soil on exposed granitic rocks, in rainforest below summit of Mt Lewis, *B.O. Van Zanten 681131*, 27 Jul 1968 (NSW ex GRO); Exposed on stones at edge of rainforest, Mossman River Gorge, *B.O. van Zanten 68972B*, *68979B*, *68988A*, 19 Jul 1968 (NSW ex GRO); Babinda Boulders, 60 km S of Cairns, wet soil in rainforest, *B.O.van Zanten 681034E*, 20 Jul 1968 (NSW ex GRO); On soil over granite rocks, in rainforest, 0.5 km along Mt Lewis Road, 16 33'S, 145 17' E, *P.I. Forster 5536*, 30 Jun 1989 (BRI492573).

Ptychostomum bimum (Schreib.) J.R.Spence *Phytologia* 87:20 (2005)

During recent work for the Flora of North America (Spence 2009, 2014), the status of *Ptychostomum bimum* was investigated, based on earlier work by Zolotov (2002). This species has usually been considered a synoicous form of *P. pseudotriquetrum*, but Zolotov documented several significant differences in leaf characters such as the non-decurrent or only weakly decurrent leaves, and thicker walled distal and median laminal cells. For the 'Flora of Australia' account (Ramsay and Spence 2006), the two species were treated as synonymous, but they can be separated based on these laminal characters as well as sexuality.

The following specimens, including types of *Bryum austroaffine* and *B. tasmanicum* (Ramsay & Seur (1994) correspond with *P. bimum* according to Ochi (1970). This species is likely to be much more common and widespread than these few specimens suggest.

Specimens examined: Australia: New South Wales: Yarrangobilly Caves, *Forsyth 1012*, xii.1901; *1014*, 1901 (syntypes of *Bryum austro-affine* Broth., H; isosyn:, NSW); Kiandra, *Forsyth 1010, 1011*, xii.1901 (syntypes of *B. austroaffine* Broth. H; isosyn: MEL, NSW). **Tasmania:** *Stuart s.n.* (type of *B. tasmanicum* Hampe, holo: BM; iso: MEL). **Victoria:** Beenak, *Willis s.n.*, July 1935 (MEL1034391); Lankey Plain, Bargo High Plains, *Theis FN 1494* (MEL1050674); Glenelg River, (Williams), [*Mueller s.n.*] (as *B. tasmanicum* Hampe (BM).

Future work on the distribution and ecology of this species with the closely related species *P. pseudotriquetrum* is needed in Australia, as well as the relationships with other southern hemisphere species related to *P. pseudotriquetrum*, including *Bryum macrantherum* Müll.Hal. from southern Africa and *B. orthothecium* Card. & Broth. from South America.

Ptychostomum pallescens (Schleich. ex Schwägr.) J.R.Spence *Phytologia* 87:21 (2005)

Two collections of this species from Tasmania were inadvertently missed during herbarium work for the 'Flora of Australia' project. Both of the specimens, brought to our attention by Bill Buck (NY), were confirmed as *P. pallescens*. The species is distributed widely in the northern hemisphere (Spence 2014) and is also found in New Zealand and southern South America so its occurrence in Tasmania is not unexpected. *Ptychostomum pallescens* is related to *P. creberrimum*, differing in its autoicous sexuality, evenly foliate rather than comose stems and larger spores.

Specimens examined: Australia: Tasmania: Mt. Field National Park, alt. 3400' (1036 m), *D.A. Ratkowsky B211 & A.V. Ratkowsky*, 07 April 1973 (NY); Tim Shea, W. of Maydena, on exposed conglomerate bank, alt. 2860 ft. (872 m), *D.A. Ratkowsky B64 & A.V. Ratkowsky*, 18 Mar 1973 (NY).

Nomenclatural Corrections

Ptychostomum pseudotriquetrum (Hedw.) J.R.Spence & H.P.Ramsay ex D.T.Holyoak & N.Pedersen *Journal of Bryology* 29: 120 (2007)

While transferring *Bryum pseudotriquetrum* to *Ptychostomum*, the basionym was incorrectly cited as *Mnium pseudotriqetrum* (Hedw.) Schwägr. rather than *M. pseudotriquetrum* Hedw. This was corrected, as indicated above, by Holyoak and Pedersen (2007).

Nomenclatural Changes

The genus ***Anomobryum*** Schimper, *Synopsis Muscorum Europaeorum* cxxxviii: 382–383 (1860).

Anomobryum auratum (Mitten) A.Jaeger, *Bericht über die Thätigkeit der St. Gallischen Naturwissenschaftlichen Gesellschaft* 1873-74: 142 (1875).

Basionym: *Bryum auratum* Mitten, *Journal of the Proceedings of the Linnaean Society, Botany, Supplement* 1: 67 (1859).

The genera *Anomobryum* and *Bryum* were combined in Spence and Ramsay (2002) based on overall similarity in morphology. However, molecular work since then (Pedersen and Hedenäs 2005; Pedersen et al. 2007) suggests that the two genera are not related, and that their morphological similarities are due to convergence. Although subtle, a significant difference between the two genera is the presence of elongate incrassate median and distal laminal cells in *Anomobryum* which in *Bryum* tend to be relatively shorter and wider. *Bryum auratum,* with these elongate cells is thus returned to the genus *Anomobryum* as *A. auratum* (Mitt.) A.Jaeger, while *Bryum harriotii* with *Bryum*-like laminal areolation remains in *Bryum.*

The genus ***Imbribryum*** N.Pedersen *Bryologist* 108: 449 (2005).

The genus *Imbribryum* was described based on the species *Bryum alpinum* With. and its allies (Pedersen and Hedenäs 2005, Pedersen 2005). This genus consists of relatively large species with elongate evenly foliate stems and strongly imbricate leaves; median and distal laminal cells are often incrassate and large rhizoidal tubers arise from macronemata in leaf axils. They have a strong preference for wet habitats such as streams, springs and waterfalls growing on rock or soil. *Imbribryum* is related to *Gemmabryum* section *Tuberibryum* (Spence 2007) and future work may indicate that some or most of the tuber-producing species in this section may be *Imbribryum* species. The following five Australasian species match the described characteristics of the genus as currently understood and are transferred from *Gemmabryum* to *Imbribryum.*

Imbribryum australe (Hampe) J.R.Spence & H.P.Ramsay, *comb. nov.*
Basionym: *Bryum australe* Hampe, *Iconones Muscorum Novorum vel Minus Cognitorum* 26 (1844).
Lectoype (designated by Ochi 1970): Swan River, W.A., *L. Preiss s.n.* BM; isolecto: MEL.

Imbribryum cheelii (Broth.) J.R.Spence & H.P.Ramsay, *comb. nov.*
Basionym: *Bryum cheelii* Broth., *Proceeding of the Linnaean Society of New South Wales* 41: 591 (1916).
Type: Shellharbour, New South Wales, 1 Oct. 1900, *E. Cheel 407* (holo: H-BR; iso: MEL, NSW).

Imbribryum clavatum (Schimper) J.R.Spence & H.P.Ramsay, *comb. nov.*
Basionym: *Pohlia clavata* Schimper, *Annales des Sciences Naturelles; Botanique,* sér. 2, 6: 148, 11 (1836).
Type: New Zealand, *Logan H 2813* (syntype: BM).

Imbribryum crassum (Hook.f. & Wilson) J.R.Spence & H.P.Ramsay, *comb. nov.*
Basionym: *Bryum crassum* Hook.f. & Wilson, *Flora Novae-Zelandiae* 2: 86, f. 1 ('1855' [1854]).
Type: Manukau Bay, New Zealand, *W. Colenso 136* (iso: BM).

Imbribryum laevigatum (Hook.f. & Wilson) J.R.Spence & H.P.Ramsay, *comb. nov.*
Basionym: *Bryum laevigatum* Hook.f. & Wilson, *London Journal of Botany* 3: 546 (1844).
Type: Tasmania, *J.D. Hooker 2856* (holo: BM).

The genus ***Gemmabryum*** J.R.Spence & H.P.Ramsay *Phytologia* 87: 63 (2005).

Gemmabryum was described for small species of *Bryum* that typically produce abundant gemmae, as either rhizoidal tubers or leaf axil bulbils (Spence and Ramsay 2005), or in rare cases both, e.g. *G. indicum* (Dozy & Molk.) J.R.Spence & H.P.Ramsay. One group of species, known as the informal group '*Apiculata*', includes species with small tubers and very long narrow laminal cells. Included in this latter group are *G. apiculatum* (Schwagr.) J.R. Spence & H.P. Ramsay and *G. inaequale* (Taylor) J.R.Spence & H.P.Ramsay among others.

Gemmabryum tuberosum (Mohamed & Damanhuri) J.R.Spence & H.P.Ramsay, *comb. nov.*

Basionym: *Bryum tuberosum* Mohamed & Damanhuri, *Bryologist* 93: 288 (1990).

Type: Genting Highlands, Pahang, Malaysia, *M.A. Hadji Mohamed 5397* (holo: KLU).

This species (as *Bryum tuberosum* Mohamed & Damanhuri) was placed in *Rosulabryum* by Spence and Ramsay (2006) because of its slightly obovate leaves. However, it shares a number of characters with the *Gemmabryum* '*Apiculata*' group such as the very small tubers and elongate laminal cells. Overall, based on additional morphological studies, it is better placed in *Gemmabryum* and is therefore transferred to it here.

Gemmabryum caespiticium (Hedw.) J.R.Spence *Phytologia* 91: 497 (2009)

Species of *Gemmabryum* section *Caespitibryum* including the cosmopolitan *G. caespiticium* and its allies, have been examined recently using molecular data (e.g., Pedersen et al. 2007). The relationships of this taxon (as *Bryum* caespiticium) still remain ambiguous as it has been placed near both *Ptychostomum* and *Gemmabryum* in different molecular studies. The plants share several features with *Gemmabryum*, including small size, imbricate leaves with a weak limbidium or limbidium absent, elongate distal laminal cells, and short proximal laminal cells. There are also recent reports of rhizoidal tubers in the literature, although these require confirmation.

Bryum caespiticium Hedw. was recently transferred to *Gemmabryum caespiticium* (Hedw.) J.R.Spence for the Flora of North America (Spence 2009). However, if the species is finally resolved to be a member of *Ptychostomum*, then the correct name will become *P. imbricatulum* (Müll.Hal.) D.T.Holyoak & N.Pedersen instead of *P. angustifolium* (*sensu* Spence and Ramsay 2006).

Gemmabryum coronatum (Schwägr.) J.R.Spence & H.P.Ramsay, *Phytologia* 87: 66 (2005).

Spence and Ramsay (2006) treated *Bryum angustifolium* Bridel as a synonym of *Ptychostomum angustifolium* (Bridel) J.R.Spence & H.P.Ramsay. However, it has since been transferred into synonymy with *Gemmabryum coronatum* (Holyoak and Pedersen 2007).

Ochiobryum J.R.Spence & H.P.Ramsay, *Phytologia* 87: 68 (2005).

There has been some confusion about the present identity of *Bryum blandum* Hook.f. & Wilson which was transferred to the new genus *Ochiobryum* (Spence and Ramsay 2005). In the same year, it was transferred to *Imbribryum* Pederson by Pederson and Hedenas (2005). This latter genus was not typified until later that year (Pederson (2005), giving *Ochiobobryum* priority.

Ochiobryum blandum (Hook.f. & Wilson) J.R.Spence & H.P.Ramsay is related to *Imbribryum* but differs in extremely long laminal cells throughout the leaf and the complanate habit. Pederson & Hedenas (2005) moved *B. blandum* to their new genus as *I. blandum*. However, as they looked at only three of the taxa in the larger *I. alpinum* complex they were unable to determine sister relationships of the two genera. Until more work is done on the relationship between *Ochiobryum* and typical *Imbribryum*, the *I. laevigatum* group, as well as the New Guinean species, we prefer to retain *Ochiobryum* as a separate entity.

The genus ***Plagiobryoides*** J.R.Spence, *Phytologia* 87: 24 (2005).

Plagiobryoides cellularis (Hook.) J.R.Spence, *Phytologia* 91: 498 (2009).

Spence and Ramsay 2006) transferred the widespread tropical species *Bryum cellulare* Hook. to the genus *Plagiobryum* since it appeared to be morphologically closest to it and was the only Australian representative in that genus. However, the species exhibits several differences from *Plagiobryum*, including the more or less symmetrical capsule, and spores shed singly, not in tetrads as in *B. cellulare*. During work for the Flora of North America by Spence (2009) the genus *Plagiobryoides*, was described for this species and its relatives, and the required combination *Plagiobryoides cellularis* (Hook.) J.R.Spence was made. Thus the genus *Plagiobryum*, is no longer represented in the bryoflora of Australia although it does occur in New Zealand.

The genus ***Rosulabryum*** J.R.Spence, *Bryologist* 99: 222 (1996).

Rosulabryum rubens (Hedwig) J.R.Spence, *Novon* 19: 399 (2009).

Recent molecular work (Pedersen and Hedenäs 2005; Pedersen et al. 2007) shows that *Gemmabryum rubens* (Hedw.) J.R.Spence & H.P.Ramsay (Spence and Ramsay 2006), long considered a member of the small tuber-producing species in the informal '*Erythrocarpa*' group (*Gemmabryum* section *Tuberibryum* sensu J.R.Spence), is in fact very close to *Rosulabryum capillare* (Hedw.) J.R.Spence. The morphology of *G. rubens* is very different from most other species in that section of *Gemmabryum,* as it consists of plants with wide leaves, serrate distal margins, a distinct limbidium, large tubers and wide and relatively short distal and median laminal cells. Morphologically it appears to be closest to species of *Rosulabryum* section *Trichophora.* Spence (2009, 2014) transferred this species to *Rosulabryum*, as *P. rubens* (Hedwig.) J.R.Spence.

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Circumscription and phylogenetic relationships of *Prostanthera densa* and *P. marifolia* (Lamiaceae)

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Abstract

Prostanthera densa A.A.Ham. and *P. marifolia* R.Br. (Lamiaceae) are endemic species with restricted distributions within the near-coastal regions of New South Wales (Australia). *Prostanthera marifolia* was previously presumed extinct, but is now known from three small geographically close populations in the Manly-Warringah area of metropolitan Sydney. This species is morphologically very similar to *P. densa*, which is known from five disjunct populations, distributed south from Port Stephens to Jervis Bay. The nucleotide sequence variation of the *psb*A-trnH chloroplast spacer region, and the external transcribed spacer (ETS) region of nuclear ribosomal DNA were analysed to evaluate the phylogenetic relationships and taxonomic integrity of these species. Trees generated from *psb*A-*trn*H and ETS data provided support for recognising *P. marifolia* as separate from *P. densa*. A multivariate statistical evaluation of the morphological variation of each population of these taxa supported the distinction of these two morphologically similar and closely related species. Based on molecular and morphological data we recommend these two species continue to be recognised. The ETS data highlighted the genetic distinctiveness of four disjunct populations of *P. densa*. Since there is apparently no gene flow between populations of *P. densa*, it was concluded that the conservation of this species requires all populations to be protected.

Introduction

Prostanthera marifolia R.Br. (Lamiaceae) is a small shrub recorded from the Sydney Harbour region of the Central Coast, New South Wales (Brown 1810; Conn 2007). Since first collected in the early 1900s, all subsequent attempts to re-collect this species were unsuccessful. As a result, this species was presumed extinct (Conn 1992). In 2001, a number of plants that broadly agreed with the circumscription of *P. marifolia* were located at three sites in the Manly-Warringah area of Metropolitan Sydney, near Garigal National Park. The conservation status of this species was re-assessed according to the *New South Wales Threatened Species Conservation Act 1995* and is now classified as 'critically endangered' (Conn 2007). *Prostanthera densa* A.A.Ham. is morphologically similar to *P. marifolia* and is confined to a series of disjunct populations throughout coastal and near-coastal New South Wales, occurring at Port Stephens, North Coast Botanical region (Anderson 1961; Jacobs and Pickard 1981); Cronulla, Helensburgh and in the Royal National Park (all three occurring near Sydney, Central Coast Botanical region); and on the Beecroft Peninsula near Jervis Bay (South Coast Botanical region) (Fig. 1). The identity of each species has frequently been confused because *P. marifolia* was poorly known due to local extinctions caused by urban development in central metropolitan Sydney, inadequate circumscription and poor representation in Australian herbaria.

In this study, the morphological variation within and between populations of *P. marifolia* and *P. densa* is assessed empirically. The genetic distinctiveness of individuals attributable to both species is quantified. Together, these data provided insights into the taxonomy, phylogenetic relationships, and conservation status of known populations.

Materials and methods

Molecular phylogenetic analyses

Individuals from five populations of *P. densa*, representing all known extant populations, were included in this study. New collections were made from two of the three extant populations of *P. marifolia* in the Manly-Warringah region. The suitability of several potential outgroup species were assessed using the known molecular phylogeny of *Prostanthera* (Wilson et al. 2012). *Prostanthera granitica* and *P. tallowa* were recovered as suitable outgroup taxa for the ETS data, but only *P. tallowa* formed a sister relationship to the ingroup for the *psb*A-*trn*H region. Therefore, *P. tallowa* was used as the outgroup species for both molecular regions used in this study. Collection details of all voucher specimens are given in Table 1.

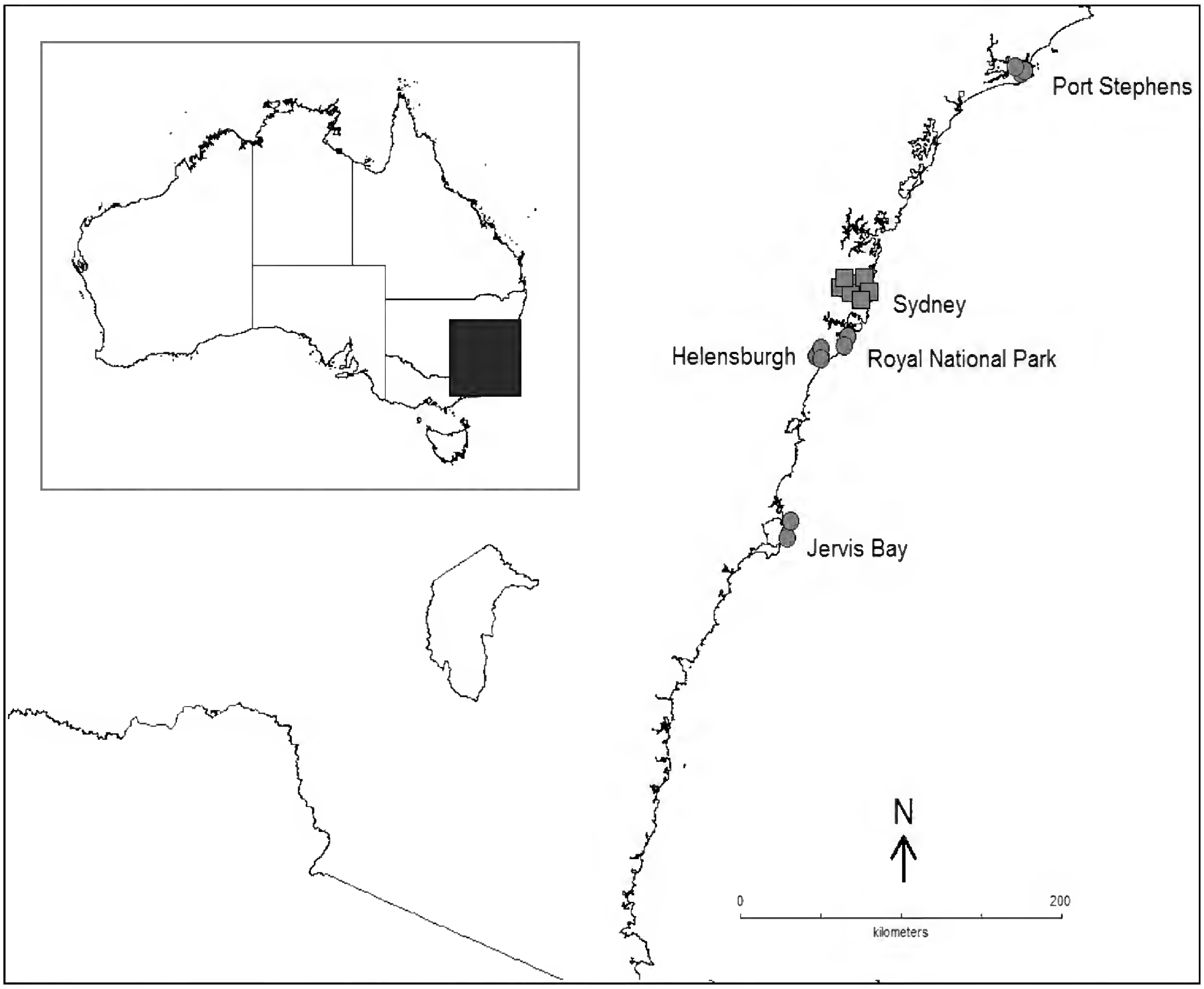

Fig. 1. Distribution of *Prostanthera densa* (red dots) and *P. marifolia* (blue squares) in coastal and near-coastal New South Wales, Australia. Insert map: locality of detailed map in Australia. The geographic distributions are based on collections held at MEL, NSW and SYD.

Table 1. *Prostanthera* specimens of *P. densa* and *P. marifolia* used for DNA sequence and morphological analyses Legend: The collections cited are listed in an approximate north–south order; collection voucher = collector, collection number and herbarium abbreviations (in parentheses); NP = National Park; PW = Parkway; s.n. = sine numero; * = specimen sequenced with only one direction. Genbank numbers are given for each marker.

Taxon	Population	Collection voucher	ETS	*psbA-trn*H	Morphology
P. marifolia	Manly-Warringah	Conn 4380A (NSW)	JX047657	KF145108	
		Conn 4444 (NSW)			✓
		Skelton *s.n.* (NSW)			✓
		Conn 5676 (NSW)	KF112054	KF145107	✓
	Longueville	Rupp *s.n.* (MEL43365)			✓
P. densa	Port Stephens	Wilson 37 (NSW)	JX047677	KF145100	✓
		Johnstone 1003 (NSW)	KF112057		✓
	Cronulla	Conn 2563 (NSW)			✓
		Conn 4381A (NSW)	KF112048	KF145103	✓
	Royal NP	Wilson 173 (NSW)	KF112049*	KF145101	✓
	Helensburgh	Scott 4 (NSW)	KF112053	KF145102	✓
		Wilson 221 (NSW)	KF112050	KF145104	
		Wilson 222 (NSW)	KF112051	KF145105	✓
		Wilson 242 (NSW)	KF112052	KF145106	
	Jervis Bay	Henwood 800 (SYD)	KF112056	KF145110	✓
		Conn 2571 (NSW)			✓
		Miles (NSW496550)	KF112055	KF145109	
P. tallowa	Kangaroo Valley	Wilson 234 (NSW)	JX047664	KF692284	

Selection of molecular markers

Two markers were used in this study: the *psb*A-*trn*H chloroplast intergenic spacer region and the external transcribed spacer (ETS) region of nuclear ribosomal DNA. The *psb*A-*trn*H regions have been used at the interspecific level in the Lamiaceae (Albaladejo et al. 2005; Gobert et al. 2006). Similarly, the ETS region of nuclear ribosomal DNA has been found to evolve faster and consequently have greater variability than the internal transcribed spacer (ITS) region, which is more frequently used, making ETS particularly useful for studies below the generic level (Baldwin and Markos 1998; Linder et al. 2000; Stappen et al. 2003; Wilson et al. 2012).

DNA extraction, amplification and sequencing

Total genomic DNA extractions and polymerase chain reaction (PCR) to amplify the selected regions (*psb*A-*trn*H and ETS) were conducted according to methods used by Wilson et al. (2012). Primers are listed in Table 2.

Table 2. Primers used for amplification of markers

Fragment	Primer Name	Direction	Sequence	Author(s)
*psb*A-*trn*H				
	*psb*A	5′ to 3′	GTTATGCATGAACGTAATGCTC	(Tate and Simpson 2003)
	*trn*H^{GUG}	3′ to 5′	CGCGCATGCTGGTGGATTCACAATCC	(Sang et al. 1997)
ETS				
	ETS-PROS2	5′ to 3′	GCAGCGACGACATCCCAACC	(Baldwin and Markos 1998)
	18S-E	3′ to 5′	GCAGGATCAACCAGGTAGCA	(Wilson et al. 2012b)

Sequence alignment and phylogenetic analyses

Multiple sequence alignments were initially performed using the Clustal W alignment tool (Larkin et al. 2007) implemented in the alignment editing program BioEdit 7.0.9.0 (Hall 1999). Alignments were edited manually as necessary in this program. A consensus of the forward and reverse sequences was created for most samples (Table 1).

Maximum parsimony (MP) analysis was conducted using PAUP* 4.0b10 (Swofford 2003) and Bayesian inference (BI) analysis was undertaken using Mr Bayes 3.1.2 (Huelsenbeck and Ronquist 2001). The settings for MP analyses were as follows: nucleotide substitutions and indel events were weighted equally, random taxon addition starting tree with tree-bisection–reconnection (TBR), branch swapping with uninformative characters excluded, and the MULTREES option = yes. Length of the shortest tree (L), consistency index (CI), retention index (RI) and rescaled consistency index (RC) were calculated to test the results of each heuristic search. Branch support was assessed by bootstrap analysis (BS), using 1000 replicates with the above heuristic search settings. Bayesian analysis used datasets without indels with the 'TVM+G' model as indicated by Modelltest (Posada and Crandall 1998), and the rate variation across sites was set as gamma-distributed. Tree space was searched using the Metropolis Coupled Markov Chain Monte Carlo analysis, using four chains starting at randomly selected trees. The chains were run for 5,000,000 generations in two simultaneous runs, saving one tree every 100 generations. The 'burn-in' value of 30,000 was set for all analyses.

Estimates of the evolutionary divergence between the populations of *P. densa* and *P. marifolia*, using ETS data, was analysed using the Kimura 2-parameter model (Kimura 1980), conducted in MEGA5 (Tamura et al. 2011). The analysis involved 13 nucleotide sequences. All positions containing gaps were treated as missing data. The final matrix contained 327 characters.

Multivariate statistical analyses

Twenty morphological characters were measured (Table 3) from 13 specimens, including most of those sampled for molecular phylogenetic analyses (Table 1). Specimens used in the phenetic analysis represented the morphological range of variation found within and between populations of *P. densa* and *P. marifolia*. The primary aim of the morphometric analyses was to empirically identify any new, or previously recognised, taxonomic units within the sample. To achieve this, a range-standardised distance matrix of the data was produced using the Gower metric association measure (Gower 1971). Cluster analysis was performed using flexible Ungrouped Pair-Group Method using Averages (flexible UPGMA), with β-value = -0.1000 as implemented in PATN Version 3.11 (Belbin and Collins 2006). Association measures were used to ordinate samples in Semi-Strong Hybrid (SSH) multidimensional scaling, with CutOff = 0.900; number of random starts = 100; maximum iterations = 1,000; random seed value = 1,235 (Belbin 1991, 1995). Correlation values for each morphological character in the SSH were calculated using Principal Component Correlation (PCC).

Table 3. Morphological characters used, including character codes, in multivariate analysis of selected specimens of *Prostanthera densa* and *P. marifolia*.

Character code	**Definition (units)**	**Character code**	**Definition (units)**
IntL	Length of 5th most distal internode (mm)	ProW	Width of prophylls (mm)
IntHD	Density of hairs on distal internodes (mm^2)	KTL	Length of calyx tube (mm)
LfL	Length of leaf lamina (mm)	KABL	Length of abaxial calyx lobe (mm)
LfW	Width of leaf lamina (mm)	KADL	Length of adaxial calyx lobe (mm)
LfW_L	Distance of maximum width of leaf lamina from base/total lamina length ratio	KOHD	Density of hairs on outer surface of calyx (mm^2)
LfHD	Density of hairs on abaxial lamina surface (mm^2)	KIHD	Density of hairs on inner surface of adaxial calyx lobe (mm^2)
LfGD	Density of glands on abaxial lamina surface (mm^2)	CTL	Length of corolla tube (mm)
A1L	Length of a_1 axis (mm)	CADLL	Length of adaxial corolla lobe (mm)
AntL	Length of anthopodium (mm)	CABLL	Length of abaxial corolla lobe (mm)
ProL	Length of prophylls (mm)	AAL	Length of anther appendage (mm)

Results

Phylogenetic analysis

The total length of the *psb*A-*trn*H matrix was 403 characters, of which two characters (~0.50%) were variable and one of these was parsimony-informative. The resulting single tree (Fig. 2) placed the *P. marifolia* samples as unresolved members of a polytomy that consisted of a strongly supported clade containing all of the *P. densa* samples (BS=100%; PP=0.97). The relationships between the samples of *P. marifolia* and between accessions within the *P. densa* clade were not resolved.

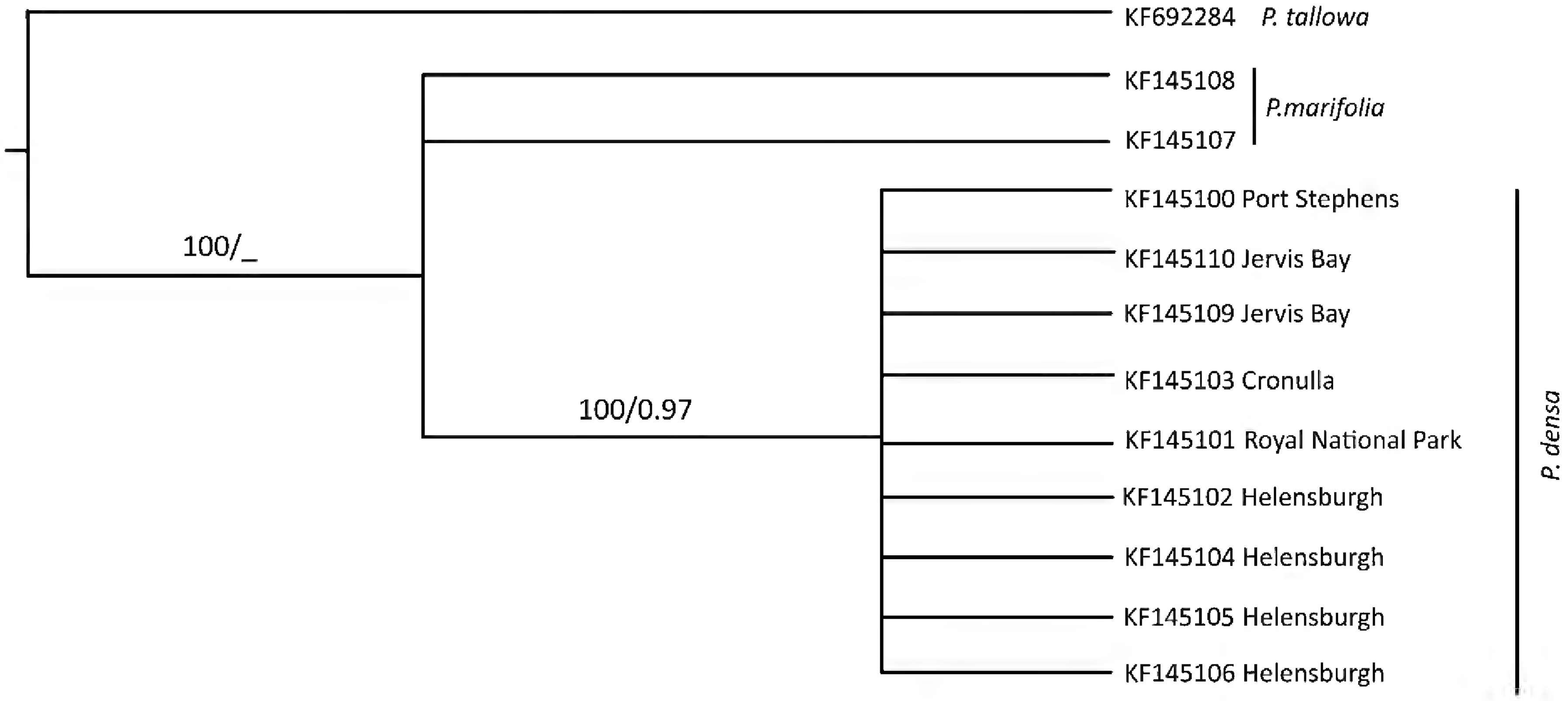

Fig. 2. The single tree from maximum parsimony analysis of the *psb*A-*trn*H chloroplast sequence data. Bootstrap values (%) from Maximum Parsimony analysis, followed by Bayesian posterior probabilities are reported on branches. Samples used are named according to GenBank identifiers, locality of populations and accepted taxonomy (refer to Table 1 for further details).

The ETS alignment was 351 characters in length (plus two indels) and had 22 variable sites (including one indel), all being parsimony-informative (6.3% of the total sites). A region containing eight base pairs could not be unambiguously aligned and so was removed before analysis. A strict consensus of 18 trees from Maximum Parsimony analysis (not presented), as well as the Bayesian inference tree (Fig. 3), were unable to resolve the relationship between a *P. marifolia* clade (BS=67%; PP=0.99) and accessions of *P. densa*. Four strongly supported clades of *P. densa* formed an unresolved polytomy. Individuals from Cronulla and the Royal National Park were recovered as a clade (BS=100%; PP=1.0), whereas each of the other disjunct populations formed strongly supported clades (Helensburgh: BS=97%; PP=0.93; Jervis Bay: BS=97%; PP=1.0; Port Stephens: BS=97%; PP=0.98).

Our sampled individuals from within Port Stephens and Helensburgh showed no genetic divergence. Accessions of *P. marifolia* from two populations differed from each other (genetic divergence = 0.0031). Two accessions of *P. densa* from the Jervis Bay population were divergent (genetic divergence = 0.0093). However, the single accessions of *P. densa* from the disjunct populations of Cronulla and Royal National Park were genetically identical for ETS.

ETS distance data supported the relative genetic dissimilarity of *P. densa* and *P. marifolia* (genetic divergence = 0.0180). Each of the well-supported populations of *P. densa* were on relatively long branches compared to those of *P. marifolia*, but none of the populations of *P. densa* or *P. marifolia* formed a well-supported relationship with any other population. Within *P. densa*, the Jervis Bay population was genetically the most divergent from the other populations. A comparison of this population to Cronulla–Royal National Park revealed a genetic divergence=0.0362, to that of Port Stephens =0.0331, and to Helensburgh =0.0234. The *P. densa* Helensburgh population is genetically most similar to *P. marifolia* (genetic divergence=0.0139). Thus,

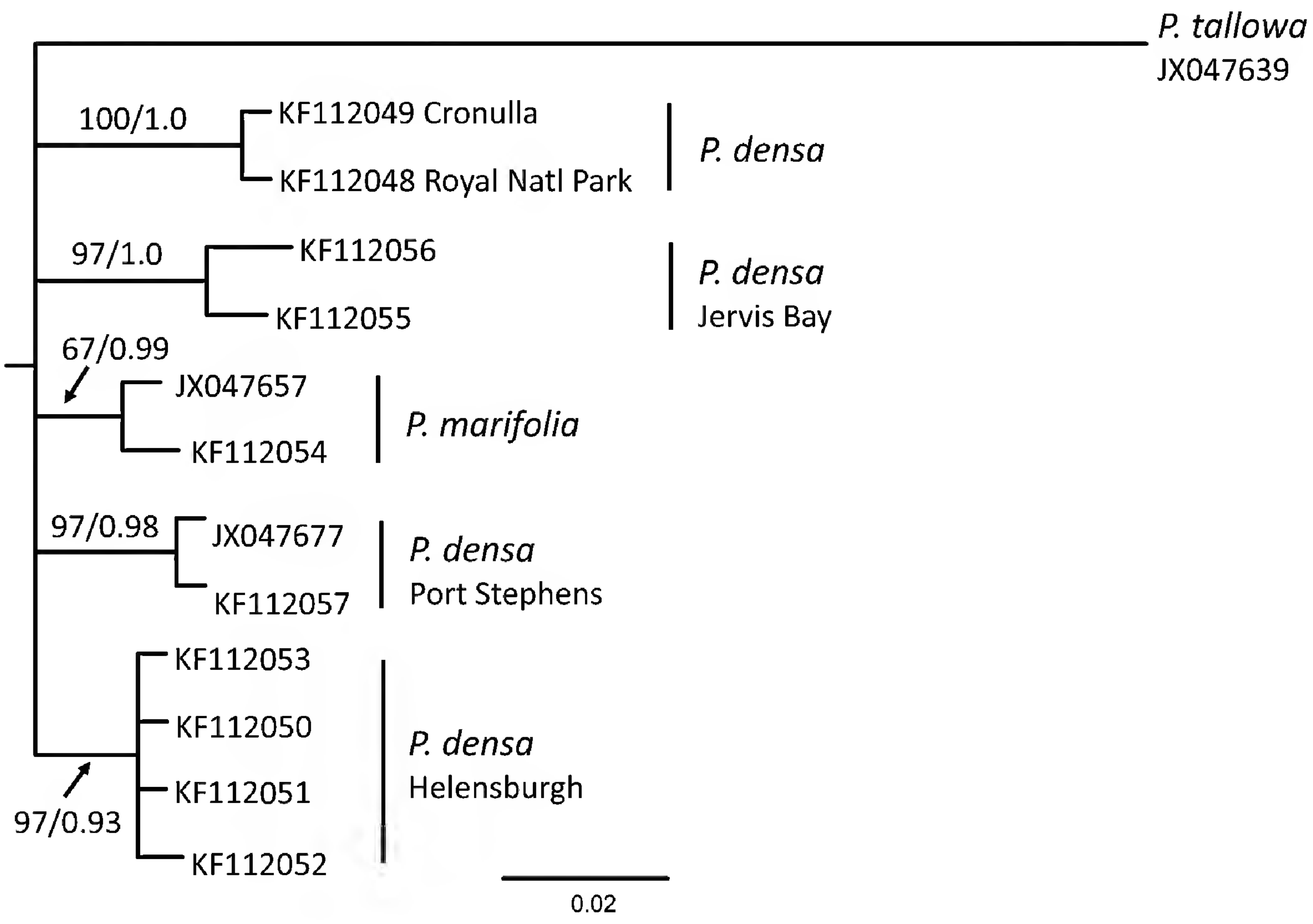

Fig. 3. 50% Majority Rule tree based on Bayesian analysis of the ETS nuclear sequence data. Bootstrap values (%) from Maximum Parsimony analysis, followed by Bayesian posterior probabilities are reported on branches. Samples used are named according to GenBank identifiers, locality of populations, and accepted taxonomy (refer to Table 1 for details). Scale bar = number of nucleotide changes.

the ETS data confirms the contention that populations of *P. densa* and *P. marifolia* are relatively genetically distinct, but cannot provide any insight into relationships between the populations of these two taxa.

Multivariate analysis

Cluster analysis and ordination supported the recognition of *P. densa* as morphologically distinct from *P. marifolia*. However, the Helensburgh accessions of *P. densa* were morphologically more similar to *P. marifolia* than to any other accession of *P. densa* (Figs 4 and 5). Compared to *P. densa, P. marifolia* has the following distinguishing characteristics: (1) longer internodes with shorter hairs; (2) leaves that are shorter; (3) leaves narrower and more glandular; (4) prophylls shorter and narrower; (5) shorter anther appendages (Table 4). The disjunct populations within *P. densa* form a morphological continuum. The characters that best separate *P. densa* from *P. marifolia*, based on Kruskal-Wallis and r^2 values, are summarised in Tables 5 and 6.

Discussion

In this study the fast evolving nuclear ETS marker (Baldwin 1992; Baldwin and Markos 1998; Linder et al. 2000), provided about ten times more variability than the *psb*A-*trn*H marker. The Bayesian inference tree derived from the ETS data (Fig. 3) shows that most of the variation is found between populations of *P. densa*, and reveals a relatively high similarity between the allopatric accessions of *P. densa* from Cronulla and from Royal National Park to the south of Sydney. In contrast, accessions from two geographically close, but functionally allopatric populations of *P. marifolia* received weak bootstrap support for a sister relationship. Analysis of the ETS data did not, however, provide any insights into the phylogenetic relationships between *P. marifolia* and *P. densa.*

The *psb*A-*trn*H spacer is often useful for distinguishing between species (Kress et al. 2005). In our study it recovered a well-supported clade comprising the *P. densa* populations, but was unable to resolve the relationship between the samples of *P. marifolia.* This result is not inconsistent with the notion that two distinct taxa are present.

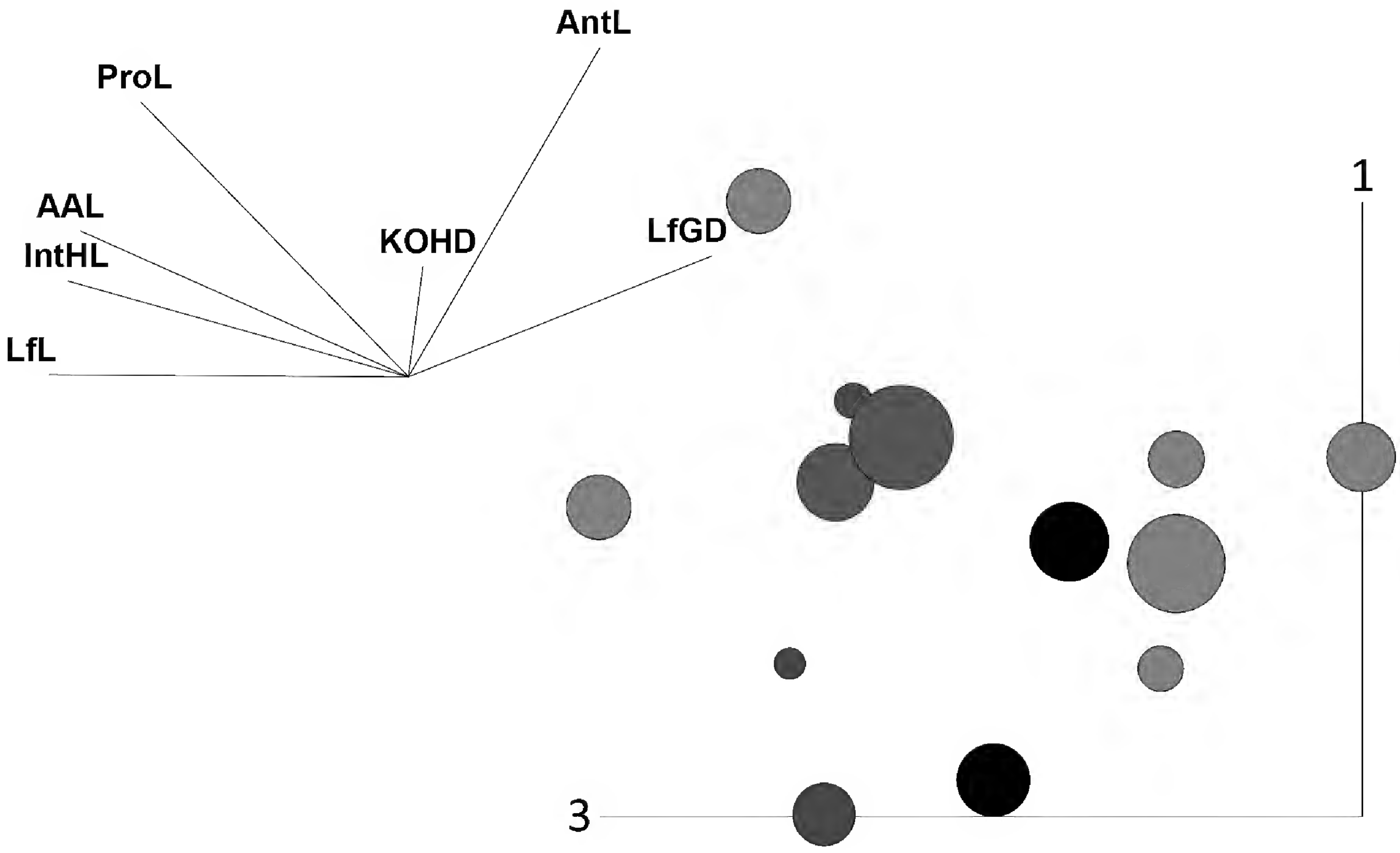

Fig. 4. Three dimensional ordination of the specimens plotted onto axes 1 and 2, with the size of each coloured circle representing its position in the third dimension. A character vector diagram of seven most important characters based on r^2 values is provided (alphabetic character codes as listed in Table 3). Colour codes: yellow = *Prostanthera marifolia*; dark brown = *P. densa* Helensburgh; red-brown = *P. densa* Jervis Bay; blue = *P. densa* Cronulla/Royal National Park; bright green = *P. densa* Port Stephens.

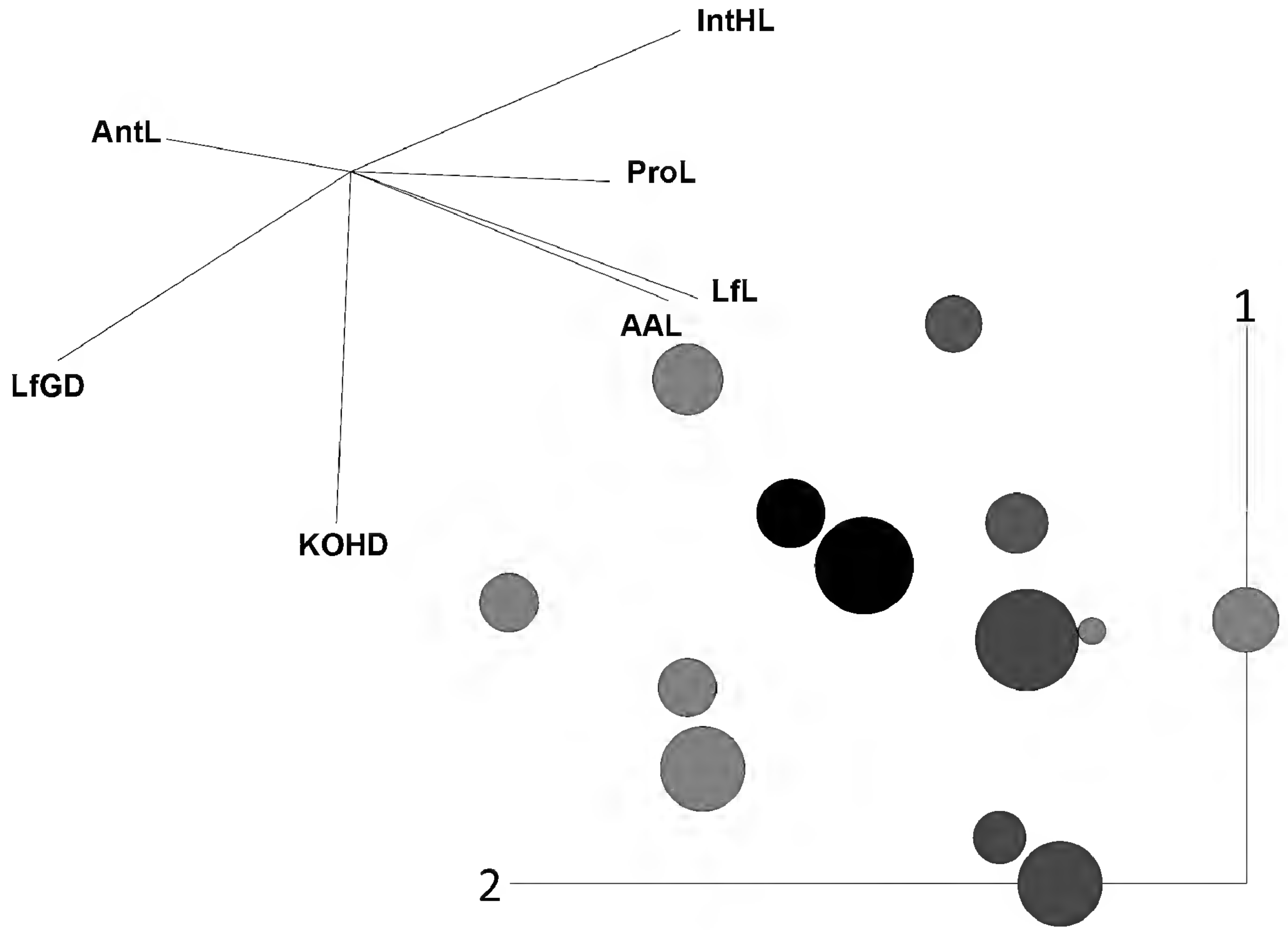

Fig. 5. Three dimensional ordination of the specimens plotted onto axes 1 and 3, with the size of each coloured circle representing its position in the second dimension. A character vector diagram of seven most important characters based on r^2 values is provided (alphabetic character codes as listed in Table 3). Colour codes: yellow = *Prostanthera marifolia*; dark brown = *P. densa* Helensburgh; red-brown = *P. densa* Jervis Bay; blue = *P. densa* Cronulla/Royal National Park; bright green = *P. densa* Port Stephens.

Table 4. Morphological differences between *Prostanthera densa* and *P. marifolia*. Character abbreviations as in Table 3.

Character	*P. densa*	*P. marifolia*
Internode length (IntL)	(2–)4–7(–12.5) mm	8.3–9.5(–14.5) mm
Internode hair length (IntHL)	up to 0.96 mm	(0.9–)1–1.4 mm
Leaf length (LfL)	up to 5.5(–8) mm	(6–)8–10(–13) mm
Leaf width (LfW)	2.8–3.5(–5.5) mm	(1.7–)5–7.1 mm
Leaf gland density on abaxial surface (LfGD)	(8.7–)17–22 mm^2	4–8.7(–13) mm^2
Prophyll length (ProL)	up to 2.5 mm	(2–)3.5–4.5(–5.5) mm
Prophyll width (ProW)	up to 0.24 mm	(0.22–)0.3–0.7(–1.7) mm
Anther appendage length (AAL)	up to 0.48 mm	(0.5–)0.8–0.9(–1.2) mm

Table 5. The five most useful characters to discriminate between ***Prostanthera densa*** and ***P. marifolia***, ranked by Kruskal-Wallis values Character abbreviations as in Table 3.

IntHL 7.7357	LfL 6.1929	IntL 5.4857	LfGD 5.4857	AAL 5.2572

Table 6. Seven morphological characters with the highest correlation values (as measured by r^2 values) based on Principal Component Correlation (PCC). Character abbreviations as in Table 3.

ProL 0.900	KOHD 0.883	AAL 0.856	LfL 0.846
LfGD 0.835	IntHD 0.799	AntL 0.753	

The multivariate analysis of 20 morphological characters also established the presence of two morphologically discrete taxa, congruent with *P. densa* and *P. marifolia* and supported by the *psb*A-*trn*H molecular data. The multivariate analysis further supported the conclusion that each taxon comprises a subset of more or less morphologically distinct populations. However, even though the *psb*A-*trn*H tree and the morphological data support the recognition of *P. densa* as a distinct taxon sister to *P. marifolia*, the morphological circumscription of each taxon is challenging.

The morphological similarity between *P. densa* growing near Helensburgh and *P. marifolia* was first recognised by Hamilton (1920). He characterised *P. densa* as being larger ('9–12 dec') and having an 'upright spreading habit', whereas *P. marifolia* was a 'scrambling undershrub of 3–5 dec'. In general, our field observations support his conclusions. Nevertheless, the density of the surrounding vegetation and degree of exposure to off-shore winds does influence the overall habit of *P. densa*. Although not included in the multivariate analyses, mature leaves of *P. densa* usually have an entire margin, unlike those of *P. marifolia* that appear to always have occasional teeth present. The utility of this character to distinguish these species is unknown. There appears to be no consistent morphological differences between the various populations of *P. densa*. The Port Stephens population tends to have leaves that are longer, with larger prophylls and a podium with a longer a_1 axis. The Helensburgh population has internodes that are longer with shorter hairs than those found in the other populations.

The type collection of *Prostanthera marifolia* (*Brown s.n.* [*Bennett* 2371], BM) and the brief description provided in the protologue (Brown 1810) are inadequate to circumscribe precisely this critically endangered species. Furthermore, the morphological similarity between *P. densa* and *P. marifolia* has made it difficult to distinguish between both species. In general, *P. densa* tends to have leaves that are larger, more 'crowded' (with shorter internodes), hairier (with longer hairs) and larger prophylls than *P. marifolia*. Other morphological differences are listed in Table 4. The morphological analyses indicate that most of the studied character states tend to overlap. In particular, populations of *P. densa* occurring in the vicinity of Helensburgh (to the south of metropolitan Sydney) shared many features with *P. marifolia*. Contrary to this, the ETS data provided no support for a relationship between populations of *P. densa* from Helensburgh and *P. marifolia* and (Fig. 3).

In this study it was found that molecular and morphological data assist in the recognition of *P. densa* and *P. marifolia*. We consider the most nomenclaturally stable conclusion is to recognise them at the species level, and to provide an enhanced description of the morphological variation within and between each species.

The conclusions of this study have implications for the conservation of *P. marifolia*, which is listed as 'critically endangered' under the *New South Wales Threatened Species Conservation Act 1995* (Conn 2007), and of

P. densa, which is listed as 'vulnerable' (under both the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* and the *TSC Act*) (Conn 1999). Since the population (consisting of 3 sub-populations) of *P. marifolia* in the Manly-Warringah area is very small (estimated population size: 100 individuals) and currently threatened by anthropogenic disturbance and habitat loss (Hughes 28 February 2011), urgent action is required to protect this species. In addition, the ETS data indicates that the four known populations of *P. densa* (Port Stephens in the north; Cronulla, Royal National Park, and Helensburgh in the centre of its distribution; Jervis Bay in the south) may each be genetically distinct. Although any future studies of the genetic diversity of these populations should use more appropriate population genetic approaches (including increased samplings and investigation of within- and between-population relationships using molecular markers, such as chloroplast and nuclear microsatellites), the conservation of the genetic diversity within *P. densa* requires resource management strategies that conserve all known disjunct populations. Each of the individual populations of *P. densa* appear to be endangered. Although all populations of this species should be prioritised for conservation actions, there is no 'critically endangered' category for populations in the *New South Wales Threatened Species Conservation Act 1995* (Anonymous 28 February 2011).

Thirteen priority recovery actions have been identified for *P. densa* by the New South Wales Office of Environment and Heritage (Anonymous without date). Action 9 of these recovery actions, listed as high priority, is to "Review taxonomic classification especially with reference to *Prostanthera marifolia*". Action 10, listed as a medium priority, is to "Review conservation status endangered/critically endangered (after taxonomic review)". As this study suggests that all known populations of *P. densa* need to be protected to conserve the genetic diversity of the species, it is strongly recommended that the conservation status of this species be upgraded to endangered or critically endangered. A survey of the current distribution of each population, as recommended in priority recovery action 1, is also likely to be important in this review of conservation status.

Taxonomic descriptions

1. ***Prostanthera densa*** A.A.Ham., *Proceedings of the Linnean Society of New South Wales* 45 (1920) 263.

Holotype: New South Wales: Central Coast: Cronulla, *A.A. Hamilton 9, anno* 1911 (NSW134507); iso.: BM, K (refer Notes below).

Erect, more or less compact to openly branched shrub, 0.3–2 m high; faintly aromatic. *Branches* subterete, moderately to densely hairy [(8–)30–90 hairs/mm^2]; hairs ± straight to variously curved and/or bent, spreading or slightly retrorse, c. 0.8–1.5 mm long, white; sparsely glandular [4–9(–13) glands/mm^2]. *Leaves* green, faintly aromatic (when crushed), usually moderately to densely hairy [(13–)30–90(–160) hairs/mm^2]; sparsely glandular [as for branches]; *petiole* (0.4–)0.8–1.5 mm long; *lamina* ovate, often appearing triangular when distal margin strongly recurved, (6–)10–15 mm long, (3.5–)7–12 mm wide [length to width ratio 1.2–1.4(1–1.7), length of maximum width from base to total lamina length ratio 0.8–4.5]; base rounded to ± truncate; margin entire, usually strongly recurved; apex rounded to obtuse; venation not visible, except for midrib raised on abaxial surface. *Inflorescence* a frondose racemiform conflorescence, uniflorescences monadic; 2–10-flowered [per conflorescence]. *Pherophylls* absent. *Podium* 0.9–2.5 mm long, moderately hairy and glandular [as for branches]. *Prophylls* inserted near middle or on basal half of podium [a_1 axis to anthopodium ratio 1–3.6], opposite, linear (broadest near middle or on distal half), 2.1–5.5 mm long, 0.2–0.7(–1.7) mm wide [length to width ratio (3.2–)6.5–10.5, length of maximum from base to total lamina length ratio 0.5–0.7], with long spreading hairs [as for branches]; base attenuate; margin entire; apex tapering. *Calyx* green, sometimes with maroon coloration; outer surface sparsely to moderately hairy [13–35(–56) hairs/mm^2], hairs spreading, 0.5–0.9 mm long; sparsely to moderately glandular [10–15 glands/mm^2]; tube (1.8–)2–4 mm long; *abaxial lobe* very broadly ovate, 2.4–2.8 mm long, 3.5–4 mm wide [length to width ratio c. 0.7], *apex* obtuse to rounded; *adaxial lobe* very broadly ovate, 2–3 mm long, 3–4 mm wide [length to width_ratio 0.5–0.8], *apex* obtuse [adaxial lobe length to abaxial lobe length ratio 0.8–1.1]. *Corolla* 12–15 mm long, pale mauve to mauve, white on inner abaxial surface of tube, with rusty-orange markings in tube; outer surface sparsely hairy [10–25 hairs/mm^2], sparsely glandular [10–16 glands/mm^2]; inner surface sparsely hairy [6–12 hairs/mm^2]; *tube* (5–)6–8 mm long; *abaxial median lobes* very broadly obovate or spathulate, 6.5–10(–12) mm long, 6–7(–9) mm wide [length to width ratio 0.9–1.4], apex bilobed (sinus 0.8–2 mm long, 2–4 mm wide distally); *lateral lobes* slightly oblong, 2.5–5 mm long, 2–2.5 mm wide [length to width ratio 1.2–2], apex slightly undulate, obtuse to almost truncate; *adaxial median lobe-pair* depressed ovate, 3–4.5 mm long, 4.5–8 mm wide [length to width ratio 0.4–0.6], deeply bilobed (sinus 1.5–2 mm long), apex of each lobe rounded. *Stamens* inserted 1.5–2 mm above base of corolla; filaments 2.5–3 mm long, glabrous; anthers 0.8–1 mm long, lobes slightly cristate on basal dorsal surface (trichomes narrowly triangular, c. 0.1 mm long), lobes with basal acumen to 0.1–0.2 mm long, connective extended to form basal appendages 0.5–1.3 mm long, terminating in a few triangular trichomes c. 0.1 mm long. Disc ± cylindrical, 0.2–0.3 mm long. *Pistil* 6–8 mm long; *ovary* cylindrical to obovoid,

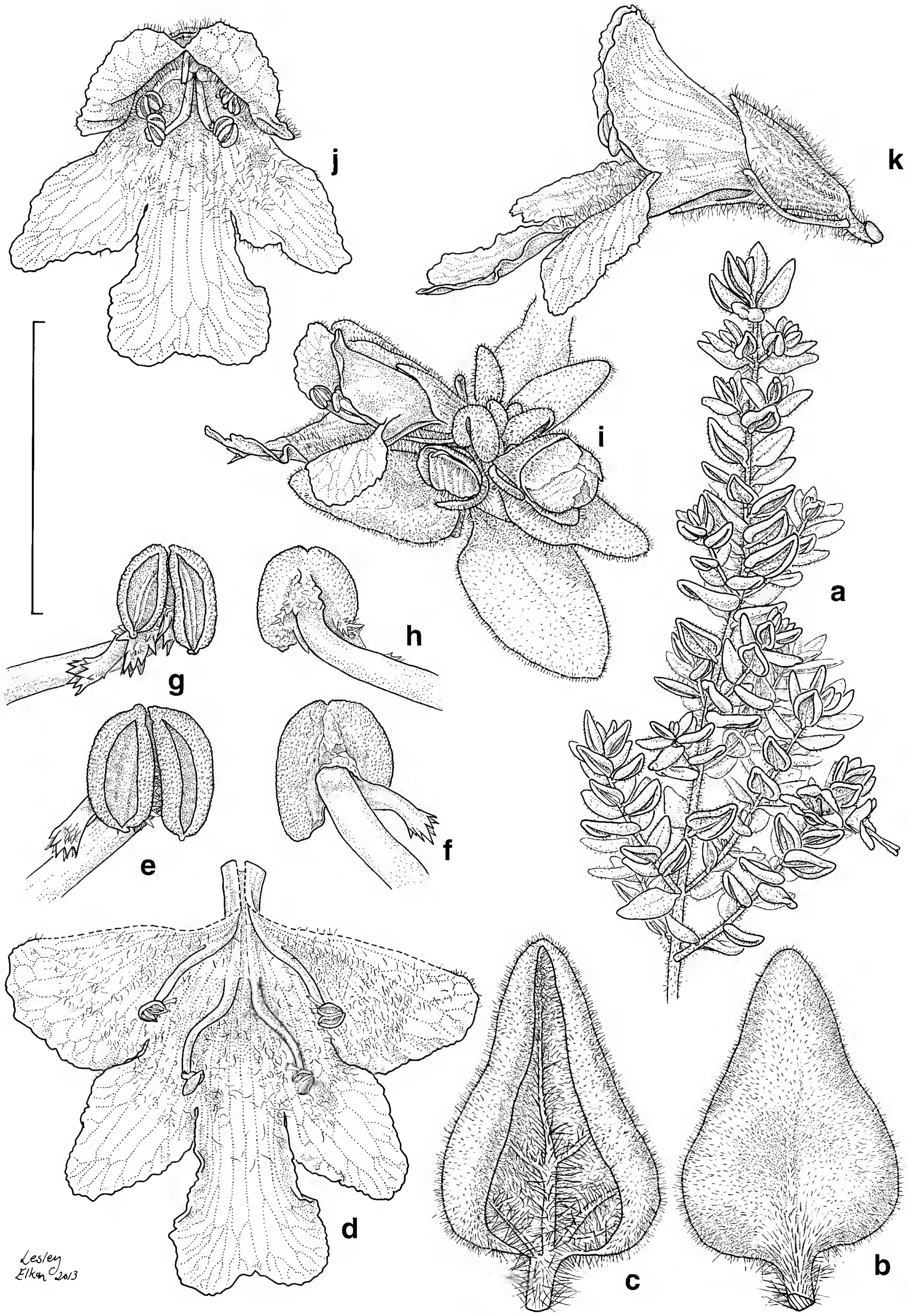

Fig. 6. Illustration of *Prostanthera densa*. **a,** habit with flowers; **b,** detail of adaxial surface of leaf showing indumentum; **c,** detail of abaxial surface of leaf showing recurved margin and indumentum; **d,** open corolla showing corolla lobes, tube and androecium; **e,** abaxial stamen, showing ventral view of dehisced anther locules, anther appendage and filament; **f,** abaxial stamen showing dorsal view of anther locules, connective, anther appendage and filament; **g,** adaxial stamen showing ventral view of dehisced anther locules, triangular trichomes on base of connective, anther appendage and filament; **h,** adaxial stamen, showing dorsal view of anther locules, connective, partial view of trichomes on base of connective, partial view of anther appendage, and filament; **i,** detail of flowering branchlets, with flowers and buds in axils of crowded leaves (internodes reduced), showing podium, prophylls, calyx, corolla and stamens in open flower; **j,** ventral view of open flower, showing open corolla, androecium and partial view of style and stigma; **k,** lateral view of open flower, showing prophylls, calyx and corolla, with abaxial stamens partially visible, and position of style and stigma indicated by stippling (all *B.J. Conn 2563*). Scale bar: a = 50 mm; b–d = 10 mm; e–h = 2.5 mm; i = 15 mm; j & k = 10 mm. Illustrator: Lesley Elkan

0.4–0.5 mm long, diameter at base 0.3–0.4 mm, lobes 0.1–0.2 mm long, glabrous; *style* 6–7 mm long; *stigma lobes* 0.2–0.3 mm long. *Fruiting calyx* not enlarged. *Mericarps* 0.8–1 mm long (presumed immature), distally c. 0.5 mm extended beyond base of style, distal diameter c. 1 mm; mature seeds slightly obovoid-cylindrical, 0.8–1.2 mm long, 0.5–0.8 mm diameter (Figs 6, 7a–d).

Habitat: Occurring in sandy soils, amongst sandstone outcrops and on sedimentary conglomerates, in low open forest and coastal shrublands, dominated by *Angophora costata*, *Corymbia gummifera*, *Eucalyptus pilularis*, *E. punctata*, *Syncarpia glomerulifera*, *Allocasuarina distyla*, *A. littoralis*, *Banksia integrifolia*, *B. spinulosa*, *Hakea sericea*, *Acacia terminalis*, *A. myrtifolia* and other myrtaceous and proteaceous shrubs.

Conservation status: This species is listed as 'Vulnerable' under the *New South Wales Threatened Species Conservation Act 1995* (Anonymous 07 September 2012). However, since all populations of this species appear to be endangered, these should be prioritised for conservation actions.

Selected specimens examined: NEW SOUTH WALES: North Coast: Port Stephens: Gan Gan Hill, *B.J. Conn 2601 & B. Timmis*, 28 Sep 1987 (A, L, MEL, NSW, RSA, S); *R.G. Coveny 16459, S.F. McCune & T.M. Tame*, 10 Mar 1993 (AD, BRI, CANB, CHR, HO, K, L, MEL, MO, NSW, PE, PRE, RSA); *R. Johnstone 1003, S. Peel & Y. Murakami*, 16 Nov 2001 (NSW); *T.C. Wilson 37 & A.J. Perkins*, 12 Dec 2006 (NSW).

Central Coast: Cronulla: Bass & Flinders Point, *B.J. Conn 2563*, 4 Jul 1987 (NSW); *4381A & H.M. Conn*, 18 Aug 2007 (NSW); Helensburgh: near Ridge Road, *B.J. Conn 2565 & B Timmis*, 18 Jul 1987 (NSW); *A.T. Fairley s.n.*, 3 Oct 2001 (NSW497964); Wilson Dam, *J.A. Scott 1–4 & A.D. Auld*, 6 Jun 2007 (BRI, NSW); Wilson Creek Road, *T.C. Wilson 221, 222, 224*, 17 Oct 2009 (NSW); Royal National Park: Audley, *R.G. Coveny 4038 & R. Bisby*, 21 Mar 1972 (NSW); Marley, *N. Byrnes s.n.*, 2 Jun 1948 (NSW128299); N of Big Marley Beach, *A.T. Fairley s.n.*, 12 Aug 2005 (NSW732721), c. 200 m off Marley Fire Trail, *T.C. Wilson 173*, 16 Apr 2008 (NSW).

South Coast: Jervis Bay: Beecroft Peninsula: Abrahams Bosom Reserve, *B.J. Conn 2566–2571 & B. Timmis*, 18 Jul 1987 (NSW), *M.J. Henwood 800, anno* 2006 (SYD); 'Trig Station', *B.J. Conn 2572–2574 & B. Timmis*, 18 Jul 1987 (NSW); Cabbage Tree Beach, *L. McDougall 84*, 28 Aug 1988 (NSW); Jervis Bay, *H. Posamentier s.n.*, Nov 1970 (NSW269427); Devils Hole, 2 miles NE of Point Perpendicular, *E.F. Constable s.n.*, 28 Feb 1960 (NSW); Currarong Road at Point Perpendicular Road junction, *T.A. James 2 & R.G. Coveny*, 29 Sep 1981 (NSW); 30 m N of Currarong Road, *J. Miles s.n.*, 25 Apr 2002 (NSW496550).

Notes: Hamilton (1920) recorded *P. densa* as growing in 'profusion on the ocean slope of the rocky headland … at Cronulla … confined to a limited area between the ocean beach at Cronulla and the northern entrance to Port Hacking.' The only extant population from the type locality now appears to be restricted to a few plants near Bass and Flinders Point.

2. *Prostanthera marifolia* R.Br. *Prodromus* (1810) 509.

Lectotype (here chosen): *R. Brown s.n.* [*J.J.Bennett 2371*], *anno* 1802–1805 [include data from WT Stearn 'Introduction' to Brown (1960)], '10 Prostanthera marifolia Prodr. 509' (handwritten label upper left of sheet), 'New South Wales: North shore of Sydney district (Port Jackson)' (lower right printed label), 'North Shore, Port Jackson' (on reverse side of label/sheet) (BM); probable isolectotypes: 'Prostanthera marifolia Port Jackson' (upper right handwritten label), 'New South Wales: North shore of Sydney district (Port Jackson)' (lower right printed label – as for lectotype) (BM); 'Prostanthera marifolia North shore of Sydney' (handwritten label near lower centre of sheet attached to following label), 'R. Brown, Iter Australiense, 1802–5 [Presented by direction of J.J. Bennett 1876] Ex. Herb. Hort. Bot. Reg. Edin.' (printed label) (LE – lower half of sheet and fragments upper left); 'Prostanthera marifolia Prodr. 509 Port Jackson' (handwritten label near lower right of sheet, in same hand as lectotype, with 'Brown' inserted in another hand), 'Port Jackson Brown Herb. Swartzii' (handwritten label lower right of sheet) (S)

Synonym: *Prostanthera* sp 'Manly Dam' (Conn 4444). *Based on:* New South Wales: Central Coast: Manly-Warringah area, *Conn 4444, Stevenson & Ewings*, 07 Mar 2002 (CANB, BRI, NSW).

Erect, openly branched shrub up to c. 0.3 m high; faintly aromatic. *Branches* subterete, sparsely to moderately hairy [16–20 hairs/mm^2]; hairs ± straight, spreading or slightly retrorse, c. 0.3–0.6 mm long, white; sparsely glandular [up to 6 glands/mm^2]. *Leaves* green, faintly aromatic (when crushed), sparsely to moderately hairy [as for branches]; sparsely glandular [as for branches]; *petiole* 0.5–1 mm long; *lamina* ovate to almost elliptic, 8–12(–15) mm long, 4–6(–8) mm wide [length to width ratio 1.7–2.2, length of maximum width from base to total lamina length ratio 4–6]; base shortly attenuate; margin entire or occasionally slightly 1-lobed on each side, rarely with one additional lobe, may appear bluntly 1-toothed on each side because margin slightly recurved; apex rounded; venation not visible, except midrib raised on lower surface. *Inflorescence* a frondose racemiform conflorescence, uniflorescence monadic; 2–8(–12)-flowered [per conflorescence]. *Pherophylls* absent. *Podium* 1–1.5(–2.3) mm long, sparsely to moderately hairy [as for branches], sparsely glandular [as

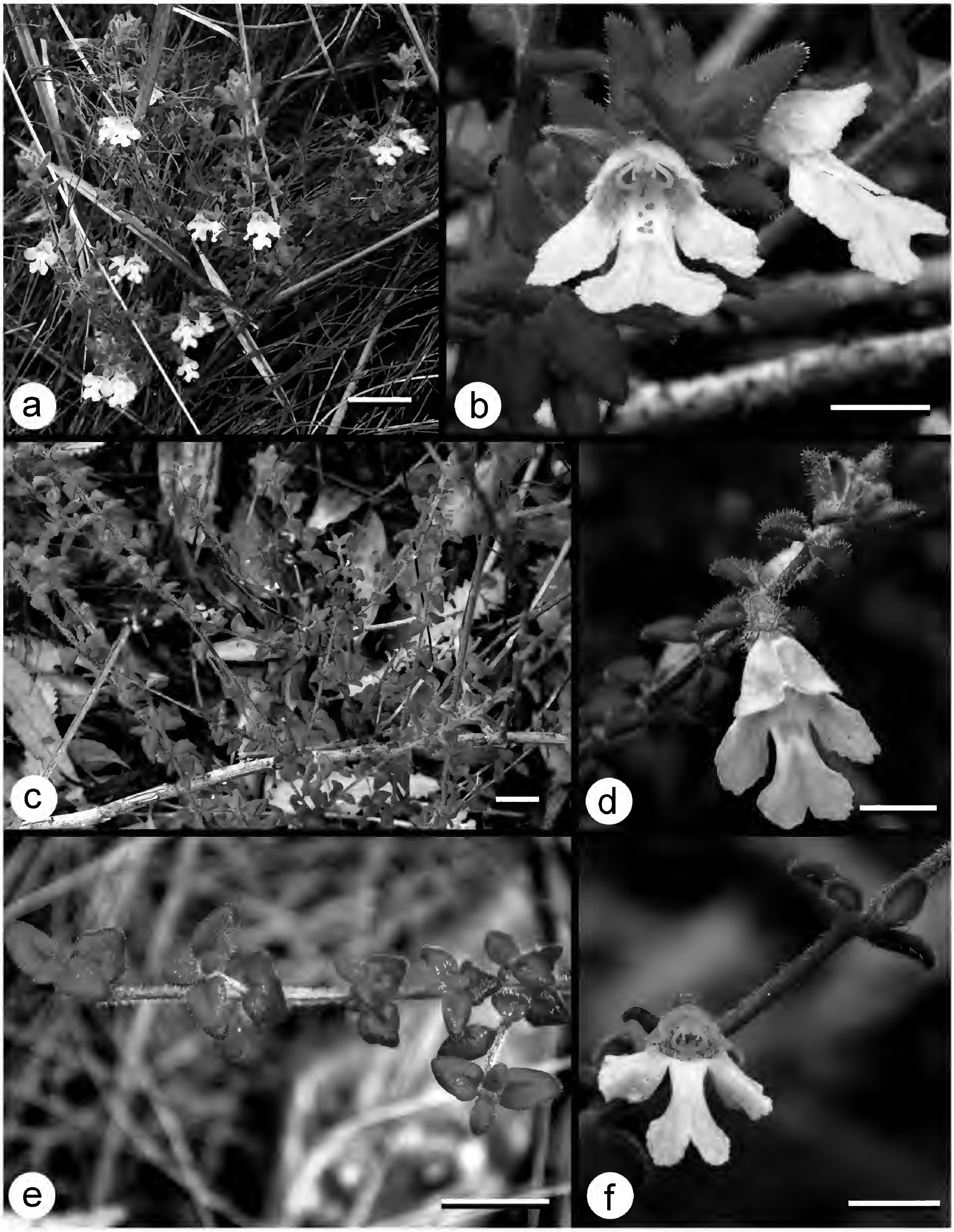

Fig. 7. Images of *Prostanthera densa* and *P. marifolia*. **a,** habit of *P. densa* from Currarong. **b,** flower and leaves of *P. densa* from Currarong. **c,** habit of *P. densa* from near Helensburgh. **d,** flower and leaves of *P. densa* from near Helensburgh. **e,** habit of *P. marifolia*. **f,** flower and leaves of *P. marifolia*. Scale bar: a, c & e = 3 cm; b, d & f = 1 cm. Photographs: T.C. Wilson.

for branches]. *Prophylls* inserted near middle or on distal half of podium [a_1 axis to anthopodium ratio 1.2–1.9], opposite, narrowly elliptic to narrowly obovate, 1–1.5 mm long, c. 0.2 mm wide [length to width ratio 5–8, length of maximum width from base to total lamina length ratio 0.6–0.9], with long spreading hairs [as for branches]; base attenuate or truncate to very slightly broader; margin entire; apex obtuse. *Calyx* light green, with mauve-purple tinge adaxially; outer surface sparsely to moderately hairy [10–18 hairs/mm^2], hairs spreading, 0.4–0.8 mm long; sparsely to moderately glandular [10–15 glands/mm^2]; tube 1.3–1.8(-2) mm long; *abaxial lobe* very broadly ovate, 2.5–3.8 mm long, 2.2–3.2 mm wide [length to width ratio 1.1–1.2], *apex* obtuse to rounded; *adaxial lobe* very broadly ovate, 2.5–3.6 mm long, 2.5–3 mm wide [length to width ratio 1–1.2], *apex* obtuse [adaxial lobe length to abaxial lobe length ratio 0.9–1]. *Corolla* (9–)10–15 mm long, mauve, white on inner abaxial surface of tube; outer surface sparsely to moderately hairy [10–30 hairs/mm^2], sparsely glandular [10–16 glands/mm^2]; inner surface sparsely to moderately hairy (similar to outer surface); *tube* (5-)6–8 mm long; *abaxial median lobes* very broadly obovate or spathulate, 8–10(-12) mm long, 6–7(-9) mm wide [length to width ratio 0.9–1.2], apex bilobed (sinus 1.8–3 mm long, 2–3 mm wide distally); *lateral lobes* obovate to slightly oblong, 6–8(–9) mm long, 4–6 mm wide [length to width ratio 1–1.5], apex slightly undulate, obtuse; *adaxial median lobe-pair* depressed ovate, 3–4(–4.5) mm long, 6.5–8(–9) mm wide [length to width ratio 0.4–0.5], deeply bilobed (sinus c. 3 mm long), apex of each lobe rounded. *Stamens* inserted 1.5–2 mm above base of corolla; filaments 3–3.5 mm long, glabrous; anthers 0.8–1 mm long, lobes slightly cristate on basal dorsal surface (trichomes narrowly triangular, c. 0.1 mm long), lobes with basal acumen to 0.1–0.2 mm long, connective extended to form basal appendages 0.6–0.9 mm long, terminating in a few triangular trichomes c. 0.1 mm long. Disc ± cylindrical, 0.2–0.3 mm long. *Pistil* 6–8 mm long; *ovary* cylindrical to obovoid, 0.4–0.5 mm long, diameter at base 0.3–0.4 mm, lobes 0.1–0.2 mm long, glabrous; *style* 6–7 mm long; *stigma lobes* 0.3–0.4 mm long. *Fruiting calyx* not to very slightly enlarged (abaxial lobe 3.5–3.8 mm long, c. 3.5 mm wide [length to width ratio 1–1.1]; adaxial lobe 3.5–3.7 mm long, c. 3.5 mm wide [length to width ratio 1–1.1]; [adaxial lobe length to abaxial lobe length ratio c. 1]). *Mericarps* 1.5–1.8 mm long, distally c. 0.5 mm extended beyond base of style, distal diameter c. 1 mm; mature seeds slightly obovoid-cylindrical, c. 1 mm long, 0.5–0.7 mm diameter (Figs 7e, 7f and 8).

Habitat: Duffy's Forest Ecological Community. Woodland dominated by *Eucalyptus sieberi* and *Corymbia gummifera*, growing in deeply weathered clay soil with ironstone nodules.

Conservation status: This species is listed as 'Critically endangered' under the *New South Wales Threatened Species Conservation Act 1995* (Anonymous 28 February 2011) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (Anonymous 2013) and as a consequence, the reference to this species being "presumed extinct" (Part 4 of Schedule 1 of the Act) has been omitted. Listing of critically endangered species is provided for by Part 2 of the Act" (Hughes 28 February 2011).

Selected specimens examined: NEW SOUTH WALES: Central Coast: Mosman, *R.H. Cambage 696*, 20 Sep 1902 (SYD), *Chapman s.n.*, 13 Jan 1907 (SYD); Manly-Warringah area: *A.D. Auld 11*, 03 Oct 2002 (NSW 499352); *B.J. Conn 4443a, Stevenson & Ewings*, 07 Mar 2002 (CANB, MEL, NY, NSW), *4443b* (CANB, MEL, NY, NSW), *4444*, (CANB, BRI, NSW); *4380A & J.T. Hadiah*, 18 Mar 2007 (NSW); *5676, J.T. Hadiah & T.C Wilson*, 19 Aug 2011 (NSW); *N.J. Skelton s.n.*, 29 Jan 2002 (NSW495446); *D. Stevenson M000–M004, M006*, 19 Oct 2001 (NSW); Hunters Hill, *A.A. Hamilton s.n.*, Sep 1906 (NSW134433); 'Port Jackson', *A. Cunningham s.n., anno* 1836 (LE – upper half of sheet); 'Suspension Bridge', *Johnston s.n.*, 20 Jan 1903 (SYD); Northbridge, *H.S. McKee s.n.*, 17 Nov 1951 (SYD); Longueville, Lane Cove, *H.M.R. Rupp s.n.*, Apr 1917 (MEL43365).

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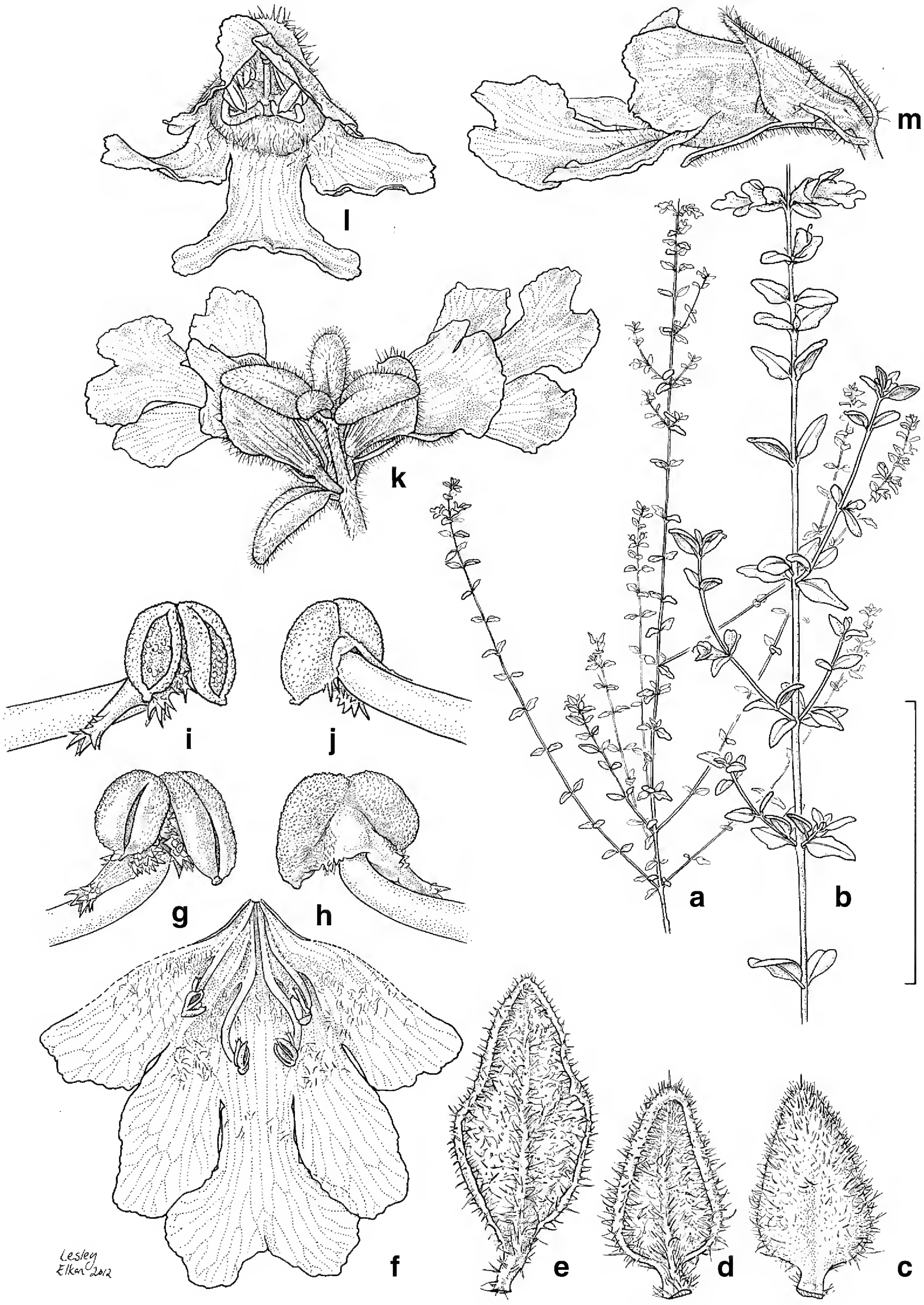

Fig. 8. Illustration of *Prostanthera marifolia*. **a,** branchlet showing open habit; **b,** detail of branchlet with flowers and developing fruits; c, detail of abaxial surface of leaf, showing hairs and slightly toothed, recurved margin; **d,** detail of abaxial surface of leaf, with margin lacking teeth; **e,** detail of adaxial surface of leaf; **f,** open corolla showing corolla lobes, tube and androecium; **g,** abaxial stamen, showing ventral view of dehisced anther locules, anther appendage, triangular trichomes on connective, and filament; **h,** abaxial stamen showing dorsal view of anther locules, connective with triangular trichomes, anther appendage and filament; **i,** adaxial stamen showing ventral view of dehisced anther locules, triangular trichomes on base of connective, anther appendage and filament; **j,** adaxial stamen, showing dorsal view of anther locules, connective, partial view of trichomes on base of connective, partial view of anther appendage, and filament; **k,** detail of flowering branchlets, with flowers in axils of leaves, internodes extended, showing podium, prophylls, calyx, and corolla of open flower; **l,** ventral view of open flower, showing open corolla, androecium and partial view of style and stigma; m, lateral view of open flower, showing prophylls, calyx and corolla, with abaxial stamens partially visible, and position of style and stigma indicated by stippling (a, b & e: B.J. Conn 4443a; c, d, f–m: T.C. Wilson 59). Scale bar: a = 150 mm, b = 50 mm, c–f = 10 mm, g–j= 2.5 mm, k = 15 mm, l & m = 10 mm. Illustrator: Lesley Elkan.

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Floral biology of large-flowered *Thelymitra* species (Orchidaceae) and their hybrids in Western Australia

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Abstract

Historically, only a few large flowered species in the genus *Thelymitra* were identified as obligate out-breeders. We compared floral presentation, pollen-pistil interactions, pollination ecology, and interspecific hybridization in two populations of *T. macrophylla* where its flowering periods overlapped with *T. antennifera* (Tenterden) and *T. crinita* (Lesmurdie) respectively. Pollen-pistil interactions were studied using glasshouse collections of *T. crinita* and *T. macrophylla* at KPBG. The number of flowers per inflorescence in *T. macrophylla* varied significantly between sites. Climatic conditions influenced flower opening and closing regimes differently in *T. crinita* vs. *T. macrophylla*. While all three *Thelymitra* species opened on warm, sunny mornings and closed by late afternoon, *T. crinita* at Lesmurdie was significantly more likely to open its perianth segments on cool days compared to the co-blooming, sympatric flowers of *T. macrophylla*. The floral lifespans of individual flowers of *T. macrophylla* and *T. crinita* were reduced significantly following application of *Thelymitra* pollen onto the stigmatic surface but were not reduced by pollinarium removal. Flowers of both species were self-compatible but neither species self-pollinated mechanically (autogamy). Fluorescence microscopy also showed that both species were inter-compatible. Natural rates of pollinarium removal by insects were low in all three species at both sites. Natural rates of pollen deposition on receptive stigmas were significantly higher in *T. crinita* vs. *T. macrophylla* but pollen deposition was less than 12% in both species. Observations and collections of pollinators were infrequent and pollinaria vectors were restricted to a few polylectic, female bees in the families Apidae, Colletidae, and Halictidae. We found a large number of hybrids between *T. antennifera* and *T. macrophylla* at Tenterden but few obvious hybrids between *T. crinita* and *T. macrophylla* at Lesmurdie. As expected, all hybrids showed characteristics intermediate between their two putative parent species, including pollen configuration in the *T. crinita* × *T. macrophylla* specimens. Due to malformations of the column, the majority of *T. antennifera* × *T. macrophylla* flowers appeared unable to attach their pollinia to their respective rostella.

Introduction

Ongoing revisions of *Thelymitra* J.R.Forst. & G.Forst. have expanded this genus to over 100 species from the southern Philippines to seasonally moist-temperate Australasia (Brown *et al*., 2008; Jeanes 2004, 2006, 2009, 2013). While a range of vegetative and floral characters is used to segregate species of *Thelymitra*, orchid taxonomists rarely use labellum traits in this genus. Most of the species in the genus have a radially symmetrical perianth with a labellum identical to the two lateral petals. When taxonomists compare and segregate taxa in the genus *Thelymitra*, they are more likely to focus on the relative size, degree of fusion, inflation, and ornamentation of structures confined to the hooded column (see Bishop 1996; Erickson 1965; Jeanes 2006; Rupp 1942). Variation in the physical size of the flowers and mitra ornamentation in *Thelymitra* species was used in the interpretation of major trends in floral evolution by Burns-Balogh and Bernhardt (1988).

When the Australian botanist, Robert David Fitzgerald (1830–1892) examined the flowers of several *Thelymitra* species, he subdivided them into two reproductive systems based on his observations and an experimental procedure he derived from Darwin (1862). Fitzgerald noted that small-flowered species had friable pollinia (contents of each anther cell crumbled instead of remaining in a cohesive and entire pollinium). Their fragments fell onto their receptive stigmas spontaneously as their solitary anthers dehisced. In contrast, the large-flowered species produced entire and paired, pollinia that attached to a viscidium (naked and detachable rostellum) upon anther dehiscence. In large-flowered species the pollinia didn't fragment or fall onto the stigma. Fitzgerald showed that the paired pollinia in a large-flowered, *Thelymitra* species could be withdrawn completely, when the tip of a pin adhered to the viscidium. The pollinia did not contact the stigma lobes when the pollinarium (two pollinia pairs + one viscidium) was removed in this manner.

Therefore, Fitzgerald's published texts and folios (Fitzgerald 1875–1894) concluded that self-pollinating *Thelymitra* species could be recognized on the bases of their smaller flowers and tardily opening perianth segments. However, Fitzgerald warned that the transition from cross- to self-pollination was gradual and so discrete it could occur within the same species. Recent taxonomic revisions of the genus suggest that almost half of the >100 (A. Brown, pers. comm.) described species are facultative to obligate self-pollinators (Jeanes 2004, 2006, 2009; Jones, 1988). Regardless of flower size, Fitzgerald never described insect-mediated pollination in a *Thelymitra* species Cheeseman (1880), working in New Zealand, found thrips feeding on pollen of *T. longifolia,* a small-flowered species, but discounted these tiny insects as pollinators.

In fact, insect-mediated and putative cross-pollination has been described, thus far, in only six large-flowered species. Jones (1981) was the first to observe bees carrying the pollinaria of Australian *T. media* and *T. aristata,* both large-flowered species, on the last two abdominal segments of their abdomens. The bees were observed to clasp the ornamented and pigmented clinandrium or mitra (*sensu* Burns-Balogh and Bernhardt 1988) hooding the exposed pollinarium and stigma. Bernhardt and Burns-Balogh (1986) also observed and caught a few, female bees on large-flowered, *T. megcalyptra* (syn. *T. nuda*) and these bees also landed on and clasped the ornamented and pigmented mitra. Remnants of the pollinia were found, once again, on the dorsum of the bees' abdomen. Similar observations, collections, and abdominal depositions of pollinaria were found on bees collected on large-flowered *T. antennifera* (Dafni and Calder 1987), *T. epipactoides* (Cropper and Calder 1990), and *T. ixioides* (Sydes and Calder 1993). The dominant pollinators of all three species were female, native, and polylectic bees in families Apidae and Halictidae. The exception to the rule was *Syrphus damaster* (Syrphidae) and the solitary wasp (*Eurys* species) carrying pollinaria of *T. antennifera* on their heads. All *Thelymitra* species studied failed to secrete nectar and did not offer edible pollen to insect foragers. Dafni and Bernhardt (1990) concluded that insect-pollination within the lineage was most likely based on guild mimesis in which the *Thelymitra* flower mimicked co-blooming species offering pollen and/or pollen and nectar to female bees foraging for their offspring. These included the yellow flowers of *Goodenia* and *Hibbertia* species for *T. antennifera* and a wide range of blue-purple flowers of various petaloid monocotyledons for *T. megcalyptra* and similar species. The bee's abdomen appears to clasp the underside of the mitra. When the bee prepared to fly away, the abdomen unclasped and swung downward, contacting the viscidium. As the same bee prepared to clasp the mitra of a second column, the pollinia-laden abdomen should swipe against the stigmatic lobes.

It is curious that all six studies described above were completed in eastern Australia when the south western corner of the state of Western Australia is the centre of diversity for the genus *Thelymitra* and appears to support the largest populations of large-flowered species (Brown *et al.* 2008; Jeanes 2006, 2009; Jones 1988). As a number of species have overlapping flowering periods and distributions, interspecific hybrids were recorded frequently (Bates and Weber 1990; Brown *et al.* 2008).

We selected *T. antennifera, T. crinita,* and *T. macrophylla* for additional studies on the floral biology of large-flowered species for three reasons. First, living collections of *T. crinita, T. macrophylla* and their putative hybrid were included in the glasshouse collection at the Kings Park and Botanic Garden (KPBG) in West Perth, Western Australia. This afforded opportunities to test breeding systems of two large-flowered species at the intra- and interspecific levels. Second, extensive populations of *T. macrophylla* were found at two, disjunct sites. At one site, it overlapped with the flowering of an extensive population of *T. antennifera* and their putative hybrid while, at the second site it overlapped with *T. crinita* and their putative hybrid. With two large populations of *T. macrophylla*, it became possible to compare the inflorescence length vs. the number of flowers per inflorescence at two sites and then compare the influence of climate on the opening and closing of flowers at each site. Third, the morphology of the mitra of *T. crinita* is similar to eastern *T. ixioides* (Sydes and Calder 1993) while the mitra of *T. macrophylla* is similar to eastern *T. megcalyptra* (Bernhardt and Burns-Balogh 1986). This offered the opportunity to compare prospective pollinators and their visitation rates of two, co-blooming species *in situ*. It also gave us the opportunity to compare characters of parent species and their putative hybrids.

Comparing the floral biology of three, large-flowered species in large populations allowed us to test hypotheses regarding the evolution in a lineage. This required a combination of techniques and protocols using biometry, breeding experiments, and field and glasshouse observations, as floral presentation in flowers 'pollinated-by-deceit' is usually a multi-layered syndrome (Dafni and Bernhardt 1990).

Materials and methods

Study species. We studied populations of *T. antennifera*, *T. crinita*, *T. macrophylla*, and their putative hybrids (Figs 1–8). Descriptions of floral morphology of all three species and the *T. antennifera* × *T. macrophylla* hybrid follow Brown *et al.* 2008.

Study sites, field populations *vs* glasshouse collections. Field and glasshouse studies on *T. macrophylla* (scented sun orchid), *T. crinita* (blue lady orchid), and *T. antennifera* (lemon-scented orchid) represented one season of study (1 September–23 October, 2009). The field site for *T. antennifera* (approximately 500 flowering stems), *T. macrophylla* (approximately 100 flowering stems) and the hybrid between *T. antennifera* and *T. macrophylla*, (here after *T. antennifera* × *T. macrophylla*; approximately 50 flowering stems) was located near Tenterden, Western Australia. Pressed vouchers were deposited in the National Herbarium of New South Wales (NSW) and the herbarium of the Missouri Botanical Garden (MO).

The second site for field research included *T. crinita* (approximately 300 flowering stems), *T. macrophylla* (approximately 85 flowering stems) and hybrids between *T. crinita* and *T. macrophylla* (here after *T. crinita* × *T. macrophylla*; 6 flowering stems) was located in Lesmurdie, Western Australia (intersection of Welshpool and Pomeroy). At the Lesmurdie site, we tagged 15 stems in bud of *T. macrophylla* and 17 stems in bud of *T. crinita* and observed them from 6–23 October 2009. Data collected on these 32 flowering stems is described below in the subsections on 'Flowering patterns' and 'Natural rates of pollinaria removal *vs.* pollinaria deposition'. Deposition of herbarium vouchers for *T. crinita* and *T. macrophylla* were as above. Vouchers of the putative hybrid between *T. crinita* and *T. macrophylla* were collected and identified on 22 October 2009, by Dr. Andrew Brown.

Glasshouse collections. All hand-pollination work was completed using potted plants in a glasshouse (15°C–22 °C day temperature regulation) located at KPBG. All glasshouse specimens of *T. crinita* and *T. macrophylla* were collected from Canning Mills Road, east of Perth, WA, in September 1998. All glasshouse hybrid specimens (*T. crinita* × *T. macrophylla*) were collected from the Fiona Stanley Hospital site south of Perth, WA, in September 2009.

Statistics. All statistical analyses were performed using the R statistical language and programming environment (R Development Core Team 2011). We used the following abbreviations in our results: 'F' = test statistic for an analysis of variance test; 'W' = Wilcoxon rank sum test; 'χ^2'= Chi-square test; 'DF' = degrees of freedom; 'sd' = standard deviation of a sample; 'n' = sample size; and 'P' = probability of obtaining a given test statistic's value or greater at random.

Flower counts and flowering patterns

Flower bud number *vs.* length of the inflorescence. We counted the number of flower buds on *T. antennifera* and *T. macrophylla* at the Tenterden site. At the Lesmurdie site, we counted the flower buds on 17-tagged inflorescences of *T. crinita* and 15-tagged inflorescences of *T. macrophylla* from 6–23 October 2009 (see above). We tested for a difference in the average number of flowers per stem produced by *T. macrophylla* between the Tenterden and Lesmurdie sites using One-Way ANOVA. We recorded the number of flowers that opened daily on inflorescences of *T. crinita* and *T. macrophylla* at the Lesmurdie site from 6–23 October 2009. We also recorded daily weather conditions.

Flower bud opening *vs.* ambient temperature (*in situ*). A few previous studies suggest that mature, perianth segments do not open unless there is an absence of cloud cover and ambient temperatures exceed the low 20's (see review in Bernhardt and Burns-Balogh 1986). During September and October 2009, mean daily temperatures varied from 14.3–37.0 °C. Therefore, each day we observed flowers opening at the Lesmurdie site, the day was recorded as cool (<21°C) or warm (to at least 21°C).

Cloud cover. We recorded whether the day was cloudy or sunny. A cloudy day refers to whether the sun remained occluded by stratus clouds at least from 9 a.m. – Noon. All rainy days were recorded as cloudy days. A sunny day refers to a day in which the sun was not occluded by clouds from 9 a.m. – Noon. A Three-Way ANOVA was used to test for differences in the ratio of open to the total number of flowers per stem to determine the role of weather effects on *T. crinita* and *T. macrophylla*. These effects were identified as sunlight, (sunny day *vs*. cloudy day), and temperature (warm *vs*. cold). This gave us the three-way interaction of species, sunlight, and temperature. These ratios were transformed using the arcsine transformation for ratio data to better fit a normal distribution (Sokal and Rohlf 2003). Post-hoc analysis of the three-way interaction was done using pairwise t-tests.

Floral lifespans (glasshouse collection). To determine the floral life spans of *T. crinita* and *T. macrophylla* under controlled conditions, we used glasshouse plants exclusively. The first day a bud in the glasshouse opened, it was labeled with a jeweler's tag and subjected to one of two treatments (control *vs*. pollinarium removed). Specimens labeled controls were not manipulated. We recorded the number of days they opened and closed prior to withering. A withered flower was defined as a flower with a browned or crustose stigma and its labellum covered the stigma before the flower closed for the last time. Such flowers never reopened the following day. The second group of flowers had their pollinaria removed with clean toothpicks the first day they opened. They were recorded as withered using the same criteria as above. A mixed effect ANOVA model was used to test for differences in lifespan between the main treatment effects (control and pollinarium removed) and species (*T. crinita* and *T. macrophylla*), as well as the interaction of treatment and species. Since individual plants received both the control and experimental treatments, individual plant identifiers were included in the model as a blocking (random) effect.

Peduncle (flowering stem) length *vs.* number of flowers per inflorescence (glasshouse collection). The length of the stem and the number of flowers produced were measured for 13 specimens of *T. crinita*, 15 *T. macrophylla* specimens, and eight specimens of their putative hybrid. We used a One-Way ANOVA to test for differences among species and the hybrid in the number of flowers per stem. A second One-Way ANOVA was used to test for differences in the length of flowering stems. Tukey's HSD post-hoc tests were used to determine the sources of differences in the One-Way ANOVAs.

We counted the number of flowers on stems of the recurrent hybrid, *T. antennifera* × *T. macrophylla*, at the Tenterden site. We recorded which flowers on the stem had a normal column in which their pollinia connected to the rostellum and which flowers had malformed columns so that the pollinia did not connect to the rostellum. We calculated the average proportions of normal and malformed columns.

Hand-pollination experiments

Hand-pollination of flowers. To determine the compatibility system in glasshouse plants of *T. crinita* (n = 13 flowering stems) and *T. macrophylla* (n = 15 flowering stems) we divided all flowers on all stems into four experimental groups – control (unmanipulated), self-pollinated, cross-pollinated, and reciprocal hybridization. In all cases the entire pollinarium was removed from the anthers using a wooden toothpick (used once and discarded) and transferred to the receptive stigma. Because flowers opened only on warm, sunny days and because flowers closed by early afternoon, hand-pollinations were completed as soon as the flowers opened each morning. Self-pollinated flowers received pollen from the same flower (autogamy) whereas cross-pollinated flowers received pollen from the anther of a second flower of the same species in a separate container. In the reciprocal hybridizations, the entire pollinarium was removed from the anther of one species and its pollen was rubbed onto the stigma of the second species until a pollen smear was visible. The controls received no treatment. Each flower (one bud on each peduncle) was identified using a small jeweler's tag along with the type of treatment the flower received.

Analyses of hand-pollinations (pollen tube/pistil interactions). Experimental samples were harvested six days following the initial treatment, or in the case of the control flowers, six days after opening. These flowers were then collected, fixed, and preserved (*sensu* Lipow *et al.* 2002). Protocols used to split pistils lengthwise using a razor blade followed Edens-Meier *et al.* (2011) in order to locate pollen tubes on stigmas and/or within pistils. Softening, staining, and observing under epifluorescence followed Lipow *et al.* (2002).

Statistical analyses. A Multivariate Analysis of Variance (MANOVA) was used to test for differences in the three response variables (grains on stigma, pollen tubes in stigma, pollen tubes in ovary) among the independent variables for pollination treatment (control, cross, self, reciprocal hybridization) and species (*T. crinita* and *T. macrophylla*). Since data were recorded as counts, a square root transformation was used to develop a normal distribution (Sokal and Rohlf 2003).

Natural rates of pollinaria removal *vs* pollinaria deposition

Tenterden site. On 27 September and 2 October 2009, we examined peduncles of *T. antennifera*, *T. macrophylla*, and the hybrid of *T. antennifera* and *T. macrophylla* at the Tenterden site at random. We counted the number of flowers per inflorescence and the number of flowers on each stem in which the entire pollinarium was missing.

Statistical analyses (Tenterden). Kruskal-Wallis test were used to assess differences in the ratios of pollinaria removed to total flowers among *T. antennifera*, *T. macrophylla* and their hybrid.

Lesmurdie site. Seventeen flowering stems of *T. crinita* were tagged during the observation period from 7 October–23 October 2009 and 15 flowering stems of *T. macrophylla* from 6–23 October 2009. Every day we checked columns on each flower on each inflorescence for missing pollinaria and whether the stigma retained pollinaria fragments and/or a visible pollen film on the stigma. In both species, stigmas retaining pollinia fragments and/or a visible pollen film, closed and failed to reopen within 24 hours (see below). We excluded all flowers showing evidence of insect attack as these flowers closed early following physical damage. Pollen deposition on stigmas was observed using 3x optivisors.

Wilcoxon Rank Sum tests were used to compare the ratios of pollinated/total number of flowers and the ratios of pollinaria-removed/total number of flowers between *T. crinita* and *T. macrophylla* at the end of the 17-day observation period.

Insect observations, collections, and pollen load analyses

Catching insects (both sites). Insects were observed from September–October 2009, for approximately 200 hours. We arrived at the field site by 8 a.m. and left at 5 p.m. Insects landing on flowers were collected with butterfly nets and euthanized in a killing jar with ethyl acetate. Specimens were pinned, labeled, and identified. Bees less than 9 mm in length flew very rapidly and landed on *Thelymitra* flowers for a second or less. Consequently, it was not possible to follow these small bees from flower to flower. We had to catch them as soon as we saw them. We failed to catch more than half the bees we observed (see results). Pinned specimens were donated to the Entomology Department of the Western Australian Museum (Welshpool, WA) and identified by Dr. Terry Houston.

Identification of pollinaria and pollen load analyses (both sites). Pollinaria worn by insects were removed with a probe and stained with Calberla's fluid (Bernhardt and Dafni 2000). To determine whether the insect collected pollen on other species flowering within the same site, each insect was placed on a glass slide and washed in two–four drops of ethyl acetate. The scopae of bees were scraped with a probe to dislodge additional pollen loads. Staining and mounting of pollen residue left on the glass slide followed Bernhardt and Dafni (2000). The pollen slide was co-referenced with the pinned insect specimen. The pollen of a particular plant species was counted as present on a slide if we counted in excess of 25 grains based on protocols established for insect-pollinated Australian species (see Bernhardt 1989).

Hybrids

***T. antennifera* × *T. macrophylla* (Tenterden).** We counted and collected specimens resembling standard descriptions of *T. antennifera* × blue, large-flowered *Thelymitra* species as described by Brown *et al.* (2008). We recorded the number of flowers per inflorescence, floral characters of fresh specimens, and observed whether pollinia connected to the rostellum in open flowers. Pollen grains were removed from pollinia and stained with Calberla's fluid (see Bernhardt and Dafni 2000). Pressed vouchers were deposited as above.

***T. crinita* × *T. macrophylla* (Lesmurdie).** We counted and observed what we thought were intermediate specimens between *T. crinita* × *T. macrophylla*. These specimens were later collected by Andrew Brown for herbarium deposition. Consequently all morphometric analyses of *T. crinita* × *T. macrophylla* were based exclusively on known intermediate specimens (K. Dixon, pers. comm.) grown in a glasshouse (KPBG). We examined macroscopic and microscopic characters as above.

Results

Floral characters and flowering patterns

***Thelymitra antennifera* (Tenterden):** *Thelymitra antennifera* produced a mean of 1.7 flowers per stem (Table 1). Flowers of *T. antennifera* opened sluggishly on 26, 27 September and 2 October 2009, starting at 10:00 a.m. By 11:45 a.m. the flowers of only half of the population were fully opened. Flowers did not begin closing until after 4:00 p.m. Perianth segments were yellow (Fig. 1). The hood lacked a discernable midlobe and the prominent yellow papillose anther was flanked by two brownish burgundy lateral lobes (staminodia, Figs 1, 6). On 27 September, a mean of 93.3% of flowers were open per stem (sd=16.8). On 2 October, all flowers were open. A Wilcoxon rank sum test confirmed that a significantly higher percentage of flowers was open on 2 October than on 27 September (W=1396.5, P=0.0071).

Table 1. Floral Characters of three *Thelymitra* spp. and their hybrids (includes greenhouse = 'A' and field sites); NA = not assessed; Tenterden site = 'B'; Lesmurdie site = 'C'.

Reproductive Characters	***T. antennifera*^{B}**	**F1 *T. antennifera* × *T. macrophylla*^{B}**	***T. macrophylla***	**F1 *T. macrophylla* × *T. crinita***	***T. crinita*^{C}**
Mean length scape (in mm)	NA	NA	585.5	491	491
Mean number of flowers/scape	1.7^{B}	1.2^{B}	4^{B}; 16.5^{C}, 12.3^{A}	8^{A}	9.8^{C}, 7.7^{A}
Perianth color	yellow	red/orange/pink often with yellow margins	ranges from white, blue, to pink	blue to light purple	light blue to cobalt blue
Hood midlobe	absent; anthers dark yellow	reduced; anthers light yellow	smooth; yellow + blue band	'bumpy', light pappilose; magenta or indigo + yellow	prominent papillae; 'fuzzy'; purple blue + yellow
Trichome brush presence	absent	absent	present	present	present
Approximate number of hairs/trichome brush	absent	absent	>160	<150	<40
Color of trichome brush if present	absent	absent	white	pink to purple	pink to cobalt blue
Pollen	monads	monads	monads	monads, dyads, and tetrads	tetrads
Floral odour discernable to Human nose	strong	weak	strong	strong	absent

***Thelymitra crinita* (Lesmurdie site and glasshouse collection):** An inflorescence of *T. crinita* at the Lesmurdie site produced a mean of 9.8 flowers per stem (sd = 2.8, n = 18, range = 5–15; see Table 1). Flower buds in the glasshouse collection and at Lesmurdie opened acropetally. Perianth coloration graded from a dull, pale blue with pink highlights to a vivid, cobalt blue in *T. crinita* (See Fig. 2, Table 1).

On warm sunny days, glasshouse flowers of *T. crinita* began opening from 9:15–10:35 a.m. with perianth segments closing from 2:30–4:40 p.m. Individual flowers lived 9–26 days (mean=13.71, sd =4.46, n = 21) regardless of whether their pollinaria were removed or not (see results of ANOVA in the Comparative Flowering section below). However, if the flowers were selfed, crossed, or hybridized, the perianth segments always closed 24–48 hours later and never reopened.

***Thelymitra macrophylla* (Lesmurdie, Tenterden, and glasshouse collection):** An inflorescence of *T. macrophylla* produced between 10–23 flowers at the Lesmurdie site and between 1–11 flowers at the Tenterden site (see Table 1; Fig. 9). *Thelymitra macrophylla* produced significantly more flowers per stem (mean=16.5, sd=3.5) at the Lesmurdie site than at Tenterden (mean=4.0, sd=1.9) as determined by a One-Way ANOVA (F=274.34, DF=1,49, $P<2.2*10^{-16}$). Flower buds in the glasshouse collection, at Lesmurdie, and at Tenterden always opened acropetally in this species. Perianth coloration graded from light to deep blue in both populations and in the glasshouse plants (Fig. 3). On warm sunny days, glasshouse flowers of *T. macrophylla* began opening from 9:30–10:30 a.m. and began closing from 2:45–4:40 p.m. These flowers lived an average of 17.10 days (sd = 4.46, n = 20) whether their pollinaria were removed or not. If the flowers were selfed, crossed or hybridized the perianth segments always closed 24–48 hours later and never reopened.

Comparative flowering of *T. crinita vs. T. macrophylla* (glasshouse). Flowers of *T. crinita* lived an average of 15.3 days if they kept their pollinaria and an average of 11.7 days if the pollinarium was removed the first day the flowers opened. Flowers of *T. macrophylla* lived an average of 18.7 days if they kept their pollinaria and 15.11 days if the pollinaria were removed the first day the flowers opened. However, no significant differences were detected by the mixed effect ANOVA among treatments (F=4.60, DF=1.13, P=0.051), species (F=4.51, DF=1.13, P=0.054), nor the interaction of treatment and species (F=0.94, DF=1.13, P=0.349).

Flowering patterns of *T. crinita* and *T. macrophylla* at Lesmurdie. The Three-Way ANOVA revealed that *T. crinita* flowers opened regardless of whether it was sunny or cloudy. *Thelymitra crinita* also opened on days that were cold provided it was sunny.

In contrast, *T. macrophylla* flowers did not open on cold days, even if the sun were shining. The detailed results of the ANOVA were as follows: For the main effect of Species, the average ratio of open/total number of flowers was significantly lower (F=12.789, DF=1,547, P=0.0004) for *T. crinita* (mean=0.20, sd=0.26) than for *T. macrophylla* (mean=0.26, sd=0.24) at the Lesmurdie site. The average ratio of open/total flowers was significantly higher (F=235.70, DF=1,547, $P<2.2*10^{-16}$) on sunny days (mean=0.38, sd=0.31) than on cloudy days (mean=0.05, sd=0.17). The average ratio of open/total flowers was significantly higher (F=103.71, DF=1,547, $P<2.2*10^{-16}$) for warm days (mean=0.41, sd=0.30) than cold days (mean=0.02, sd=0.10). The three-way interaction effect of Species:Sunlight:Temperature was also significant (F=10.30, sd=4,547, $P=4.8*10^{-8}$). Post hoc analysis of the three-way interaction showed that *T. crinita* had similarly higher ratios of open flowers on warm and/or sunny days than it did on cold and cloudy days. *Thelymitra macrophylla* however, had higher ratios of open flowers on warm days than cold, regardless of sun exposure.

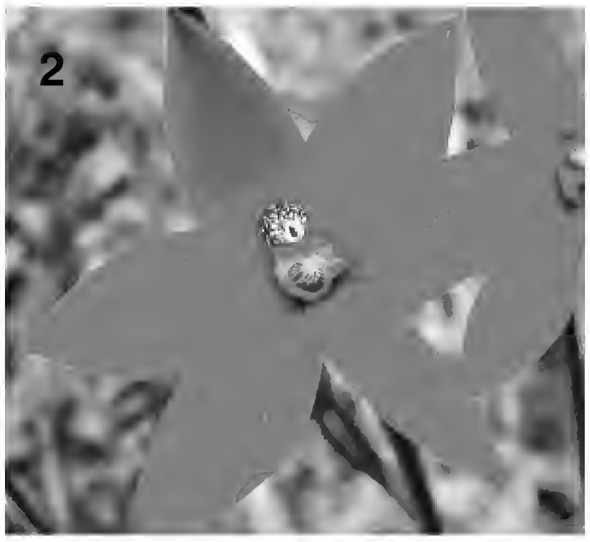


Fig. 1. *Thelymitra antennifera* and putative hybrids of *T. antennifera* × *T. macrophylla* (Tenterden, Western Australia).

Fig. 2. Flower of *Thelymitra crinita* (Lesmurdie, Western Australia).

Fig. 3. Flower of *Thelymitra macrophylla* (Lesmurdie, Western Australia).

Fig. 4. Flower of putative hybrid *Thelymitra antennifera* × *T. macrophylla* (Tenterden, Western Australia). Note that the rostellum is retained but no pollinia connect to the viscidium.

Flowers produced by the hybrid, *T. antennifera* × *T. macrophylla* at Tenterden. The mean number of flowers per stem produced by the *T. antennifera* × *T. macrophylla* hybrids was 1.2 (sd=0.84). However the mean number of flowers with malformed columns (rostellum never contacted pollinia) per stem was 0.59 (sd=0.81) for a final ratio of 2.03 normal flowers for every malformed flower (Figs 4, 5).

Flowers produced by *T. crinita, T. macrophylla,* and *T. crinita* × *T. macrophylla* (glasshouse collections). *Thelymitra crinita* produced a mean of 7.7 flowers per stem (sd=2.69). *Thelymitra macrophylla* produced a mean of 12.3 flowers per stem (sd=3.27), and the hybrid produced a mean of 8.0 flowers per stem (sd=3.16). We found significant differences in the number of flowers per stem among the two species and their putative hybrid (F=9.68. DF=2,33, P=0.0005). Post-hoc analyses revealed that *T. macrophylla* produced significantly more flowers than *T. crinita* and the hybrid, but that the number of flowers produced by *T. crinita* and the hybrid did not differ significantly from one another. *Thelymitra crinita* produced a mean stem length of 411.7 mm (sd=63.6). *Thelymitra macrophylla* produced a mean stem length of 585.5 mm (sd=63.8), and the hybrid produced a mean stem length of 491.0 mm (sd=97.9). We found significant differences in stem lengths among the species and their hybrid ($F=20.23, DF=2.3, P=1.8*10^{-6}$). Post hoc analyses revealed that *T. macrophylla* had longer stems than both *T. crinita* and their hybrid, while *T. crinita* and their hybrid produced stems that did not differ significantly in height (Table 1).

Fig. 5. Flower of putative hybrid *Thelymitra antennifera* × *T. macrophylla* (Tenterden, Western Australia). Note difference in colour with Fig. 4 and also note that both pollinia pairs dropped attaching to rostellum.

Fig. 6. Flower of putative hybrid *Thelymitra crinita* × *T. macrophylla* (Lesmurdie, Western Australia). Note the white trichome brushes and the much reduced papilla on the median lobe of the hood.

Fig. 7. Flower of putative hybrid *Thelymitra crinita* × *T. macrophylla* (Lesmurdie, Western Australia). Note the pinkish/purple trichome brushes.

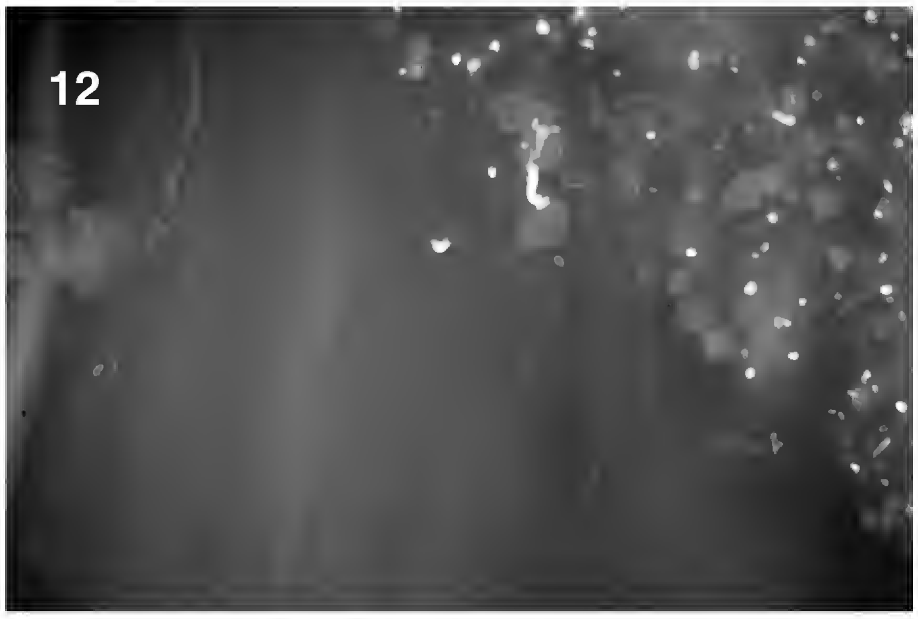
Fig. 8. Flower of *Thelymitra antennifera* (Tenterden, Western Australia) with red blotches. This specimen was found with *T. antennifera* (all perianth segments yellow) and putative hybrids of *T. antennifera* × *T. macrophylla*.

Fig. 9. Inflorescence of *Thelymtira macrophylla* in situ (Tenterden, Western Australia). Note the few flowers and flower buds on the peduncle.

Hand-pollination experiments *T. crinita* and *T. macrophylla* (glasshouse). Flowers labeled as controls in the glasshouse failed to self-pollinate in both species. Flowers deprived of pollinaria the first day they opened did not set fruit by agamospermy in either species. This does not mean, however, that each species was self-incompatible. Hand-manipulated pollination events resulted in a full response of pollen tubes germinating and growing through ovary tissue in both species. Both *T. crinita* and *T. macrophylla* were self-compatible (Figs 10, 11) based on the evidence that they each accepted their own pollen and produced pollen tubes that extended through the ovary within six days following pollen deposition on their stigmas. Based on results of hand-manipulated hybridizations, *T. crinita* and *T. macrophylla* showed degrees of interspecific compatibility. When pollen from *T. crinita*, was transferred to the stigma of *T. macrophylla*, we observed a number of swollen grains on the surface of the stigma although most pollen tubes penetrated into the ovary. We observed a similar response in pollen tubes of *T. macrophylla* when placed on stigmas of *T. crinita* (Figs 12, 13).

The MANOVA revealed that, regardless of species, fewer pollen tubes were found in the styles and entering the ovaries under the control treatment compared to the three manipulation treatments for both species. Furthermore, that same pattern held true for the number of grains on the stigmas of *T. crinita* flowers. In *T. macrophylla*, the control treatment yielded fewer grains on the stigmas than in the cross-pollination treatment. Detailed results are as follows:

The MANOVA detected significant differences in the response variables among the pollination treatments, and the interaction of species and treatment, but no significant difference between the two species (Table 2). Examination of individual ANOVA tables for each response variable revealed significant differences in the number of grains on stigmas among the treatments and the interaction of treatment species, significant differences in the number of tubes on stigmas among treatments, and significant differences in the number of tubes in ovaries among treatments (Table 3). Post-hoc analyses of the significant treatment main effect for all dependent variables (grains on stigma, tubes in stigma, tubes in ovary) via pairwise t-tests showed that the control treatment yielded significantly fewer ($P<0.05$) grains and tubes than the three manipulated treatments (cross, self, and reciprocal hybridization). Post-hoc analysis of the significant interaction effect for the number



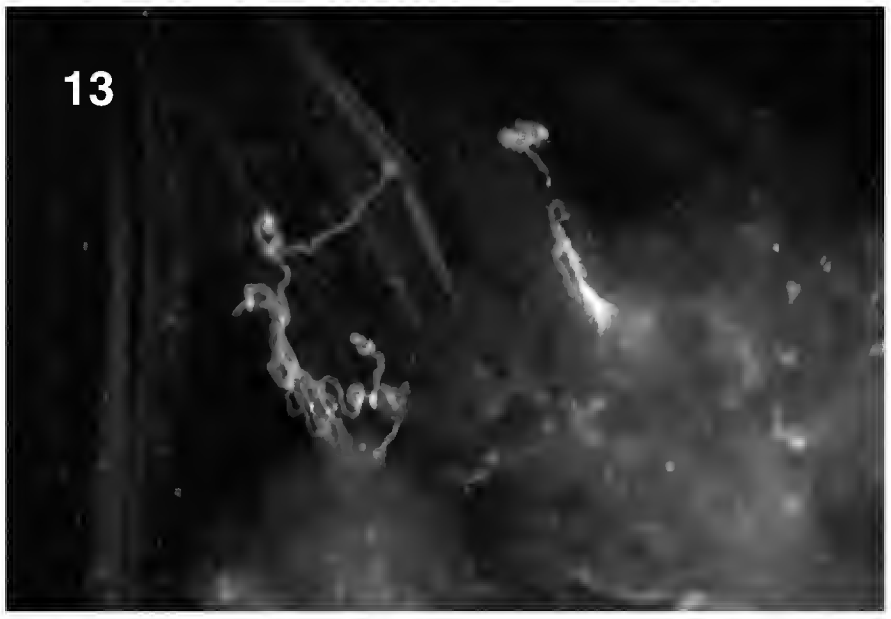


Fig. 10. Pollen tubes reach ovules in the ovary of *Thelymitra crinita* following glasshouse, hand-manipulated self-pollination.

Fig. 11. Pollen tubes reach ovules in the ovary of *Thelymitra crinita* following glasshouse, hand-manipulated cross-pollination.

Fig. 12. Swollen pollen grain with bloated pollen tube of *Thelymitra crinita* on stigma of *T. macrophylla* (glasshouse collection).

Fig. 13. Aberrant pollen tubes of *Thelymitra macrophylla* in ovary of *T. crinita* (glasshouse collection).

of grains on stigmas via pairwise t-test revealed significantly fewer ($P<0.05$) grains on stigmas for the control treatment than the three manipulated treatments for *T. crinita*. In contrast, *T. macrophylla*, had significantly fewer ($P<0.05$) grains on stigmas under the control treatment compared to the cross treatment. All other pairwise comparisons were not significant ($P>0.05$) (Tables 2, 3).

Natural rates of pollinaria removal *vs* pollinaria deposition

***Thelymitra antennifera* and *T. macrophylla* (Tenterden).** Time and budget restraints made it impossible for us to record rates of pollinaria removal in the *T. antennifera* population throughout its flowering season. On September 27 we counted 50 flowering stems of *T. antennifera* and found that only five flowers on five stems lacked their pollinaria. We were unable to detect the presence of pollinia or pollinia fragments on receptive lobes. On 2 October, we checked an additional 31 stems and found that only three flowers on three different stems lacked their pollinaria (no evidence of pollinia deposition on stigmas) even though all flowers on all stems were open. On 2 October, we found that on 31 flowering stems of *T. macrophylla* that a total of seven flowers had their pollinaria removed on four stems. On the same date we found that on 47 stems of the hybrid, *T. antennifera* × *T. macrophylla,* four flowers had their pollinaria removed on four separate stems. The mean ratio of flowers at the Tenterden site with pollinaria removed/total number of flowers was 0.081 (sd=0.261) for *T. antennifera*, 0.054 (sd=0.156) for *T. macrophylla*, and 0.043 (sd=0.141) for *T. antennifera* × *T. macrophylla*. The Kruskal Wallis test revealed no significant difference between these species and their hybrid ($\chi^2=0.340$, $DF=2$, $P=0.844$) at Tenterden.

***Thelymitra crinita* and *T. macrophylla* (Lesmurdie).** Over a 17-day period of observations at Lesmurdie, a total of nine inflorescences of tagged *T. crinita* experienced pollinaria removal by insects. A total of twenty-one flowers of *T. crinita* had their pollinaria removed but only four flowers showed fragments of pollinia on their stigmas. A total of 11 inflorescences of tagged *T. macrophylla* experienced pollinaria removal. Fifty flowers of these tagged stems had their pollinaria removed and five flowers had pollinia fragments left on their stigmas. The mean ratio of pollinated/total number of flowers was 0.117 (sd=0.136) for *T. crinita*, and 0.023 (sd=0.048) for *T. macrophylla*. The Wilcoxon Rank Sum test revealed that *T. crinita* appeared to have a higher ratio of pollinated/total number of flowers than *T. macrophylla* ($W=177.0$, $P=0.048$). The mean ratio of flowers with pollinaria removed/total flowers was 0.160 (sd=0.169) for *T. crinita*, and 0.178 (sd=0.178) for *T. macrophylla*. No significant difference in these ratios was detected by the Wilcoxon test ($W=117.5$, $P=0.7155$).

Table 2. MANOVA (multiple analyses of variance) Table for pollen grains on stigma, pollen tubes on stigma, and pollen tubes in ovary by treatment and species. DF = degrees of freedom; Den-DF = denominator degrees of freedom; F = F-statistic; Num-DF = numerator degrees of freedom; P = P=value; Wilks = Wilk's λ.

Source	DF	Wilks	F	Num-DF	Den-DF	P
Treatment	3	0.06322	69.6	9	297.07	$<2.2\times10^{-16}$
Species	1	0.97284	1.1	3	122.00	0.337572
Treatment*Species	3	0.77335	3.7	9	297.07	0.000221
Residuals	124					

Table 3. ANOVA (analysis of variance) Tables for pollen grains on stigma, pollen tubes on stigma, and pollen tubes in ovary by treatment and species. DF = degrees of freedom; F = F-statistic; P = P-value.

Response Variable	Source	DF	F	P
Grains on stigma	Treatment	3	25.149	6.3×10^{-13}
	Species	1	1.0282	0.3125
	Treatment*Species	3	9.1596	1.6×10^{-5}
	Residuals	124		
Tubes in stigma	Treatment	3	561.2700	$<2\times10^{-16}$
	Species	1	1.6821	0.1970
	Treatment*Species	3	1.5846	0.1965
	Residuals	124		
Tubes in ovary	Treatment	3	163.7622	$<2\times10^{-16}$
	Species	1	0.0096	0.9223
	Treatment*Species	3	1.1176	0.3447
	Residuals	124		

Insect observations, collections, and pollen load analyses

***Thelymitra antennifera* (Tenterden).** Insects were observed infrequently on all three species comparable to their low rates of pollinaria removal (see above). At 11:30 a.m. on 26 September 2009, at the Tenterden site, we observed but were unable to collect a small black bee entering a half-open flower of *T. antennifera*. It then gathered pollen from an open flower of *Chamaescilla corymbosa* (blue squill) before it left the site. On 6 October 2009, we collected one female bee (*Leioproctus* species, subgenus *Leioproctus*) on a *T. antennifera* flower but it did not carry pollinaria or pollinia fragments. Other visitors to *T. antennifera* included flies in the family Bombyliidae. These insects never carried pollinaria.

***Thelymitra macrophylla* (Tenterden).** We collected *Lasioglossum* (subgenus *Chilalictus*) on *T. macrophylla* at Tenterden, and it carried remains of pollinaria from the host flower. Fragments of pollinia were found on the stigma of the same flower visited by this bee.

***Thelymitra macrophylla* (Lesmurdie).** We collected five bees between 16–22 October 2009 on *T. macrophylla*, of which three were females of *Lasioglossum* (subgenus *Chilalictus)*, one female of *Leioproctus*, (subgenus *Leioproctus*) and one female of *Homalictus* species (Halictidae). Pollinaria were found on two specimens of *Lassioglossum* species and one specimen of *Leioproctus* species. In all three cases, the viscidium was attached dorsally towards the tip of the abdomen (Fig. 14). The pollen loads found in the scopae of all bees were mixed with pollen of co-blooming members of the Myrtaceae, papilionoid legumes and unidentified monocotyledons. One syrphid fly carried the remains of the viscidium on its proboscis. We did not find whole pollinaria on any of these flies but two specimens carried individual grains of *T. macrophylla* suggesting they may have consumed pollen mixed with stigmatic fluids. Syrphid flies also carried mixed loads of pollen from co-blooming species including Asteraceae, *Hakea* species, Goodeniaceae, Myrtaceae, and several unidentified *Stylidium* species. We note that the two syrphid flies carrying grains of *T. macrophylla* also carried the distinctive pollen of *Orthrosanthus laxus* (large blue flag: Iridacae). The flowers of *O. laxus* did not secrete nectar and syrphid flies were observed probing the longitudinally dehiscent anthers. Syrphid flies were observed on the flowers of *O. laxus* for the duration of their flowering period. We never observed bees on *O. laxus*.

***Thelymitra crinita* (Lesmurdie).** We caught only three bees on *T. crinita* on 21 and 22 September 2009. One female *Leioproctus* species, (subgenus *Leioproctus*) was found to carry the pollinarium of *T. crinita* with the viscidium attached to her stinger. The other two bees were females of *Amegilla chlorocyanea* (Fig. 15). They did not carry any pollinia. However, on 23 October, 2009, at 10:10 a.m., another bee of the same species (recognized by its large bluish, green-banded abdomen) was observed visiting flowers on six plants of *T. crinita*

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Fig. 14. Pinned specimen of female *Leioproctus* sp. carrying pollinaria of *T. macrophylla* (Lesmurdie, Western Australia).

Fig. 15. Pinned specimen of female *Amegilla chlorocyanea* collected on flowers of *T. crinita* (Lesmurdia, Western Australia).

remaining less than a second on each flower. Its legs touched the mitras. Stigmas were examined after the bee left the area and pollinia residue was found on seven flowers on six flowering stems. All seven flowers closed the following day. We observed and collected both syrphid and bombyliid flies visiting *T. crinita*. None carried the pollen of the host flower.

Hybrids

***Thelymitra antennifera* × *T.* macrophylla (Tenterden).** The flowers of the hybrid between *T. antennifera* and *T. macrophylla* (Tenterden) resembled the description and photograph of flowers of *T.* ×. *macmillanii* (*sensu* Jones 2006). These hybrids showed intense variation of pigmentation patterns grading from pale pink with whitish perianth margins through deep red with yellowish perianth margins (Table 1; Figs 4, 5). Floral fragrance of these hybrids resembled a weak lemon scent compared to the much stronger lemon scent of

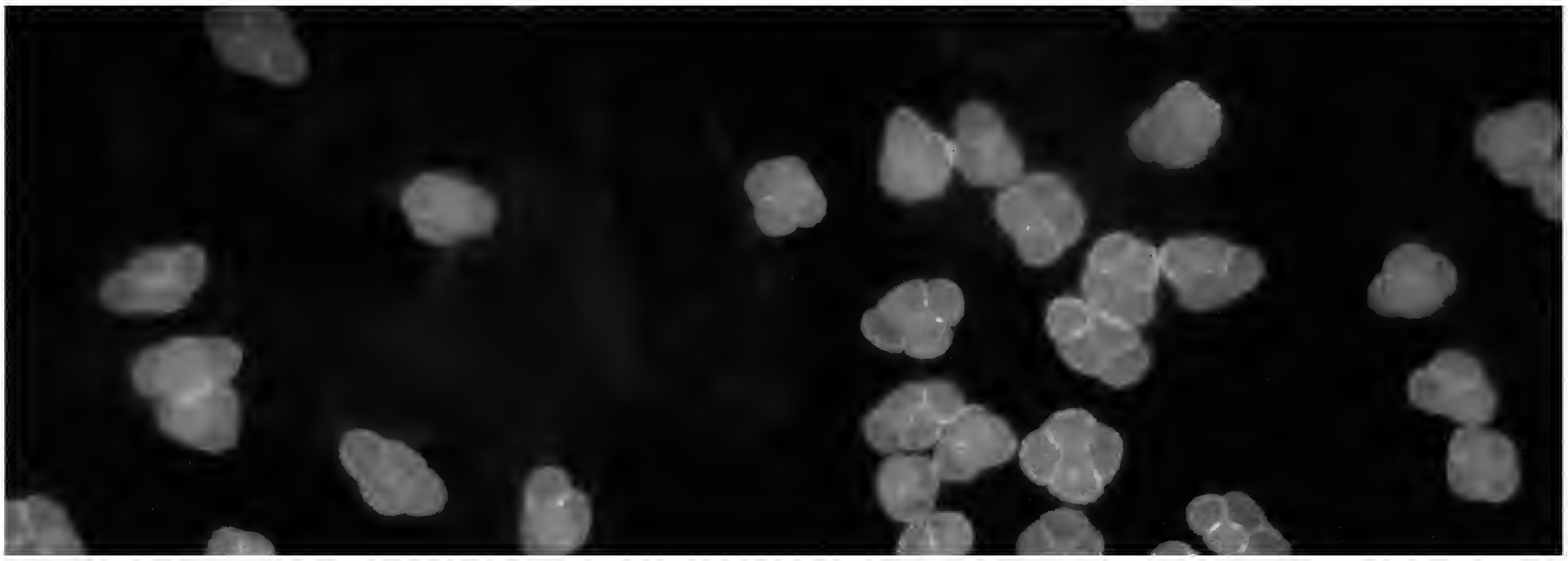

Fig. 16. Tetrads of *Thelymitra crinita* under epifluorescence.

Fig. 17. Adjacent inflorescences of *Thelymitra macrophylla* and *T. crinita* (Lesmurdie, Western Australia).

Fig. 18. Mature flower bud of *Thelymitra crinita* bearing the pollinarium of *T. macrophylla* following physical contact with the open flower.

T. antennifera sensu stricto. However, we report for the first time the malformation of the column of these putative F_1 hybrids (see above). In most cases the pollinia did not drop onto the rostellum at maturity. When the flower was tapped lightly with a probe, the pollinia fell out of the anther onto the ground. The viscidium was always retained by the rostellum after the pollinia fell from the flower. In other cases we observed the pollinia never dropped out of the anther and never connected to the rostellum. Field investigations on 3 October 2009, showed that out of a total of 49 flowering hybrid stems, 20 inflorescences bore 1–3 open flowers in which the pollinia never connected to the viscidium.

We also report flowers of *T. antennifera* with red splotches on their perianth segments (Fig. 6). These flowers were never used in any of the data subsets described above. The plants producing these flowers were found adjacent to pure yellow *T. antennifera* and/or the putative F_1 hybrids. We never saw plants with splotched flowers growing adjacent to plants of *T. macrophylla*. These splotched flowers retained the normal brownish burgundy lateral lobes found in *T. antennifera sensu stricto.* (Table1). In addition, the pollinia in these splotched flowers were attached normally to the viscidium.

***Thelymitra crinita* × *T. macrophylla* (Lesmurdie).** It was more difficult to discriminate between hybrids produced by *T. crinita* and *T. macrophylla* at the Lesmurdie site as both were blue flowered species (Figs 7, 8) and putative F_1 plants showed a more subtle gradation of characters (Table 1). Indeed, our four putative hybrids required collection and confirmation by Dr. Andrew Brown, one of Western Australia's most prominent orchidologists. The gradation of characters was most striking at the microscopic level. Specifically, pollen grains of *T. macrophylla* were dispersed as monads while pollen grains of *T. crinita,* were dispersed as tetrads (Fig. 16), as in *T. ixiodes* (Sydes and Calder 1993). In the putative hybrids at Lesmurdie and in the glasshouse collections, we found a mixture of tetrads, triads, dyads, and monads in the putative hybrids (Table 1). Molloy and Dawson (1998) had much the same results when they compared F_1 hybrids and species of hybrid origin in some *Thelymitra* species in New Zealand. When *T. ixiodes, T. formosa, T. cyanea*, or *T. aemula* all containing tetrad pollen, crossed with a second species with monad pollen, the offspring produced pollinia containing a mixture of monad and tetrad grains.

We did not observe insects alternating their foraging on the flowers of both species at Lesmurdie because our protocol was to capture any bee as it landed on the flower, with the exception of the much larger (>10 mm in length) *Amegilla chlorocyanea* (Apidae, see above). However, sympatric, co-blooming populations of both species often grew so close to each other that flowers touched. On one occasion, when the wind was blowing, a bud of *T. crinita* was blown into the interior of a *T. macrophylla* flower and its perianth segment removed the pollinarium from the anther (personal observation by R. Edens-Meier, Figs 17, 18).

Discussion

Variation in floral characters and flowering patterns. Differences in the numbers of flowers per peduncle varied between the three, large-flowered species and showed some degree of intermediacy when two species hybridized (Table 1). This was anticipated based on previous descriptions of all three species (Brown *et al.* 2008; Jones 1988). However, we did not anticipate the significant difference between the number of flowers per peduncle in disjunctive populations of *T. macrophylla* with the southern (Tenterden) population offering fewer flowers than the northern (Lesmurdie) population. If fewer flowers per peduncle in the southern population were genetic in origin, it would explain the fewer flowers per stem in the recurrent hybrid, *T. antennifera* × *T. macrophylla* (Tenterden). *Thelymitra antennifera* produced less than two flowers per peduncle (as usual; see Jones 1988) while *T. macrophylla* (Tenterden) had a mean of only four flowers per peduncle. Does a consistent and positive correlation exist between peduncle length, the number of flowers per peduncle, and northern distributions of *T. macrophylla* in Western Australia? We cannot answer this question, unfortunately, because the most recent treatment of the taxonomy of *T. macrophylla* (Jeanes 2013) did not consider variation in the number of flowers per peduncle along a geographical distribution.

Tagged flower buds of *T. macrophylla* and *T. crinita* showed variation in the floral life spans of these large-flowered *Thelymitra* species. The literature on pollen-pistil interactions in some orchid flowers showed that removal of the pollinarium and/or the deposition of pollen on the stigma interrupted and shortened their lifespans (Huda and Wilcock 2012). In both *T. crinita* and *T. macrophylla* hand-pollination (both cross and self) triggered premature closing of the perianth segments. However, when freshly opened flowers of both species were deprived of their pollinaria the decline in their floral lifespans was not statistically significant in either species. Much the same response was recorded previously in controlled experiments on flowers of *Mystacidium venosum* (Luyt and Johnson 2001) and *Chloraea alpina* (Clayton and Aizen 1996). Glasshouse collections of *Thelymitra crinita* and *T. macrophylla* failed to self-pollinate in the absence of pollinarium vectors. Field records at Lesmurdie showed that insect-mediated pollinations occurred in less than 12% of the flowers on tagged stems in both species. We argue that if a large-flowered *Thelymitra* species were to close its perianth segments permanently following pollinarium removal, without pollen deposition on its stigma, that this process would be maladaptive. In fact, it would be especially maladaptive in outcrossing orchids with mimetic, 'food flowers'. A review of pollination in orchids with mimetic, 'food flowers' showed that this system was visited infrequently by pollinators (see below and see Tremblay *et al.* 2005). Allowing *Thelymitra* flowers to reopen after the pollinarium is removed, (provided preferred climatic conditions prevail) may be interpreted as selectively advantageous. It may improve female fitness in these two species. Both species were pollinated infrequently because they were so pollinator limited (*sensu* Vance *et al.* 2004). In particular, insect-mediated, pollinarium removal in *T. macrophylla* was far higher than actual rates of pollen deposition on the stigma. This indicated that most bees visited *T. macrophylla* only once (see below).

This was also the first field study that showed that opening and closing perianth segments varied between two *Thelymitra* species as *T. crinita* continued to open on cool days, provided it was sunny, while *T. macrophylla* remained closed even if it were a cloudless day. Why do large-flowered *Thelymitra* species open and shut at all? We did notice that pollen-eating syrphid flies remained active on cloudy, cool days, and were often observed foraging on the large, blue flowers of *Orthrosanthus laxus* (Lesmurdie; Bernhardt and Edens-Meier, unpublished) through late afternoons. By the time a large-flowered *Thelymitra* species opens its perianth segments for the first time, its anther has already dehisced, and all of its pollinia are connected to the rostellum. Consequently, both pollinia pairs are now naked and exposed while the perianth segments are open. Hover flies (Syrphidae), thrips, or other pollinivorous insects have access to these exposed pollinia and may damage them while feeding. As hoverflies were observed feeding on stigmatic fluids in this study, and in earlier publications (Cady and Rotherham 1970; Dafni and Calder 1987) these insects may also contribute interspecific hybridization when they carry pollinia fragments on their mouthparts between co-blooming species. A second explanation may be based in part on visual *vs.* pollinator memory. By opening for only part of the day, these mimetic flowers produce a temporary but vivid, visual cue on an erratic basis based on climate. The prospective pollinators may be less able to discriminate and reject the mimics on their standard foraging routes as the mimics close and thus 'vanish' from sight only to reappear at another time.

Therefore, variation in the opening and closing of large-flowered *Thelymitra* species may increase some reproductive success at two levels. First, it may increase the ability of flowers of some species to exploit the density-limited guild of pollinating bees that visit a mimetic flower more than once. We note, for example, that *T. crinita* opened on cold but sunny days, unlike *T. macrophylla*, and the rate of pollinated stigmas on tagged peduncles of *T. crinita* was 9% higher than in *T. macrophylla*. Second, when two or more sympatric *Thelymitra* species have overlapping flowering periods, but respond to different climatic cycles, this may afford some interspecific isolation as different pollinators may be active under different temperature and cloud cover regimes.

Breeding systems. Rogers (1913) dissected fresh flowers of *T. antennifera* and insisted this species was unable to self-pollinate. This was confirmed by the field studies of Dafni and Calder (1987). *Thelymitra crinita* and *T. macrophylla* now join a small, but increasing number of populations of large-flowered *Thelymitra* species that fail to self-pollinate when pollinators fail to arrive (Cropper and Calder 1990; Sydes and Calder 1993). Based on our glasshouse experiments, both *T. crinita* and *T. macrophylla* should be classified as self-compatible. This is not atypical for the Orchidaceae as floral presentation encouraging out-crossing tends to accompany self-compatibility in the majority of orchid genera studied to date based on recent reviews. For example, Edens-Meier *et al.* (2010) showed that all outcrossing *Cypripedium* species studied to date lack pre-zygotic self-incompatibility (Bernhardt and Edens Meier 2010; Tremblay *et al.* 2005).

Pollinarium removal *vs.* insect visitations. Darwin (1862, 1877) was among the first to note that orchid flowers received, at best, infrequent visits from their pollinators. He was also unaware (Darwin 1862) that the *Orchis* and *Ophrys* species he studied were food and sexual mimics, respectively. As Darwin did not have the time or energy to spend the entire day and the entire flowering season observing insect visitors, he recorded the natural removal of pollinaria in the flowers of populations near his house. This allowed him to determine natural rates of insect visits and pollinaria dispersal over several seasons. Our own records of pollinarium removal in 11 inflorescences of *T. macrophylla* at Lesmurdie in 2010 indicated strongly that the rate of pollinarium removal in flowers of tagged plants was ten times higher than the rate of pollinia deposition on the stigmas of the same flowers.

Of nine, tagged flowering stems of *T. crinita*, only 21 flowers had their pollinaria removed while 11% of all the flowers on these stems were insect-pollinated. In fact, *T. crinita* produced fewer flowers per stem than *T. macrophylla* (Table 1) at Lesmurdie so *T. crinita* had a higher rate of reproductive success than its congener growing at the same site. There are two possible and interrelated explanations for the very 'modest' success of the flowering stems of *T. crinita*. First, *T. crinita* flowered later than its congener and its flowering peak occurred under warmer, sunnier, mid-spring conditions when bee numbers presumably increased. Second, *T. crinita* was the only species to attract females of *Amegilla chlorocyanea* and, as described above, at least one female visited several flowers on several stems without receiving an edible reward. Bees in this genus are unusually large by Australian standards (>10 mm in length) so they may carry more pollinia on their abdomens leaving a broader film of pollinia fragments upon contacting stigmatic lobes.

Otherwise, bee visitation to both species was similar to collections and descriptions in previous publications on the pollination biology of large-flowered, blue *Thelymitra* species. Insects carrying pollinaria on their abdomens were all female bees that clasped the mitra but their visits were, at best, dismally infrequent (Bernhardt and Burns-Balogh 1986; Sydes and Calder 1993). Cropper and Calder (1990) suggested that the infrequent visits of female *Nomia* species to *T. epipactoides* provided an explanation of why this orchid was so rare. However, our populations of *T. crinita* and *T. macrophylla* were common *in situ* (Brown *et al.* 2008). In fact, pollinator visits to food mimicking, orchid species are rarer than pollinator visits to sexually mimetic orchids (see review in Tremblay *et al.* 2005). Reproductive success in food mimicking, orchid species should be highest when their flowers occur at far lower frequencies than those of the rewarding, co-blooming species mimicked by the orchids (Dafni and Bernhardt 1990). Our sites offered hundreds of large-flowered, *Thelymitra* species in bloom. We suspect that their rates of pollinaria removal and deposition were probably low in part because they equaled or even outnumbered their pollen and/or nectar producing model flowers. Large-flowered *Thelymitra* species seem less likely to fool prospective pollinators when they grow *en mass* in large populations compared to a few flowering orchid stems interspersed among their model, co-blooming species. Perhaps this is why at least half the species in the genus *Thelymitra* show such a consistent shift towards facultative autogamy to sub-cleistogamy (Bates 1999; Jeanes 2004). Jeanes (2013) placed *T. macrophylla* in the *T. nuda* complex. It contains 15 species (*sensu* Jeanes 2013), of which two appear to self-pollinate. An additional explanation may be based on foraging speed of bees *vs.* pollen load. Morse (1981) found that foraging speeds of both *Bombus terricola* Kirby and *B. vagans* Smith visiting milkweed flowers (*Asclepias syriaca*) decreased with increasing numbers of attached pollinia. As flowers of *T. crinita* and *T. macrophylla* attached pollinaria to the abdomens of their visiting bees this, presumably, represented a form of drag that could alter a bee's speed and foraging ability, especially if pollinaria proved difficult to remove. For this reason, most small to medium sized bees (halictids and *Leioproctocus*: see Cropper and Calder 1990) may have chosen to avoid these flowers after a single visit while a large bee (*e.g. Amegilla chlorocyanea*) might visit flowers on several stems before abandoning a mode of floral presentation that failed to offer edible rewards.

While *Leioproctus fulvescens* (Colletidae) pollinates some flowers of *T. longifolia* in New Zealand (Lehnebach *et al.* 2005) this is the first time members of this bee genus have been found visiting flowers of *Thelymitra* species in Australia. This study also adds members of the genera *Homalictus* (Halictidae) and *Amegilla* (Apidae) to the list of potential pollinators of large, blue-flowered species. *Thelymitra macrophylla* and *T. crinita* also appear to belong to a small but increasing number of large-flowered species exploiting females of *Lasioglossum* (subgenera *Chilalictus*, *Parasphecodes*; Halictidae; see Bernhardt and Burns-Balogh 1986; Dafni and Calder 1987; Sydes and Calder 1993). What do the genera *Amegilla*, *Exoneura*, *Homalictus, Leioproctus* and *Nomia*, representing three different families, have in common aside from some species making infrequent visits to *Thelymitra* species? All appear to be genera dominated by species in which the females show polylectic foraging habits. In these bee genera, many species appear to collect pollen from a wide variety of unrelated angiosperm species and a single bee may carry pollen from three to five different plant families in the same pollen load (Bernhardt 1989, 1995, 1996). In fact, some of these bee species forage on flowers offering pollen as the only reward including *Acacia* (Bernhardt 1989), *Dianella* (Bernhardt 1995) and *Hibbertia* (Bernhardt 1984, 1986, 1996; Dafni and Calder 1987). As some *Dianella* and *Hibbertia* species have porate-porose anthers, bees forage using sonication (Bernhardt 1984, 1986, 1995, 1996), hence these insects attempt to clasp (and vibrate?) the mitras or ornamented anthers (*e.g. T. antennifera*; Dafni and Calder 1987) of some large-flowered *Thelymitra* species.

Evolutionary significance of recurrent hybrids? Interspecific hybridization between some *Thelymitra* species appears unavoidable in Western Australia (Brown *et al.* 2008) as populations are often large, pollination events are few and different species probably share the same pollinators. As the pollinator quickly recognizes and rejects the floral presentation of the mimetic flower of one species it may actually be more likely to visit the flower of a second species in which color, odor and mitra sculpturing differ. Therefore, what is the significance of the hybrids observed and collected in this present study aside from their morphological intermediacy? Burns-Balogh and Bernhardt (1988) hypothesized that introgression was a powerful evolutionary mechanism in mitra diversification and speciation within the *Thelymitra* lineage. There is no genetic evidence to back up this hypothesis although McAlpine (1978) found morphological evidence for backcrossing between the recurrent hybrid, *T.* × *truncata*, and one of its parent species, *T. ixioides*. Instead, the origin of some *Thelymitra* species, endemic to New Zealand, reflected a history of interspecific hybridization and amphidiploidy according to Molloy and Dawson (1998). In contrast, Bower (2001) noted that introgression in *Thelymitra* species was often prevented following recurrent interspecific crosses as the first generation of hybrids were sterile.

Flowers of *T. antennifera* (Tenterden) with red blotches, in the company of many, typical *T. antennifera* plants and many flowering stems of *T. antennifera* × *T. macrophylla* make us wonder if backcrossing occurred in the past even though the majority of F1 hybrids produced malfunctioning columns? While this hybrid was and is an inefficient disperser of pollinia, we still do not know whether its stigma can accept and process the pollinia of *T. antennifera* if transported by a potential pollinator? Considering the size of the F1 population hybridization between *T. antennifera* and blue large-flowered *Thelymitra* species may be increasing in Western Australia when we compare Brown *et al.* (2008) to Nicholls (1951, Plate 44). The text in Nicholls describes *T.* × *macmillanii* (Jones 2006) but it is clear that some of the flowers illustrated (Nicholls 1951, Plate 44 b, e, g, h) are obviously *T. antennifera* × a blue and large-flowered species (see Brown *et al.* 2008). Nicholls wrote that *T. macmillanii* was present but very rare in Western Australia. It is now obvious that those red-orange hybrids are not rare today.

In fact, taxonomists with molecular laboratories might consider analyses of *T. crinita* × *T. macrophylla* and its parent species. The F_1 hybrid provided such a subtle gradation between the two parents, its presence went largely unnoticed prior to this study, except for some rescued plants collected and now grown in a glasshouse at KPBG (see above). Pollinarium structure showed no obvious dysfunction. The combination of tetrad, dyad, and monad grains in the pollinia did not indicate obvious male sterility as grains stained with Calberla's fluid remained as large as those in either parent species and filled with granular cytoplasm (Edens-Meier and Bernhardt, unpublished). Genetic analyses may provide an older history of gene filtration/migration between one or both of the parental species.

We think that we have made it clear that this genus makes an excellent field model system for floral evolution for interested evolutionary botanists with sufficient funding. Our study of one field season demonstrates the need to extend this study over a number of years to gather additional information to expand upon preexisting data and hypotheses. What is needed in particular is for populations in this study to be monitored over a far longer period of time (at least five years), especially during this period of global climatic confusion.

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A new species of *Melaleuca* (Myrtaceae) from north-east Queensland

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Abstract

Melaleuca lophocoracorum A.J.Ford, Craven & Brophy is described, illustrated and diagnosed against the allied species *M. styphelioides* and *M. squamophloia.* Notes on habitat, distribution, conservation status and leaf essential oil content are provided.

Introduction

During fieldwork in the Ravenshoe area of northern Queensland (Australia) by the first author, an unusual *Melaleuca* was noticed. The leaves were conspicuously twisted, similar in appearance to those of *M. styphelioides* Sm., yet the bark was rough and scaly rather than being flaky and papery. Subsequent visits secured fruiting collections for examination and leaf samples which were analysed for component oils. The oil analysis showed that the Ravenshoe plant produced an aromatic oil with a qualitatively different essential oils profile to that of *M. styphelioides* which produces a terpenoid oil. *Melaleuca squamophloia* (Byrnes) Craven, produced an aromatic oil also, however the analysis reveals entirely different components (see Table 2). Subsequently, flowering specimens were obtained for further examination and comparison with *M. styphelioides* and *M. squamophloia*. Taking into account the essential oils evidence, and evidence from the morphological studies, it became apparent that the Ravenshoe plant represents an undescribed species of *Melaleuca* related to *M. styphelioides* and *M. squamophloia*. Geographically, this new species occurs 700 km and 1100 km north of the most northerly populations of *M. styphelioides* and *M. squamophloia*, respectively.

Byrnes (1984, 1986) originally described *M. squamophloia* as a variety of *M. styphelioides*, based primarily upon its geographic range being between the known ranges of *M. styphelioides* and *M. bracteata* F.Muell. This variety held features linking the two, suggesting a possible “past hybridisation event” (Craven and Barlow 1997, p. 118). Craven and Barlow (1997) and Brophy *et al.* (1999) suggest a relationship between *M. stypheliodes, M. squamophloia* and *M. bracteata*. Molecular data (Edwards *et al.* 2010) supports *M. bracteata* and *M. squamophloia* being closely related. The species described below as *M. lophocoracorum* is compared to *M. squamophloia* and *M. styphelioides* on the basis of having twisted leaves, which are lacking in *M. bracteata*.

Taxonomic Treatment

Melaleuca lophocoracorum A.J.Ford, Craven and Brophy, ***sp. nov.***

Distinguished from *M. squamophloia* by the staminal filament length (0.9–3.9 mm versus 5.5–10.2 mm), indumentum of bract subtending triad (pubescent versus glabrous), number of ovules per locule (28–44 versus 40–55), embryonic cotyledon form (obvolute versus planoconvex) and dominant oil type (methyl eugenol versus elemicin and isoelemicin).

Holotype: Queensland: North Kennedy: Ravenshoe State Forest, off track to Bally Knob via Wooroora road, *A. Ford 6106*, 27 Dec 2012 (BRI); *isotype*: CANB, CNS, DNA, HO, L, MEL, MO, NSW.

Shrub (single-stemmed or multistemmed) or small tree (often multistemmed), 2–10 m high, stem diameter up to 30 cm (dbh); bark hard, fibrous to scaly, neither papery or flaky. *Branchlets* glabrescent, pilose to puberulous with short and long simple, colourless hairs (longest hairs 4 mm long). *Leaves* alternate, twisted, 2.8–8.5 mm long, 2.7–3.8 mm wide, 1.1–3.7 times as long as wide, sessile, colleters present; *lamina* glabrescent, ciliate, ovate to narrowly ovate-elliptic or elliptic, base obtuse to cuneate-obtuse, apex acute to narrowly acuminate, acumen slightly thickened, veins longitudinal; obscure, 3–10, both surfaces sparsely clothed when young in colourless sericeous to puberulous hairs, minor venation invisible, oil glands dense, distinct, 2–6 diameters apart, mostly in longitudinal rows. *Infloresences* spicate, pseudoterminal or interstitial, with 3–9 triads, up to 25 mm long and 18 mm diameter; each triad subtended by a gland dotted and pubescent broadly ovate leaf-like bract 3.5–4 mm long and 2.5–3.5 mm wide, moderately persistent; middle flower of the triad ebracteolate; lateral flowers of the triad subtended by a single deciduous, narrowly ovate bract 1.8mm long and 0.8 mm wide, adaxial surface glabrous, abaxial surface pubescent and also with two subulate to broadly lanceolate bracteoles 1.3 mm long and 0.6 mm wide, adaxial surface glabrous, abaxial surface pubescent. *Hypanthium* puberulous, 1.3–1.6 mm long, 1.8 mm diameter, urceolate. *Calyx lobes* ovate-triangular, costate on abaxial surface, minutely puberulous more so proximally, ciliate, scarious, 0.9–1.4 mm long, 1–1.5 mm wide, apex pointed. *Petals* cream, caducous, 1.8–2 mm long, conchiform. *Stamens* 15–25 per bundle; filaments cream, 0.9–3.9 mm long, bundle claw 2.6–3.1 mm long and 0.5 mm wide, 0.7–3.5 times as long as filaments. *Style* 6.7–7.5 mm long, curved, glabrous. *Ovary* usually 3-locular, densely hairy, ovules 28–44 per locule. *Fruit* persistent, lasting >3 years, 2.6–3.1 mm long, 3 mm diameter, calyx lobes persistent (lasting >12 months) but eventually weathering away and leaving low undulations around rim of hypanthium; *testa* brown, membranous, *seed* straight or slightly curved, oblong, c.1 mm long, *embryo* straight or slightly curved, cotyledons about same length as radicle, cotyledons obvolute. *Specific wood density* 870 kg/m^3. *Seedlings* (at the tenth leaf stage) with stems puberulous with antrorse colourless hairs; leaves glabrous on both surfaces, elliptic to narrowly elliptic-obovate, apex acute, base attenuate; one longitudinal vein on each side of midvein, secondary venation difficult to discern; oil dots in more or less longitudinal rows, distinct. *Coppice/resprout growth* with stems red-pink, densely pilose, hairs white to 1.5 mm long; leaves similar to adult leaves except longer and narrower on coppices, glabrous on both surfaces, margin ciliate-fimbriate, oil dots distinct and in longitudinal rows, 7–10 longitudinal veins conspicuous. (Fig. 1a–d).

Distribution: Only known from the Ravenshoe area where all collections come from Ravenshoe State Forest, Queensland, Australia.

Phenology: Flowers reported in December and January, fruits are persistent and only dehisce if burnt or the twig/branch dies.

Habitat: This species has been recorded from three vegetation types. 1. Open woodland 12–16 m high on rhyolite slopes above creeklines; dominated by *Eucalyptus portuensis* and *Syncarpia glomulifera*, understory of *Acacia calyculata, Pimelea linifolia, Platysace valida, Themeda triandra* and *Xanthorrhoea johnsonii*. 2. Riparian community 6–10 m high on seasonal creek with much rhyolite rock; *Lophostemon suaveolens* and *Melaleuca viminalis*. *Lepidosperma laterale* and *Gahnia* conspicuous. 3. Closed, or nearly so, tall woodland 12–20 m high on rhyolitic alluvium, poorly drained and swampy. The soil in this habitat is relatively deep and stays damp for a substantial period of the year. Although in close proximity to a creek, this habitat is not along the creek. Dominated by *Lophostemon suaveolens* and *Melaleuca*. Understorey of *Lantana camara*, *Gahnia aspera*, *Rhynchospora corymbosa* and small herbs. Altitude range: all collections currently come from 900m.

Etymology: The epithet *lophocoracorum* is arbitrarily derived from the Greek *lophos*, ridge, crest, and *corax*, raven, in reference to the novel Ravenshoe by Henry Kingsley (1830-1876) in which both the primary family dealt with in the novel and their home were named Ravenshoe, the name Ravenshoe apparently itself derived from the words ravens and hoe, the latter being a projecting ridge of land.

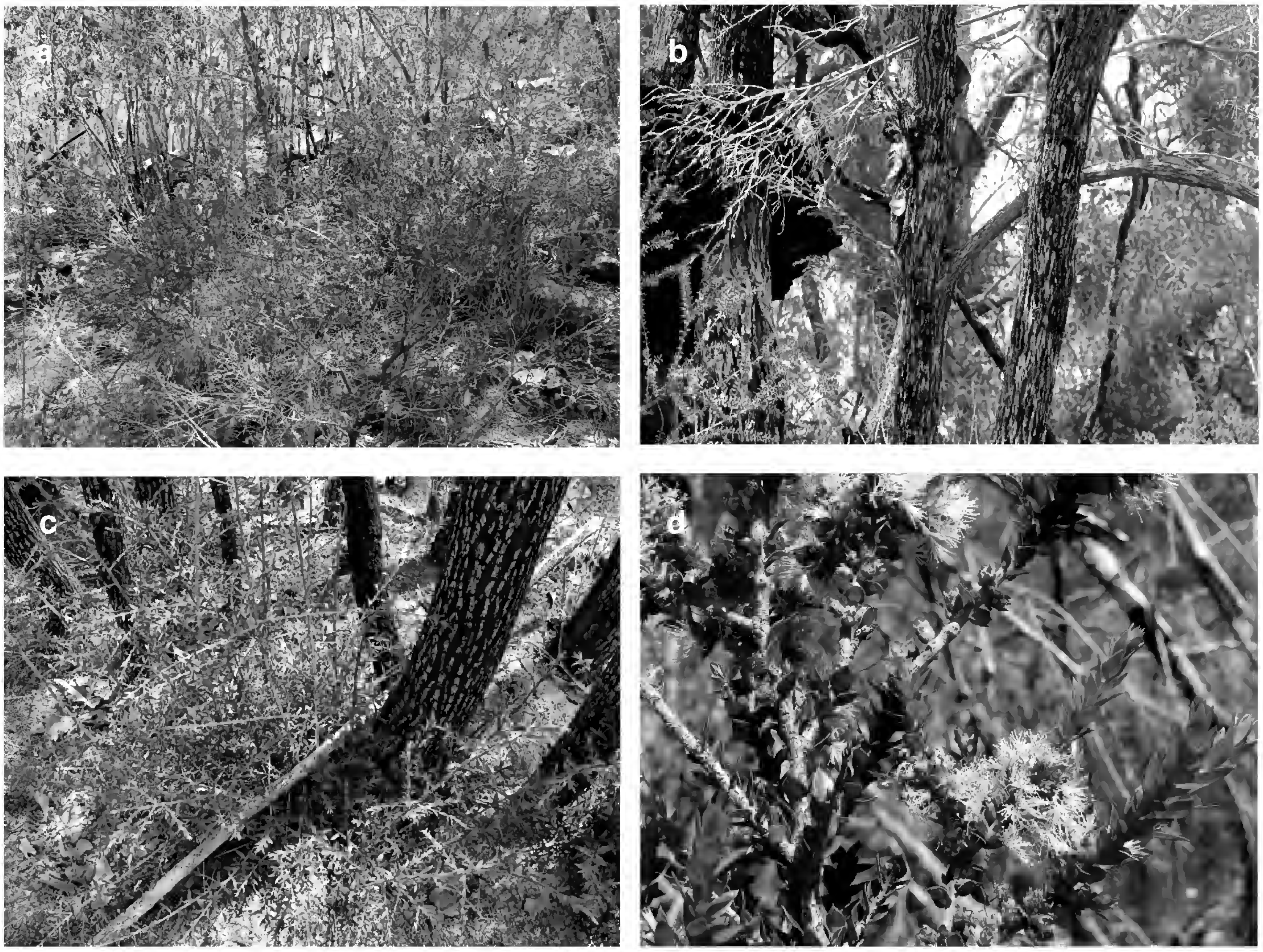

Fig. 1. *Melaleuca lophocoracorum*. **a,** habit of mature plant growing on rocky creek sides. **b,** branch resprout following fire. **c,** basal resprout following fire, also showing scaly bark. **d,** apical section of branchlets with inflorescences.

Affinities: Using morphological features alone *M. lophocoracorum* is related to both *M. styphelioides* and *M. squamophloia*. All three species are compared in Table 1. An oil analysis of *M. lophocoracorum* (Table 2) contrasts sharply against the analyses of the two putatively related species (Brophy *et al.* 1999).

Notes: *Melaleuca lophocoracorum* exhibits substantial growth form and habit variation between the three habitats outlined above. In the first two habitats (1 & 2, above), individuals of *M. lophocoracorum* are shrub-like, usually multistemmed (see fig. 1a) and attain heights of 2–4 m. In habitat three (3, above), plants are usually more tree-like, and attain heights of 10 m and stem diameters of 30 cm, although they can also be multistemmed (see figs 1b and c). Soil depth appears to play the major role in determining plant height and diameters, with habitat 3 having a much deeper soil profile, which retains moisture in the driest times of the year. The other two habitats (1 & 2), however, have much shallower soils, although moisture appears to play an insignificant role in habitat two as plants there are similar to those in habitat one. At this stage it is not apparent what role fire plays in the population dynamics of *M. lophocoracorum*, although given the restricted population size and extent of occurrence it is worth future monitoring (see below for more details).

Melaleuca lophocoracorum is fire tolerant, surviving by basal and branch resprouting (see figs 1b and c). However, although the bark is rough and thick, a large proportion of large diameter stems in habitat 3 were killed following the fire in 2012. No recruitment of seedlings was observed.

Melaleuca lophocoracorum germinates easily and grew vigorously under shadehouse conditions in Atherton, north Queensland. However, it can also be added to the list of Myrtaceae species that are susceptible to myrtle rust whilst growing in a shadehouse.

The leaves of *M. lophocoracorum* are softly prickly to touch and lack a pungent point at the apex. Both the flowers and leaves lack any distinctive or substantial aroma.

Table 1. Morphological, distributional and chemical comparison of *Melaleuca lophocoracorum, M. squamophloia* and *M. styphelioides.*

	M. lophocoracorum	***M. squamophloia***	***M. styphelioides***
Bark type	fibrous to scaly	fibrous to scaly	papery
Leaf blade indumentum	sericeous to pubescent, glabrescent	pubescent to puberulous, glabrescent	pubescent, sericeous-pubescent or puberulous, glabrescent
Leaf longitudinal veins	3–10	7–15	15–30
Number of triads in inflorescence	3–9	5–16	4–15
Bract subtending triad	pubescent	glabrous	pubescent
Staminal filament length (mm)	0.9–3.9	5.5–10.2	8.5–12.5
Stamen bundle claw length (mm)	2.6–3.1	3–4	4–5.5
Style length (mm)	6.7–7.5	7.5–8.5	7–11
Ovules per locule	28–44	40–55	45–55
Cotyledon form	obvolute	planoconvex	obvolute
Leaf oil type	aromatic,major component methyl eugenol	aromatic, major components elemicin and isoelemicin	aromatic, terpenoid, major component caryophyllene oxide
Distribution range (°latitude)	17	26–28	22–35

Table 2. Results of leaf oil analysis of *Melaleuca lophocoracorum* (voucher: *Ford 6000*)

Compound	**%**
α-pinene	trace
Δ-3-carene	trace
myrcene	trace
limonene	trace
p-cymene	trace
β-elemene	0.1
β-caryophyllene	0.6
aromadendrene	trace
allo-aromadendrene	0.1
α-humulene	0.1
bicyclogermacrene	0.1
γ-cadinene	trace
δ-cadinene	0.1
caryophyllene oxide	0.6
methyl eugenol	91.3
globulol	0.1
viridiflorol	0.1
spathulenol	0.3
eugenol	4.0
elemicin	0.7
Oil Yield % (w/w, dry weight)	2.4

Conservation Status: All existing collections have been made in the Ravenshoe State Forest within the Wet

Tropics bioregion (Department of the Environment 2012). *Melaleuca lophocoracorum* has a very narrow geographical range, with an extent of occurrence estimated to be less than 1 km^2 and an area of occupancy estimated to be less than 1 hectare, and is considered at risk at this time. An approximate estimate of the population sizes is not known, but an optimistic guess of less than 600 mature individuals is neither conservative nor extravagant. Nonetheless, due to the extremely limited distribution and estimated population sizes we suggest that *M. lophocoracorum* be listed at least as "Vulnerable" under the IUCN (2012) as it fulfils the criteria under categories VU D1 and D2. We recommend a thorough search of adjacent areas to ascertain more accurate population and occurrence estimates.

Other specimens examined: Queensland: North Kennedy: Ravenshoe State Forest (ex-State Forest Reserve 488), off Wooroora Road NNW of Bally Knob, *Ford 5977 & Collins*, 6 Feb 2012 (BRI, CANB,CNS); *loc. cit.*, *Ford 6000*, 2 May 2012 (BRI, CANB, CNS)

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Allan Cunningham's cryptic publications

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Abstract

It has been asserted that the botanist/explorer Allan Cunningham (1791–1839) published very little. It is shown that, on the contrary, in the five years while he resided at Strand-on-the-Green (1831–1836) he was remarkably productive, although a large number of his publications were cryptic, buried in the works of others, particularly those of W.J.Hooker (*Curtis's Botanical Magazine*) and J.Lindley (*Edwards's Botanical Register*). The events leading to these cryptic publications are described, and an Appendix listing his publications (7 major, and 57 'cryptic' ones) is presented.

Introduction

Allan Cunningham (1791–1839) is rightly remembered as one of Australia's foremost botanists and explorers of the early 19th century. Cunningham spent about 18 years in Australia (December 1816–February 1831, and February 1837–June 1839). In that time he took part in Oxley's first inland expedition from the Blue Mountains, accompanied Phillip Parker King in four circumnavigations of Australia, making many of the first botanical collections from the north and north-west coasts, visited Timor (twice), Mauritius, Tasmania, New Zealand (twice) and Norfolk Island, and made thousands of collections of plants, many of which later served as type specimens. He led several major expeditions north and south from Bathurst, found Pandora's Pass into the Liverpool Plans, and discovered the Darling Downs, and access to them from Moreton Bay through Cunningham's Gap. He was involved in the establishment of the Newcastle and Moreton Bay colonies, and in later life was consulted on establishment of the colonies at Swan River, Adelaide and various settlements in the Darwin region.

It has often been commented that Cunningham, like other early botanical visitors to Australia, published very little. For example, John Lindley in his notice of Cunningham's death (Lindley 1840, p. 2) said "*In this gentleman both Geography and Botany have sustained a real loss; for he was an excellent practical Botanist. How little he regarded posthumous fame is seen by the fewness of his published works, a brief sketch of the Flora of New Zealand being the only systematic account of his Botanical discoveries printed during his life…*". In the only modern biography of Cunningham (McMinn 1970) only eight papers by Cunningham are listed (two are incorrectly cited as being published in "*Ann. Sci. Nat.*" [*Annales des Sciences Naturelles, Botanique*] of 1835, both being wrongly cited references to French notices of Cunningham papers that first appeared in *Curtis's Botanical Magazine*). Is this a true reflection of his scholarship? I hope to show that it was not.

Discussion

Cunningham was sent to Australia primarily to make collections of seeds, bulbs and live plants to supplement the King's (private) Garden at Kew – his official title was King's Collector for Kew. He also prepared in parallel pressed specimens to send to William Aiton at Kew and to Joseph Banks (later to Robert Brown) at Soho Square, principally as vouchers for the propagation material. Thus, while surviving herbarium specimens were in fact secondary products of his travels, they have furnished his major legacy.

Cunningham was the son of Allan Cunningham Senior (1742–1828), a Scots gardener from Renfrewshire, who moved to London in the 1780s to become Head Gardener at Wimbledon House, owned by Earl Spencer. Despite his family background Allan Cunningham and his brother Richard both had a very good education, including Greek and Latin. Originally he studied for the law, and worked for a year or two in a conveyancer's office at Lincoln Inn in London. Tiring of this, he spent several years at Kew as Aiton's assistant working on preparing the second edition of *Hortus Kewensis* for publication. In this period he became well acquainted with Robert Brown, who in fact wrote much of *Hortus Kewensis* for Aiton, so he was a well-educated and quite competent botanist by the time he arrived in Australia, well able to reliably identify the plants he was collecting. He was very well aware that he was collecting many previously unknown species, and he expected that these would be described (and his role in discovering them acknowledged) by professional botanists. This did not happen until, as described below, his brother Richard intervened by contacting William Hooker. Allan himself undertook description of his discoveries from 1825.

William Aiton's interest was in redeveloping Kew as the leading botanic garden in Europe after the disruption of the Napoleonic Wars. This meant cultivating the largest possible number of rare, new and unusual plants. While he welcomed the flow of new propagation material from Australia, he had an interest only in displaying it, not in describing it. His motivation was horticultural rather than scientific. The specimens sent to Banks were added to his herbarium, along with material from many other sources, but Banks had long moved on from undertaking botanical research to matters of state. His librarian Robert Brown inherited Banks's herbarium on the latter's death in 1820, and eventually took it with him when appointed first Keeper of Botany in the British Museum. However, lack of interest in his first attempt to produce an account of the Australian flora, his *Prodromus* (Brown 1810), had blunted Brown's interest in large scale descriptive works and thereafter he wrote mainly short taxonomic papers on restricted groups. This aroused the displeasure of, among others, Lindley (1832, t. 1514), who in discussing *Dillwynia glycinifolia* complained "*Its genus, however, is to us, as it was to Smith and De Candolle, a matter of uncertainty, which, unfortunately for science, seems little likely to be cleared up, although it is now nearly thirty years since materials for the completion of the Flora of Australia were furnished by the liberality of the British government. It is time that this were looked to: and much to be wished that some enterprising naturalist would convert to an useful purpose the rich stores of information regarding Australasian Vegetation procured at the national expense, and now open to all inquirers, which are lying unemployed at the British Museum. When we see the fate of the plants collected in Flinders's expedition* [i.e. Robert Brown's collections], *and in the fatal journey up the Congo by the lamented Christian Smith, we can scarcely wonder that a wise and careful government should object to pay the expenses of scientific expeditions.*"

Although Cunningham was forbidden under his employment contract from sharing his collections with others, for fear that they would 'leak' to the nursery trade in England, diluting Kew's novelty value, he was aware that colonists in New South Wales were sending seeds home, as were some of the officers and crew on King's voyages, and some of the members of his inland expeditions. Matters became more serious when William Baxter arrived in the colony, to undertake wholesale seed collecting for the nurseryman Henchman and others during the 1820s. Baxter made several trips to King Georges Sound and other localities in SW Western Australia (1823–25, 1828–29). There he re-collected a number of undescribed species which Cunningham had found several years earlier, but which languished neglected in London.

At this time William Hooker was Professor of Botany at Glasgow University, and Allan Cunningham's brother Richard was William Aiton's amanuensis, and, in effect, deputy. [To avoid confusion, hereafter Richard Cunningham will be referred to by his full name, 'Cunningham' used alone refers to Allan Cunningham]. Richard was very concerned about the lack of recognition of his brother's work and, in a series of letters to Hooker in the period 1823–1829, developed a scheme whereby Richard would privately send live specimens of new plants that had been collected by his brother and flowered at Kew to Hooker for publication in *Curtis's Botanical Magazine*, the supporting notes coming from Allan's diaries but disguised so as to protect his position. Towards the end of this period Aiton reluctantly gave limited approval for material to be sent to Hooker, but actually authorised very little (various letters from Richard Cunningham to Hooker). Richard sent specimens anyway, and suggested that Hooker thank Aiton for his generosity, which he did! In mid-1824 Allan Cunningham wrote to his brother from Sydney "*I wish I could fairly (situated as I am in relation to Kew) send periodically to Dr. Hooker specimens of my plants, after supplying Mr. Aiton's & Mr. Brown's Herbaria. I wish to* *act uprightly to all concerned, but when I consider that the persons to whom I am bound to send my plants do not publish them, but rather sedulously study to keep them from the public &c, thereby giving full opport^{y} for others to claim the merit of Discovery, I regret it much, & feel disposed to give that to others who would do justice to any thing interesting I might send. I have no hesitation in saying that so soon as I am released from my present tie, I shall not scruple to act as I have said.*" The original of this letter has been lost, but the above extract was quoted by Richard Cunningham in a letter to Hooker (Cunningham 1825).

Allan Cunningham requested recall to England in the late 1820s, and arrived back in July 1831, renting a cottage at Strand-on-the-Green across the river from Kew. There he began the task of sorting and studying his collections. He was now free of his contractual obligations and lost no time in taking up his own correspondence with Hooker. It was arranged that Richard Cunningham would send Hooker from time to time choice fresh specimens of new Cunningham taxa which had flowered in Kew, and Allan would supply Hooker with text. Hooker would prepare the drawings and publish the descriptions in *Curtis's Botanical Magazine*. The text that Allan Cunningham prepared was complete, as required for publication. He supplied names, Latin descriptions, notes on provenance and habitat, and often discussion of related or confusable taxa. This text still survives in the original letters in the Director's Correspondence files at Kew, and matches the published text virtually word for word. From comments in some later letters to Hooker from Cunningham, it appears that towards the end of this collaboration, Cunningham was sometimes providing the text directly to the printer in London, who inserted it appropriately adjacent to Hooker's illustration. This was the case with, for example, *Eurycles*, discussed below.

The first instance of this collaboration between Cunningham and Hooker was the case of *Geitonoplesium*. Cunningham wrote to Hooker (Cunningham 1832) pointing out that Brown had described a New South Wales plant as *Luzuriaga cymosa*. Cunningham had spoken with Brown at Kew and together they had examined the N.S.W. plant in flower. Both agreed that the N.S.W. plant was not *Luzuriaga* (a Peruvian genus). Cunningham commented "*Believing as I now do that Mr. Brown has no Intention to correct his mistake himself, I now make you the Comments with a view of providing a brief remark on the plant, which you have had some time before you for publication.*" The description of *Geitonoplesium cymosum* appeared a month later in *Curtis's Botanical Magazine* vol. 59 (Feb. 1832) as Plate 3131. The text accompanying it is a masterpiece of diplomacy. As Cunningham had suggested in his letter, Hooker adopted Brown's previous description under *Luzuriaga* as the basis of the new genus, and Brown's diagnosis of the species after the new combination. Cunningham's suggestion of this combination was given as '*in litt.*'. The derivation of the name and its general distribution at the bottom of the page are virtually *verbatim* from Cunningham's letter (and attributed to him). On the second text page Mr. Aiton is credited with sending the live material (although this had been done by Richard Cunningham), and Brown is acknowledged as originally doubting the assignment to *Luzuriaga*. Most of the remaining text is taken directly from Cunningham's letter, slightly paraphrased. All egos were thus protected. This is the first of Cunningham's cryptic publications, but as the Code provides that a name is only to be attributed to an author in the publication of another when both the name and description are clearly indicated as having been supplied by that author, judged on internal evidence [author's emphasis], the combination *Geitonoplesium cymosum* is correctly attributed to Brown, although the expanded form A.Cunn. ex R.Br. is certainly warranted in this case (*Geitonoplesium cymosum* (R.Br.) A.Cunn. ex R.Br.).

The following month, on 8th March, Cunningham wrote again to Hooker. Richard Cunningham had just sent to Glasgow from Kew live material of eight Cunningham plant introductions, and Allan supplied the necessary text. The plants were *Pittosporum cornifolium* A.Cunn. *mss* from New Zealand, and the Australian *Hymenanthera dentata* R.Br., *Baeckea saxicola*, *Leucopogon lanceolatus* R.Br., '*Leucopogon gnidiifolius*' (based on *Styphelia gnidium* Vent., but the new combination never formally published), *Acrotriche ovalifolia* R.Br., *Epacris onosmaeflora* A.Cunn. and *Anthocercis albicans* A.Cunn. *Pittosporum cornifolium* A.Cunn. appeared in *Curtis's Botanical Magazine* (1832) as t. 3161, and the previously described species *Hymenanthera dentata* R.Br. appeared as t. 3163 with Cunningham's notes attached. *Baeckea saxicola* appeared as t. 3160, with the name attributed to Cunningham. However he did not supply Hooker with a Latin diagnosis in his letter (only details of collection and habit, which were reported by Hooker), and the formal description omits his name. The name is thus nomenclaturally *Baeckea saxicola* A.Cunn. ex Hook. *Leucopogon lanceolatus* R.Br. appeared as t. 3162 in the same publication with notes by Cunningham, separating it from *Styphelia gnidium* Vent. (now *Leucopogon parviflorus* (Andrews) Lindl.). This second *Leucopogon* species was not illustrated in *Curtis's Botanical Magazine* by Hooker, although his remarks under *L. lanceolatus* indicate that he intended to. In a later letter (Cunningham 1833) Cunningham explained to Hooker that there had been a mix up of seeds at Kew. The plant that they had grown as 'L. gnidium', allegedly from seed collected from N.S.W. (New South Wales), was in fact from his King George Sound seed. Lindley had subsequently published this plant in *Edwards's Botanical Register* as t. 1560 (1833), calling it *Styphelia parvifolia* Andrews, but Cunningham was scathing in his criticism of the illustration in Andrews' *Botanists Repository* (Andrews 1803) ("…*as for the* *wretched [illustration] of the Bot. Rep^{y} named Styphelia parviflora, which was clearly a Kind of Leucopogon, no human being could say what it was, without a perfect knowledge of the history of the plant."*). *Acrotriche ovalifolia* R.Br. appeared as t. 3171 with Cunningham's notes attached. *Epacris onosmaeflora* A.Cunn. appeared as t. 3168, with the name and description attributed to Cunningham, based on his previous publication of the species in Field's *Memoirs* (Cunningham 1825). *Anthocercis albicans* A.Cunn., published by him in Field's *Memoirs*, was never illustrated by Hooker in *Curtis's Botanical Magazine*. For all contributions Mr. Aiton was thanked for providing live material (actually sent by Richard Cunningham).

Richard Cunningham sent another three large batches of living material (41 species) to Hooker during April 1832, and Allan Cunningham provided notes on all of them in a letter of 30th April (Cunningham 1832). In this letter he mentioned that he intended to embark on a detailed enumeration of Australian *Acacia*, a genus which he had found wherever he went. This enumeration was never published in its entirety, but he subsequently sent Hooker a large number of accounts of individual species. He also mentioned in particular *Grevillea robusta* A.Cunn. ex R.Br., which Kew had growing from his seed, but which he expected would never flower in Europe. He sent an herbarium specimen for Hooker to use in his drawing, supplementary to fresh leaves supplied by Richard Cunningham. This plant appeared as t. 3184 in *Curtis's Botanical Magazine*. Of the 41 plants sent to Hooker, 16 eventually appeared in *Curtis's Botanical Magazine* and are listed under cryptic publications in the Appendix below.

In May Cunningham received two pieces of unwelcome news. From Sydney he heard that his old friend Charles Fraser, the Colonial Botanist, had died. This news was ameliorated by the appointment of his brother Richard in Fraser's place. Richard Cunningham took up the position in January 1833. The other news was that Hooker would have to stand down as editor of *Curtis's Botanical Magazine* at the end of the year, due to falling subscriptions.

In July 1832 Cunningham wrote a long letter to Hooker summarising extensive research he had undertaken into the trade in New Zealand Flax (*Phormium tenax*). This letter was reprinted verbatim over five pages of the *Botanical Magazine* (t. 3199), one of the largest contributions that Cunningham made to this publication. In early September he sent Hooker an emended description of a *Daviesia* specimen forwarded from Kew some months earlier. This was published as *Daviesia virgata* A.Cunn. (t. 3196) shortly afterwards. In late September he heard from Hooker that the latter would continue as editor of *Curtis's Botanical Magazine*, but with apparently inferior recompense, and the subscription price was to be raised. The bad news from Cunningham's viewpoint was that he now found himself unable to directly access the living collections at Kew to send samples to Hooker. Richard Cunningham, now Colonial Botanist, had been able to do so, but Allan did not have staff privileges. To some extent this was overcome, because in late November Cunningham sent Hooker four new live samples, received "per Messenger" from Kew. It is possible he obtained these from his friend John Smith, the head gardener.

Cunningham sent Hooker eight more plants in April 1833, but of these only one was accepted for publication: *Leucopogon richei* (Labill.) R.Br., t. 3251 (Fig. 1). This was the "Leucopogon gnidifolius" sent a year earlier. Cunningham and Brown had spent some time investigating it, both in Kew and in commercial nurseries (Lowe's and Loddiges'), discovering that it had been grown under at least four names in London. Cunningham provided a new Latin diagnosis, synonymy, and a 5-page account of its discovery.

Brown and Cunningham visited Kew on 20th May 1833, and as a result Cunningham sent six more specimens to Hooker, with descriptions following on 17th June. Of these, *Epacris heteronema* Labill., *Dracophyllum secundum* R.Br., *Calytrix virgata* A.Cunn., and *Plagianthus divaricatus* J.R.Forst. & G. Forst. were published in *Curtis's Botanical Magazine*. The *Calytrix* is particularly noteworthy. Cunningham appended to this description a short monograph, including key, of the 12 species known at that time. It is unfortunate that the name *C. virgata* coined at that time is illegitimate, being a replacement name for the valid *C. ericoides* A.Cunn. (now synonymous with *C. tetragona* Labill.)

In July 1833 Cunningham sent another consignment of four plants, which had been "sent over to him from the Gardens [Kew]". All four of these, *Cargillia australis* R.Br. (now *Diospyros australis* (R.Br.) Hiern), *Beaufortia dampieri* A.Cunn. (now included in *Beaufortia sprengelioides* (DC.) Craven), *Pimelea arenaria* A.Cunn., and *Marsdenia flavescens* A.Cunn. (Fig. 2) appeared in *Curtis's Botanical Magazine*. During August and September Cunningham was unwell, suffering from what appears to be severe migraine headaches, which affected his sight. In November however he sent Hooker another nine specimens, with descriptions following in December. Of these *Westringia cinerea* R.Br. (now included in *W. dampieri* R.Br., a specimen of which was also sent at this time, but not illustrated), *Trachymene lanceolata* (Labill.) Spreng. (now *Platysace lanceolata* (Labill.) Druce), *Cyminosma oblongifolia* A.Cunn. ex Hook. (now *Acronychia oblongifolia* (A.Cunn. ex Hook.) Endl. ex Heyhn.), *Alyxia ruscifolia* R.Br., and *Alyxia daphnoides* A.Cunn. (now *A. gynopogon* Roem. & Schult.) were all subsequently illustrated in *Curtis's Botanical Magazine*. The case of *Cyminosma* is interesting. Cunningham

Fig. 1. *Leucopogon parvifolius* (Andrews) Lindl., illustrated in *Curtis's Botanical Magazine* 60: t. 3251 (1833) as *Leucopogon richei*, from material grown at Kew, from seeds collected by Allan Cunningham at King Georges Sound. Cunningham, with Robert Brown, spent some time establishing the identity of the species, and Cunningham provided a detailed account of its original provenance by Riche.

Fig. 2. *Marsdenia flavescens* A.Cunn. illustrated in *Curtis's Botanical Magazine* 60: t. 3289 (1833), and described there by Cunningham.

had thought his plant represented a new genus and sent Hooker a detailed Latin description. Hooker chose not to use this, treating the taxon as a species of the pre-existing *Cyminosma* , and crediting Cunningham only with the name, not the description. The authority is thus A.Cunn. ex Hook. The two *Alyxia* species are noteworthy in that Cunningham provided a synopsis of the genus, which was appended to the *A. daphnoides* treatment. In a letter to Hooker of 3rd April 1834 Cunningham complained of the number of typographical errors in the treatments of *Alyxia*, and eventually persuaded Hooker to let him proof-read his contributions by liaising with the London printer. The following day Cunningham wrote again to Hooker to tell him of some *Pterostylis* species that were flowering at Kew, and to say that Mr Aiton had informed him some 4 months earlier that he was thinking of sending Hooker some specimens, and drawings by the Kew artists (see Mabberley 2004 for discussion).

On 15th April 1834 Cunningham again forwarded plants received from Kew, this time six species. Of these only three, *Pimelea hypericina* A.Cunn. (now *P. ligustrina* subsp. *hypericina* (A.Cunn.) Threlfall) *Acacia elongata* Sieber ex DC. and *Acacia umbrosa* A.Cunn. ex G.Don (now *A. binervata* DC.) were accepted for publication. No further Australian plants of Cunningham's introduction flowered in Kew for the next six months. In October he sent Hooker live material of *Chilodia scutellarioides* R.Br. (now *Prostanthera scutellarioides* (R.Br.) Briq.) which appeared in the *Botanical Magazine* as t. 3405 with a detailed history by Cunningham. With the *Chilodia* was sent *Westringia eremicola* A.Cunn. ex Benth. (t. 3438), and a number of others which were not published.

On 26th November 1834 Cunningham told Hooker that he had just received a large collection of New Zealand plant specimens from his brother Richard, including a number of new species. Richard had visited New Zealand in 1833–34, staying mainly in the Bay of Islands region. Allan had resolved to drop all other projects to compile a Flora of New Zealand, based largely on his own 1826 collections, and those of Richard. This Flora was eventually published serially by Hooker in the *Companion to the Botanical Magazine* and *Annals and Magazine of Natural History* between 1836 and 1840. In the same letter he stated that he had sent Lindley some notes on a *Dendrobium* collected by Richard. This was published in *Edwards's Botanical Register* of 1836 (t. 1828: *Dendrobium cassythoides* R.Cunn.).

Cunningham sent Hooker a box containing two live specimens, *Isopogon spathulatus* R.Br. and *Cryptandra amara* Sm. on 23rd February 1835. By return mail he received a letter of complaint from Hooker, stating that the plants were quite unsuited to *Curtis's Botanical Magazine*, and Hooker had been put to needless expense in taking delivery of them (at this time postage was usually paid on receipt of letters and packets, not at despatch). In the reorganisation of *Curtis's Botanical Magazine* which had taken place three years earlier Hooker had been instructed that only plants of high horticultural merit were to be included. Scientifically interesting but not showy did not qualify for entry. Cunningham replied on 3rd March (by prepaid letter!) that he would probably not be sending much more for *Curtis's Botanical Magazine*, as most of the remainder of his introductions to Kew "…*want in general, that external gloss or show which appears essential to meet the Eye of a public…*". He confirmed that he had provided text for *Acacia undulifolia* A.Cunn. ex G.Don to the printer and was about to send that for *Eurycles cunninghamii* Aiton ex Lindl. (now *Priophys cunninghamii* (Aiton ex Lindl.) Mabb.). These two contributions were published as t. 3394 and t. 3399 respectively, the latter notable for including a synopsis of the genus *Eurycles* by Cunningham. The last despatch of specimens by Cunningham from Kew came on 5th March 1835, when he sent two species of *Isopogon* and his *Acacia prominens* A.Cunn. ex G.Don. Only the last was published. Cunningham's last cryptic paper, a generic synopsis, appeared in the 1836 *Curtis's Botanical Magazine*, under *Veronica labiata* R.Br., t. 3461, where he described a number of his brother's New Zealand *Veronica* species.

Over a period of five years Cunningham had loyally supported Hooker and *Curtis's Botanical Magazine* against Lindley and *Edwards's Botanical Register*, which he viewed as inferior. His aim was to gain recognition as the discoverer of new plants, not necessarily as their describer. On several occasions in letters to his brother and to Hooker, he expressed his regret that "Professors of Botany" (i.e. Lindley, Brown, and latterly various European botanists) had not described his new discoveries. For this he principally blamed Brown and Aiton, for not making them available to the wider scientific community. However, from 1831 to 1836 he had access to his living introductions at Kew, and he took pains to bring these to Hooker's attention. Lindley, however, was antipathetic to Kew and Aiton. In his treatment of *Isopogon formosus*, Lindley (1829) had stated "*This, the most beautiful of its genus, is said to have been introduced so long since as the year 1805 to the Kew Garden. As far, however, as the public is concerned, the date of its introduction may be more properly fixed in 1824, when it was raised by Mr. Mackay, from seeds collected in the neighbourhood of Lucky Bay, by Mr. Baxter, on his first visit to the west coast of New Holland. It is right, that in all questions about the period at which plants have been introduced, this distinction should be borne in mind, and that the world should be aware that the introduction of a plant to his Majesty's Garden at Kew, is a very different affair from its introduction to Great Britain. An object* *cannot be properly said to be introduced from one country to another, unless it is afterwards disseminated by such means as the introducer possesses; a practice which is adopted in every establishment in the world. save in that one which ought to set an example to all others.*" Lindley (1832) also criticised the lack of progress on describing the accessions received from abroad by Kew and the British Museum (Robert Brown) (see above). Lindley instead took the part of the commercial nurserymen, and *Edwards's Botanical Register*, which he edited, almost exclusively reported on introductions by the nurseries or their rich landed customers. On at least two occasions Cunningham wrote to Hooker warning him that Lindley had had drawings made for the *Register*, of plants which Hooker was in the process of publishing in the *Magazine*.

Despite his reservations, Cunningham maintained polite contact with Lindley, as he did with all the senior botanists in London, Scotland, Ireland and on the Continent. Heward (1842) noted (p. 116) that Cunningham frequently entertained botanists and like-minded friends at his cottage at Strand-on-the-Green, and provided them with access to his herbarium. Visitors certainly included Robert Brown and David Don, mentioned in letters to Hooker, but possibly not Lindley. However Cunningham did recognise Lindley as a pre-eminent authority on orchids, and obviously sent him duplicates of all or most of his Australasian Orchidaceae. Lindley published a substantial number of these in his monograph of the family (Lindley 1830–1840). These publications, however, must be attributed to Lindley, as he seems only to have used Cunningham's names, not his descriptions. These taxa are thus to be cited as, e.g. *Caladenia clavigera* A.Cunn. ex Lindl. However, when Hooker made it clear that he could not publish non-showy Australian plants, Cunningham turned to Lindley and *Edwards's Botanical Register*. In 1832 Cunningham had sent Hooker for *Curtis's Botanical Magazine* material of *Leucopogon parviflorus* (as *Styphelia gnidium*), but Hooker had not published it, only referring to the species under *L. lanceolatus*, and publishing a Cunningham cryptic paper (see Appendix, Cunningham 1832c). The following year Cunningham sent the same material and notes to Lindley, and the notes were published (Lindley 1833a), with Lindley only acknowledging that the information had come from Cunningham. In the same issue of *Edwards's Botanical Register* Lindley acknowledged receipt of material of *Gompholobium lanatum* from Cunningham under t. 1563, *Gompholobium capitatum*. Cunningham also contributed remarks on *Pultenaea mucronata* under *P. rosmarinifolia* (Lindley 1833b). The following year Lindley (1834) gave Cunningham more credit, when, under *Billardiera ovalis* (t. 1719) he described the genus *Cheiranthera* and a single species, *C. linearis*. Both the genus name and specific epithet were attributed to Cunningham, but Lindley ostensibly provided the descriptions, meaning that the authorship of each name is to be cited as A.Cunn. ex Lindl. The phraseology of the habitat description is clearly that of Cunningham. Lindley (1835) published a note on the New Zealand species *Clianthus puniceus* in which he also described two Australian species of *Clianthus*, based on Cunningham names, but again with his own descriptions. This article was reprinted in part in *Edwards's Botanical Register* of 1835 (21: t. 1775) with mention of Cunningham's contribution. In 1836 Lindley finally allowed Cunningham space in *Edwards's Botanical Register* to publish his own short article, an account of Australian *Tristania* species under *T. macrophylla* (t. 1839). The name, but not the description, of *T. macrophylla* was attributed to Cunningham, so the technical authorship of this name must be A.Cunn. ex Lindl. However, the attached article is clearly attributed solely to Cunningham, and in it he describes three new species, *T. umbrosa* A.Cunn., *T. psidioides* A.Cunn., and *T. salicina* A.Cunn. In the same issue, under *Dendrobium densiflorum*, Lindley had inserted a note by Allan Cunningham, conveyed from his brother Richard, in which the species *Dendrobium cassythoides* R.Cunn. (now *Erythrorchis cassythoides* (R.Cunn.) Garay) is described. Later the same year Allan Cunningham contributed a note on apetalous *Fuchsia* species. Cunningham's final contribution to *Edwards's Botanical Register* was posthumous. When Lindley described *Dendrobium cucumerinum* (Lindley 1843) he included a five page essay by Cunningham on the geographical distribution of Australian orchids.

As well as the short communications discussed above, Cunningham also published seven major stand-alone papers. The first of these were two chapters contributed to Field's *Memoirs* in 1825, one of which enumerated 102 species collected mainly north of Bathurst, of which 67 were newly described, as well as a new genus, *Fieldia*. In 1827 he contributed a substantial botanical Appendix to P.P. King's *Narrative*. On his return to Britain he took an active part in the scientific community, publishing an account of inland exploration of New South Wales up until 1832, with a detailed map, in the *Journal of the Royal Geographical Society* in 1832. Later the same year, in the same issue of the *Journal* Cunningham made two further contributions. A letter had been received from Lieut.-Colonel Dumaresq describing how a recaptured escaped convict claimed that he had twice followed a broad navigable river from the western side of Liverpool Plains north-west to the Gulf of Carpentaria, where it emptied into a vast lake. At its northern end aborigines described Malays with bows and arrows, who were harvesting large numbers of sandalwood trees. Cunningham corresponded with the Secretary of the Geographical Society (drafts of this correspondence are held in the Mitchell Library, Allan Cunningham Papers 1827–32, f. 10–12, Call No. D 79), showing that the convict had almost certainly travelled from the Castlereagh River to the Gwydir, and followed it for some distance, but that it was impossible that he had reached the Gulf, and his accounts of baboons, hippopotamus and Malay fishermen were inventions. In a separate article, two letters from Surveyor-General Major Mitchell's expedition to the Peel and Namoi Rivers were published, and again Cunningham provided a commentary, concluding that no major new discoveries had been made, but the probability that all the northern inland rivers eventually drained into the Darling had been increased.

Shortly afterwards Cunningham published a paper on the geology of the north-western slopes of New South Wales and the Moreton Bay region, in the *Proceedings of the Geological Society of London* in 1834–35, a description of a *Grevillea* species in the *Narrative* of his friend T.B.Wilson R.N. in 1835, a Flora of New Zealand in 1836–1840, and an account of the Kiwi in the *Annals and Magazine of Natural History* in 1840 (see Appendix for full bibliographic references of all of the above). He was elected a Fellow of the Linnean Society, and his Life Membership fees were refunded to him in recognition of his accomplishments.

He clearly intended to publish much more. Among his papers at Kew and the Natural History Museum are hundreds of draft descriptions of the plants he had collected. He almost certainly would have written a Flora of Norfolk Island had S.F.L. Endlicher not forestalled him. The tragic death of Richard Cunningham and subsequent recall of Allan to New South Wales cut his research and writing short, and ultimately hastened his own death. Had this not occurred it is possible that Allan Cunningham might well have completed the Australian Flora account begun by Robert Brown in 1810, and about which Lindley was complaining in 1832. It took another 30 years before Bentham finally prepared a comprehensive Australian Flora, (Bentham 1863–1878), drawing in part on Cunningham's collections. Candolle also published a large number of Cunningham taxa, usually taking up his manuscript names. This was particularly the case for the Asteraceae (Candolle 1836), for which Cunningham sent at least two large consignments of specimens to Geneva.

Conclusions

Cunningham was well aware of the new taxa that he had discovered, and assigned many manuscript names to his specimens. These specimens, with their manuscript names, were distributed widely. Other authors, mostly long after his death, often picked up these manuscript names, and his legacy lives on in the more than 450 species names and several genus names listed in the Australian Plant Name Index with the authority "A.Cunn. ex …". The publishing authors are a Who's Who of major botanists, including particularly G. Bentham and A.P. de Candolle, but also G. Don, W.G. Walpers, J.C. Loudon, J.C. Schauer, C.D.F. Meisner, S.F.L. Endlicher, W.J.Hooker, J.D.Hooker, E. Fenzl, F.J.H. von Mueller, J. Steetz, J. Decaisne, , R. Brown, J. Lindley, A. Gray, F.A.W. Miquel, and others.

Cunningham's publications are listed in the Appendix to this paper. There, seven major papers (including a complete Flora of New Zealand), and 57 shorter "cryptic" papers are listed, covering subjects as diverse as botanical taxonomy, geology, physical geography, botanical geography (in which he was one of the earliest researchers), and zoology. Not discussed here are the numerous, often lengthy, official reports that he prepared after each expedition for the colonial government, and official and unofficial submissions to other enquiries (particularly the Bigge Commission into the governance of New South Wales towards the end of Macquarie's governorship, and various proposals for the establishment of colonies in Queensland, South Australia, Western Australia and the Northern Territory). Together they make an impressive showing, particularly when it is remembered that while he was employed as King's Collector for Kew he was effectively barred from publishing on botany. His incredible productivity surely refutes Lindley's view (and that of others) that his published output was sparse.

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Lindley J (1833b) *Pultenaea rosmarinifolia*. Rosemary-leaved Pultenaea. *Edwards's Botanical Register* 19: t. 1584. (James Ridgeway: London)

Lindley J (1834) *Billardiera ovalis*. Oval-leaved Billardiera. *Edwards's Botanical Register* 20: t. 1719. (James Ridgeway: London)

Lindley J (1835) Note upon a handsome and hardy plant called *Clianthus puniceus*. *Transactions of the Horticultural Society of London* ser. 2 1: 519–522 (1835) [Description of *Clianthus dampieri* A.Cunn. ex Lindley and Clianthus oxleyi A.Cunn. ex Lindl., both now *Swainsona formosa* (G.Don) Joy Thomps.]

Lindley J (1836) *Tristania macrophylla*. Large-leaved Tristania. *Edwards's Botanical Register* 22: t. 1839. (James Ridgeway: London)

Lindley J (1840) Death of Mr. Allan Cunningham. *Edwards's Botanical Register* 26: 1–3. (James Ridgeway: London)

Lindley J (1843) *Dendrobium cucumerinum*. Cucumber Dendrobium. *Edwards's Botanical Register* 29: t. 37. (James Ridgeway: London)

Mabberley DJ (2004) The Botanical Magazine and George Bond's drawings of Allan Cunningham's Australian plants. *Curtis's Botanical Magazine* 17(4): 226–235.

McMinn WG (1970) *Allan Cunningham, Botanist and Explorer.* (Melbourne University Press: Carlton)

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APPENDIX

Allan Cunningham's publications

The following is a list of all publications which I have located in which Allan Cunningham was involved, either as sole author, or as a contributing author (the latter mainly in *Curtis's Botanical Magazine* and *Edwards's Botanical Register*).

A. Major stand-alone publications

Cunningham A (1825a) A specimen of the indigenous botany of the mountainous country between the colony around Port Jackson and the settlement of Bathurst…, pp. 323–365, in Field B, *Geographical Memoirs on New South Wales by Various Hands.* (John Murray: London)

Cunningham A (1825b) Journal of a route from Bathurst to Liverpool Plains, pp. 131–191, in Field B, *Geographical Memoirs on New South Wales by Various Hands.* (John Murray: London)

Cunningham A (1827) A few general remarks on the vegetation of certain coasts of Terra Australis, and more especially of its north-western shores, pp. 497–533, Appendix to King PP, *Narrative of a Survey of the Intertropical and Western Coasts of Australia*, Vol. 2. (John Murray: London)

Cunningham A (1832) Brief view of the progress of interior discovery in New South Wales, *Journal of the Royal Geographical Society of London* 2: 99–132, plus Map.

Cunningham A (1834–35) On the physical and geological structure of the country to the west of the Dividing Range between Hunter's River (lat. 32°S.) and Moreton Bay (lat. 27°S.), with observations on the geology of Moreton Bay and Brisbane River, New South Wales, *Proceedings of the Geological Society of London* 2: 107, 109–111.

Cunningham A (1836–1840) Florae Insularum Novae Zelandiae Precursor: or a specimen of the botany of the islands of New Zealand, *Companion to the Botanical Magazine* 2: 222–233, 327–336, 358–378 (1836–1837); *Annals and Magazine of Natural History* 1: 210–216, 376–381, 453–462 (1838); 2: 44–52, 125–132, 205–214 (1839); 3: 29–34, 111–115, 244–250, 314–319 (1839); 4: 22–26, 106–111, 256–262 (1840).

Cunningham A (1840) On the habits of the *Apteryx australis*, a bird of New Zealand, closely allied to the Struthionidae and named by the native inhabitants "Kiwi", *Annals and Magazine of Natural History* 4: 312–314.

B. Cryptic publications, contained within the works of others

Brown R & Cunningham A (1832), *Geitonoplesium cymosum*. Cymose Geitonoplesium, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3131. (S.Curtis: London) [Still treated as *Geitonoplesium cymosum* (R.Br.) A.Cunn. ex R.Br.].

Cunningham A (1832a) *Baeckea saxicola*, Stony Baeckea, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3161. (S.Curtis: London) [Now *Thryptomene saxicola* (A.Cunn. ex Hook.) Schauer].

Cunningham A (1832b) *Pittosporum cornifolium*, Cornel-leaved Pittosporum, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3161. (S.Curtis: London) [Still treated as *Pittosporum cornifolium* A.Cunn.].

Cunningham A (1832c) *Leucopogon lanceolatus*, Lanceolate Leucopogon, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3162. (S.Curtis: London) [Now treated as *Leucopogon affinis* R.Br.].

Cunningham A (1832d) *Hymenanthera dentata*, Tooth-leaved Hymenanthera, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3163. (S.Curtis: London) [Now treated as *Melicytis dentatus* (R.Br. ex DC.) Molloy & Mabb.].

Cunningham A (1832e) *Epacris onosmaeflora*, Onosma-flowered Epacris, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3168. (S.Curtis: London) [Now *Epacris purpurascens* var. *onosmiflora* (A.Cunn.) Maiden & Betche].

Cunningham A (1832f) *Acrotriche ovalifolia*, Oval-leaved Acrotriche, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3171. (S.Curtis: London) [Now included in *Acrotriche cordata* (Labill.) R.Br.].

Cunningham A (1832g) *Pterostylis banksii*, Large-leaved Pterostylis, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3172. (S.Curtis: London) [Still treated as *Pterostylis banksii* A.Cunn.].

Cunningham A (1832h) *Acacia cinerascens*, Grey Fragrant Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3174. (S.Curtis: London) [Now included in *Acacia binervia* (J.C.Wendl.) J.F.Macbr.].

Cunningham A (1832i) *Eriostemon myoporoides*, Cuspidate Eriostemon, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3180. (S.Curtis: London) [Now *Philotheca myoporoides* (DC.) Bayly].

Cunningham A (1832j) *Grevillea robusta*, Gigantic Grevillea, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3184. (S.Curtis: London) [Still treated as *Grevillea robusta* A.Cunn. ex R.Br.].

Cunningham A (1832k) *Grevillea canescens*, Hoary Grevillea, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3185. (S.Curtis: London) [Now *Grevillea arenaria* var. *canescens* (R.Br.) Olde & Marriott].

Cunningham A (1832l) *Acacia ruscifolia*, Butcher's-broom-leaved Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3195. (S.Curtis: London) [Now *Acacia verticillata* var. *ruscifolia* (A.Cunn. ex G.Don) Court].

Cunningham A (1832m) *Daviesia virgata*, Twiggy Daviesia, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3196. (S.Curtis: London) [Now included in *Daviesia leptophylla* A.Cunn. ex G.Don].

Cunningham A (1832n) *Phormium tenax*, New Zealand Flax, in Hooker WJ, *Curtis's Botanical Magazine* 59: t. 3199. (S.Curtis: London) [Still treated as *Phormium tenax* J.R.Forst. & G.Forst.].

Cunningham A (1832o) [Untitled] in, Recent information from Australia, *Journal of the Royal Geographical Society of London* 2: 319–324. [Commentary on a letter from Lieut.-Colonel Dumaresq reporting an account by a runaway convict of the alleged discovery of a major river flowing from the Liverpool Plains to the Gulf of Carpentaria. Dumaresq, brother-in-law to Governor Darling and formerly his private secretary, was by this time owner of a large estate, St Heliers, near Muswellbrook.].

Cunningham A (1832p) [Untitled] in, Recent information from Australia, *Journal of the Royal Geographical Society of London* 2: 329–334. [Commentary on an expedition to the Peel and Namoi Rivers by Surveyor-General Major Thomas Mitchell. This was, in effect, an extension to his account of exploration in Australia published earlier in the year in the same Journal – see under major publications above].

Cunningham A (1833a) *Pomaderris betulina*, Birch-leaved Pomaderris, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3212. (S.Curtis: London) [The author of this name must be cited as A.Cunn. alone, not A.Cunn. ex Hook. as in the Australian Plant Name Index – both the description and name are attributed to Cunningham. Still treated as *Pomaderris betulina* A.Cunn., now with two subspecies].

Cunningham A (1833b) *Pomaderris andromedaefolia*, Andromeda-leaved Pomaderris, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3219. (S.Curtis: London) [Still treated as *Pomaderris andromedifolia* A.Cunn., now with two subspecies].

Cunningham A (1833c) *Psychotria daphnoides*, Daphne-like Psychotria, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3228. (S.Curtis: London) [Of this plant Cunningham supplied only the name and provenance. The name should be attributed nomenclaturally as *Psychotria daphnoides* A.Cunn. ex Hook., and is still known under this name].

Cunningham A (1833d) *Leucopogon richei*, Riche's Leucopogon, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3251. (S.Curtis: London) [Now included in *Leucopogon parviflorus* (Andrews) Lindl.].

Cunningham A (1833e) *Epacris heteronema*, Varying-stemmed Epacris, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3257. (S.Curtis: London) [Still treated as *Epacris heteronema* Labill., now with two varieties].

Cunningham A (1833f) *Dracophyllum secundum*, Secund-flowered Dracophyllum, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3264. (S.Curtis: London) [Still treated as *Dracophyllum secundum* R.Br.].

Cunningham A (1833g) *Acacia verniciflua*, Varnished Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3266. (S.Curtis: London) [Still treated as *Acacia verniciflua* A.Cunn.].

Cunningham A (1833h) *Pimelea arenaria*, Sand Pimelea, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3270. (S.Curtis: London) [Now *Pimelea villosa* subsp. *arenaria* (A.Cunn.) C.J.Burrows].

Cunningham A (1833i) *Plagianthus divaricatus*, Spreading Plagianthus, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3271. (S.Curtis: London) [Still treated as *Plagianthus divaricatus* J.R.Forst. & G.Forst.].

Cunningham A (1833j) *Beaufortia dampieri*, Dampier's Beaufortia, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3272. (S.Curtis: London) [Now included in *Beaufortia sprengelioides* (DC.) Craven].

Cunningham A (1833k) *Cargillia australis*, Southern Cargillia, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3274. (S.Curtis: London) [Now *Diospyros australis* (R.Br.) Hiern.

Cunningham A (1833l) *Acacia graveolens*, Strong-scented Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3279. (S.Curtis: London) [Now *Acacia leprosa* var. *graveolens* Maslin & D.J.Murphy].

Cunningham A (1833m) *Grevillea arenaria*, Sand Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3285. (S.Curtis: London) [Still treated as *Grevillea arenaria* R.Br., now with two subspecies].

Cunningham A (1833n) *Marsdenia flavescens*, Yellowish-flowered Marsdenia, in Hooker WJ, *Curtis's Botanical Magazine* 60: t. 3289. (S.Curtis: London) [The authority for the name should be *Marsdenia flavescens* A.Cunn., not A.Cunn. ex Hook., as sometimes cited. Both the name and diagnosis are clearly attributed to Cunningham. The species is still recognised under this name.].

Cunningham A (1834a) *Westringia cinerea*, Ash-coloured Westringia, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3307. (S.Curtis: London) [Now included in *Westringia dampieri* R.Br.].

Cunningham A (1834b) *Alyxia ruscifolia*, Butcher's-broom-leaved Alyxia, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3312. (S.Curtis: London) [Still treated as *Alyxia ruscifolia* R.Br.].

Cunningham A (1834c) *Alyxia daphnoides*, Daphne-like Alyxia, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3313. (S.Curtis: London) [Attached to this species treatment was a short 3-page paper by Cunningham 'Synopsis of the different species of Alyxia' listing and briefly describing the 13 species of *Alyxia* found worldwide. This species is now included in *Alyxia gynopogon* Roem. & Schult.].

Cunningham A (1834d) *Cyminosma oblongifolia*, Oblong-leaved Cyminosma, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3322. (S.Curtis: London) [Now *Acronychia oblongifolia* (A.Cunn. ex Hook.) Endl. ex Heynh.].

Cunningham A (1834e) *Calythrix virgata*, Twiggy Calythrix, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3323. (S.Curtis: London) [Includes descriptions, synonymies and key to all 12 species of *Calytrix* then known from Australia. Now included in *Calytrix tetragona* Labill.].

Cunningham A (1834f) *Trochocarpa laurina*, Cinnamon-leaved Trochocarpa, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3324. (S.Curtis: London) [Still treated as *Trochocarpa laurina* (Rudge) R.Br.].

Cunningham A (1834g) *Pimelea hypericina*, Hypericum-leaved Pimelea, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3330. (S.Curtis: London) [Now *Pimelea ligustrina* subsp. *hypericina* (A.Cunn.) Threlfall].

Cunningham A (1834h) *Trachymene lanceolata*, Lance-leaved Trachymene, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3334. (S.Curtis: London) [Now *Platysace lanceolata* (Labill.) Druce].

Cunningham A (1834i) *Acacia elongata*, Slender Curved-leaved Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3337. (S.Curtis: London) [Still treated as *Acacia elongata* Sieber ex DC.].

Cunningham A (1834j) *Acacia umbrosa*, Shady Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3338. (S.Curtis: London) [Now included in *Acacia binervata* DC.].

Cunningham A (1834k) *Acacia lineata*, Narrow Lined-leaved Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3346. (S.Curtis: London) [Still treated as *Acacia lineata* A.Cunn. ex G.Don].

Cunningham A (1834l) *Morinda jasminoides*, Jasmine-like Morinda, in Hooker WJ, *Curtis's Botanical Magazine* 61: t. 3351. (S.Curtis: London) [Still treated as *Morinda jasminoides* A.Cunn.].

Cunningham A (1835a) *Acacia undulaefolia*, Waved-leaved Variable Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 62: t. 3394. (S.Curtis: London) [Still treated as *Acacia undulifolia* A.Cunn. ex G.Don].

Cunningham A (1835b) *Eurycles cunninghamii*, Small-flowered Eurycles, or Brisbane Lily, in Hooker WJ, *Curtis's Botanical Magazine* 62: t. 3399. (S.Curtis: London) [Now *Proiphys cunninghamii* (Aiton ex Lindl.) Mabb.].

Cunningham A (1835c) *Chilodia scutellarioides*, Scutellaria-like Chilodia, in Hooker WJ, *Curtis's Botanical Magazine* 62: t. 3405. (S.Curtis: London) [Now *Prostanthera scutellarioides* (R.Br.) Briq.].

Cunningham A (1835d) *Westringia eremicola*, Desert Westringia, in Hooker WJ, *Curtis's Botanical Magazine* 62: t. 3438. (S.Curtis: London) [Still treated as *Westringia eremicola* A.Cunn. ex Benth.].

Cunningham A (1835e) [Untitled, description of *Earina mucronata*, 1 p.] in Lindley J, *Oncidium ampliatum*. Broad-lipped Oncidium. *Edwards's Botanical Register* 20: t. 1699. (James Ridgeway: London) [Attribution of the generic and specific names is difficult. The account is certainly based largely on Cunningham's notes, but the way the text is structured means that the generic name must be assigned nomenclaturally to Lindley, the specific name perhaps to A.Cunn. ex Lindl. or as is usually done, to Lindley alone, i.e *Earina mucronata* Lindl.].

Cunningham A (1835f) *Grevillea wilsonii* A.Cunn., p. 273, in Wilson TB, *Narrative of a Voyage Round the World, Comprehending an Account of the Wreck of the Ship "Governor Ready" in Torres Straits, a Description of the British Settlements on the Coasts of New Holland…* (Sherwood, Gilbert & Piper: London) [Still treated as *Grevillea wilsonii* A.Cunn.].

Cunningham A (1836a) *Veronica labiata*, Fragrant White-flowered Speedwell, in Hooker WJ, *Curtis's Botanical Magazine* 63: t. 3461. (S.Curtis: London) [Now included in *Veronica derwentiana* Andrews].

Cunningham A (1836b) *Acacia prominens*, Conspicuous Acacia, in Hooker WJ, *Curtis's Botanical Magazine* 63: t. 3502. (S.Curtis: London) [Still treated as *Acacia prominens* A.Cunn. ex G.Don].

Cunningham A (1836c) [Untitled, description of *Dendrobium cassythoides* R.Cunn., 2 pp.], in Lindley J, *Dendrobium densiflorum*, Dense-flowered Dendrobium. *Edwards's Botanical Register* 21: t. 1828. (James Ridgeway: London) [This is a paper within a paper within a paper: an article by Lindley, in which he reproduces a note from Allan Cunningham, which in turn reproduces a name and description by Richard Cunningham. The last should be attributed as author of the name, although Allan Cunningham is usually cited. This species is now *Erythrorchis cassythoides* (R.Cunn.) Garay].

Cunningham A (1836d) [Untitled, on Australian *Tristania* spp., 2 pp.], in Lindley J, *Tristania macrophylla*. Large-leaved Tristania. *Edwards's Botanical Register* 21: t. 1839. (James Ridgeway: London) [*Tristania macrophylla* A.Cunn. ex Lindl. is now included in *Lophostemon confertus* (R.Br.) Peter G.Wilson & J.T.Waterh.; *Tristania umbrosa* A.Cunn. is now *Xanthostemon umbrosa* (A.Cunn.) Peter G.Wilson & J.T.Waterh.; *Tristania psidioides* A.Cunn. is now *Xanthostemon psidioides* (A.Cunn.) Peter G.Wilson & J.T.Waterh.; *Tristania salicina* A.Cunn. is now included in *Tristania neriifolia* (Sims) R.Br.].

Cunningham A (1836e) [Untitled, on apetalous *Fuchsia* spp., 1 p.], in Lindley J, *Godetia lepida*. Smart Godetia. *Edwards's Botanical Register* 22: t. 1849. (James Ridgeway: London) [The New Zealand species is still treated as *Fuchsia procumbens* R.Cunn. ex A.Cunn., although its publication is sometimes credited to Allan Cunningham, *Ann. Nat. Hist.* 3: 31 (1839)]

Cunningham A (1843) Notes, for the most part geographical, on the Orchidaceous plants of Australia, [unpaginated, 5 pp.], in Lindley J, *Dendrobium cucumerinum*. Cucumber Dendrobium. *Edwards's Botanical Register* 29: t. 37. (James Ridgeway: London)

Cunningham A (1847) *Spartothamnus* All. Cunn., p. 694, in Walpers WG, *Repertorium Botanices Systematicae*, vol. 6(4). (F.Hofmeister: Lipsiae) [The name *Spartothamnus*, and that of the only species *S. junceus* were all attributed to Cunningham, but the descriptions are by Walpers, making the author attribution in both cases A.Cunn. ex Walp. Unfortunately *Spartothamnus* is a later homonym of *Spartothamnus* Presl, and in 1895 Briquet coined the replacement name *Spartothamnella*. The species is now known as *Spartothamnella juncea* (A.Cunn. ex Lindl.) Briq.].

Cunningham A (1872) *Grevillea rosmarinifolia* A.Cunn., in Hooker JD, *Curtis's Botanical Magazine* 98: t. 5971. (L.Reeve & Co.: London) [This is an extreme case of delayed publication. The information on provenance in this article was sent to W.J.Hooker in a letter from Cunningham on 30th April 1832, and published almost *verbatim* by J.D.Hooker 40 years later! The species is still treated as *Grevillea rosmarinifolia* A.Cunn.]

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Thysanotus racemoides (Asparagales: Asparagaceae), a new species from South Australia and western Victoria

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Abstract

The new species *Thysanotus racemoides* Sirisena, T.D.Macfarl. & Conran, from South Australia and western Victoria, is described and distinguished from the previously conspecific *T. juncifolius* (Salisb.) J.H.Willis & Court, by the presence of sessile subterminal umbels and relatively longer anthers and perianth segments. The revised distribution of *T. juncifolius* is New South Wales and eastern Victoria. Descriptions, photographic plates and a map are provided for the new species and *T. juncifolius*. The key in the *Flora of Australia* is amended to accommodate the new species.

Introduction

There has been no taxonomic publication solely on *Thysanotus* R.Br. since the pioneering work carried out by Brittan (1960, 1962, 1970, 1971a, 1971b, 1972a, 1972b, 1978, 1981, 1983, 1986, 1987). Recent molecular analyses recognised *Thysanotus* in a new family Laxmanniaceae (also known as Lomandraceae) (Chase et al. 1996; Angiosperm Phylogeny Group 2003) which was considered as an odd aggregation of genera due to the lack of obvious morphological synapomorphies to define the predominantly Australian family (Chase et al. 1995; Rudall and Chase 1996; Conran 1998). Most recently, the family was placed into a greatly expanded Asparagaceae under subfam. Lomandroideae (Mabberley 2008; Angiosperm Phylogeny Group 2009).

To improve and contribute to the taxonomic knowledge (morphological and molecular) on *Thysanotus*, a phylogenetic study was begun in mid-2006 by the first author as part of a PhD project, which has resulted in the description of one previous new species (Sirisena *et al.* 2009). Morphological and molecular analyses (Sirisena 2010) supported observations of Conran (1994) and Macfarlane (unpubl.) of possible taxonomic heterogeneity in *Thysanotus juncifolius* (Salisb.) Willis & Court. From these studies it was apparent that the geographically disjunct South Australian and western Victorian form of *T. juncifolius* is phylogenetically distant from populations in New South Wales and East Gippsland in Victoria. Further herbarium investigations revealed that specimens from South Australia and western Victoria represent a new species which is clearly and consistently morphologically distinguishable from the New South Wales and eastern Victoria form.

Methods

Living plants and herbarium specimens were examined (specimens listed below, observed among the three authors) including use of light microscopy, dissecting microscopy and SEM (Scanning Electron Microscopy). Morphological descriptions were based on these observations.

Stem anatomical studies were carried out using dried material, re-hydrated in warm water with a drop of detergent and hand sectioned. The specimens were then stained in 0.05% aqueous Toluidine blue and mounted in Glycerine.

The specimens examined are summarised according to the following geographic regions: 'Botanical divisions' of New South Wales (Jacobs and Pickard 1981, modified from Anderson 1961), 'Natural regions' of Victoria (Conn 1993), and 'Floristic regions' of South Australia (Jessop and Toelken 1986).

Results

The descriptive terminology of Brittan (1981, 1987) is followed to describe the new species *Thysanotus racemoides*, as well as to redefine *T. juncifolius* s. str.

Taxonomy

1. ***Thysanotus racemoides*** Sirisena, T.D.Macfarl. & Conran **sp. nov.**

Herba perennis. Rhizoma cylindricum, c. 1–5 cm longum; radices fibrosae haud tuberosae. Planta aphylla; scapus c. 60 cm altus, tuberculatus vel glaber. Umbellae floribus 1 vel 2, bracteis ovata, c. 2 mm longis, membranaceis. Pedicelli 5–6 mm longi, prope basin articulati, florescentes erecti, fructiferi erectes. Segmenta perianthii 8–9 mm longa: tepala exteriora lineari-oblonga, 1.2–1.5 mm lata, mucronata; tepala interiora elliptica, c. 3.2–3.5 mm lata. Stamina 6 poris terminalibus dehiscentia; antherae exteriores 3 strictae, tortae, 3–6 mm longae; antherae interiores 3 curvatae, tortae, c. 6–12 mm longae. Capsula 4–7 mm x 3–5 mm, perianthio persistenti inclusa. Semina nigra, arillata, c. 1.5 mm x 1.5 mm.

Type: Lucindale Road, [Hundred] of Coles, south east South Australia, 16 Dec 1963, *A.C. Beauglehole 5923*; (holo AD96446095; iso MEL2214357A) (see Notes below).

Perennial herb with a rhizomatous rootstock, horizontal and more or less cylindrical, 1–5 cm long, pale brown or straw coloured. *Roots* fibrous, not tuberous. *Plant* leafless when flowering, aerial stems (scapes) to c. 60 cm tall with bracts along the scape, 2.5–5 mm long. *Scapes* ascending, branches often 2 or 3 per node, sometimes further subdivided, ridged, tuberculate basally, tuberculate or glabrous distally, node bracts lanceolate. *Umbels* terminal above, several sessile subterminal umbels, commonly 2-flowered sometimes with 3 or 4 flowers, bracts ovate, membranous, c. 2.5 mm long. *Pedicels* 5–6 mm long, erect in flower and fruit, articulating basally. *Perianth* segments 12–15 mm long, outer three linear-oblong, c. 2 mm wide, inner three elliptical, c. 6 mm wide, fimbriate, fimbriae c. 4 mm long. *Stamens* 6, dehiscing by posteriorly extended terminal pores, outer 3 anthers 3–6 mm long, purple (sometimes yellow), straight, slightly twisted, inner three anthers 6–12 mm long, purple, curved, twisted, filaments c. 3 mm long. *Ovary* sessile, globular, ovules 2 per locule, style curved, 5–10 mm long. *Capsule* globose, 4–7 × 3–5 mm, enclosed in persistent perianth remains, forming a short tail. *Seeds* c. 1.5 × 1.5 mm, black, globose; testa periclinal walls strongly convex, without microsculpturing; aril straw-coloured (Fig.1).

Derivation of epithet: Derived from the fact the sessile subterminal umbels make the flowering branches resemble a raceme.

Flowering period: Late October to mid to late November.

Habitat: This new species is restricted to the deep sands of inland western Victoria, eastern South Australia and the sand plains and lateritic gravels of Kangaroo Island (Brittan 1981). The species grows in a wide range of habitats from dry open forest to mallee woodland and low heaths.

Distribution: The species occurs in south eastern Australia from the Eyre Peninsula and Kangaroo Island in South Australia to western Victoria with an apparently outlying occurrence near Anglesea, SW of Geelong (Fig. 3, indicated in green).

Notes: The mapping of the AD and MEL replicates of the type collection (*Beauglehole 5923*) in AVH (2013) do not coincide (AVH 2013). Based on a comparison of Beauglehole's collections on 15 and 16 December 1963,

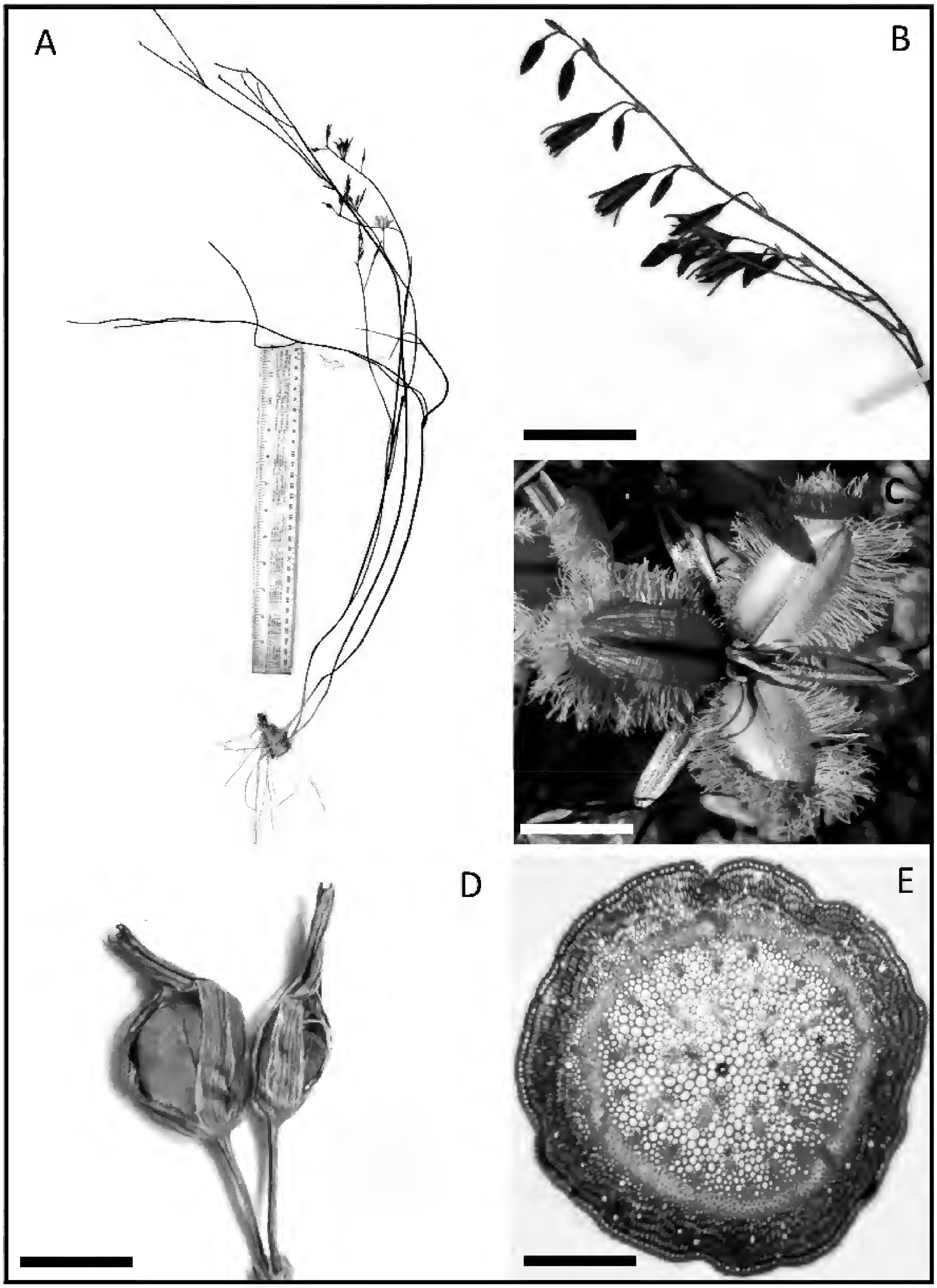

Fig. 1. *T. racemoides* A. Habit. B. Sessile subterminal umbels below a terminal umbel. C. Flower. D. Fruit. E. Transverse stem section (Specimens – A. *B. Saunders s.n.*; B. AD96020128; C,E. *US/Trujillo 1*; D. AD96446095. Scale bars: B = 3 cm; C = 12 mm; D = 5 mm; E = 500 µm. Photos - A. John G. Conran; B, D, E. Udani M. Sirisena; C. Cecilia Trujillo)

the AD geocode appears to be more likely to be correct, indicating that the collection was from c. 5 km SE of Callendale, east of the Callendale Main Road.

Proposed Conservation status: *Thysanotus juncifolius* is currently listed as 'not threatened' under Conservation Codes for South Australia (Barker *et al.* 2005) and Victoria (Walsh & Stajsic 2007) and this also seems to be appropriate for the segregated *T. racemoides*.

Specimens examined: South Australia: *South eastern region*: Mount Burr Forest Reserve, c. 12 km E of Millicent, *P. Wilson 1093*,11 Nov 1959 (AD96020128); Beachport, *R. Tate s.n.*, 13 Nov 1982 (AD96021026); Hundred of Robertson NW, *D. Hunt 258*, 21 Oct 1961 (AD96151151); Big Heath National Park, Hundred of Spence; 1 mile [1.6 km] S of and parallel to the fire break, mid-narrow neck, *C.R. Alcock 2903*, 4 Nov 1969 (AD96949199); Hundred of Caroline, Section 389, Caroline forest, *D.N. Kraehenbuehl 2562*, 30 Dec 1975 (AD97625135); Big Heath National Park, middle of park (firebreak), *J.Z. Weber 1836*, 6 Nov 1969 (AD97015200).

Kangaroo Island: 6.4 km SW of Cape Willoughby Lighthouse, *B. Overton, P. Canty, S. Kinnear NPKI40876* (AD99003160); Muston, Pelican Lagoon, *H.M. Cooper s. n.* 26 Nov 1962 (AD97915042); Some 32 km S of Kingscote and 6 km N of Destrees Bay, *C.R. Alcock 10706* 22 Oct 1986 (AD99020004, MEL715633A).

Eyre Peninsula: c. 50 m E of Long Beach Rd c. 100 m south of Jubilee Dr, Coffin Bay, Eyre Peninsula SA, *B. Saunders s. n.*, 22 Nov 2002 (AD97936175).

Murray region: Chauncey's Line – near Monarto South, *J.B. Cleland s.n.*, 30 Nov 1963 (AD96405327).

Southern Lofty region: S of Mount Compass, just before tree area of Square Waterhole, *D.E. Symon 309*, 25 Jan 1960 (AD98666202); Spring Mount, c. 8 km SE of Adelaide, *D.J.E. Whibley 1704*, 23 Nov 1966 (AD96849142); Scrub near Myponga, *D. Hunt 2904*, 26Dec 1968 (AD97011206); Cox Scrub Conservation Park near turn to Kyeema Conservation Park, *C. Trujillo US/Trujillo 1*, 17 Nov 2007 (ADU).

Victoria: *Murray Mallee:* Big Desert, c. 98.6 km from Murrayville, *E. Gardiner, G. Gardiner s.n.*, 22 Nov 1981 (AD98151033); 21.5 km WNW of Rainbow township, on unnamed track, *D.M. Parkes*, 11 Nov 1985 (MEL1545142).

Lowan Mallee: Wyperfeld National Park *A.C. Beauglehole* 29546,13 Nov 1968 (MEL535880); Little desert, 1 km SE of Broughton's Water Hole, *A.C. Beauglehole* 66628 and *A.J. Hicks*, 27 Nov 1979 (MEL595480).

Grampians: 1 mile [1.6 km from] Lake Wartook, *N.H. Brittan 59/89*, 15 Dec 1959 (PERTH2971976); Tea tree creek, Red rock creek area, S of Glenisla station, *A.C. Beauglehole* 39458, anno 1968 (MEL535882); Grampians, Black Range, track up east side of double headed mount, west side of Black Range Road, *A.C. Beauglehole* 30040, 11 Dec 1968 (MEL536387); Grampians, *A.C. Beauglehole* 67116, 8 Nov 1979 (MEL597877).

Otway Plains: S of Anglesea, *N.H. Brittan59/91*, 17 Dec 1959 (PERTH2971798); Slopes between great Ocean road and Harvey street, Anglesea, *R.V. Smith* 59/357, 3 Nov 1959 (MEL527769).

Wannon: Heath Road, Kentbruck, *C and D Woolcock* 1598, 27 Dec 1983 (MEL524045); Portland South west Portland, Emu hill area, between gorge west of Mount Richmond, *A.C. Beauglehole* 19537, anno 1946 (MEL535881); Portland far south west, Kentbruck heath, Heath Road, *A.C. Beauglehole* 39458, anno 1964 (MEL535883).

2. ***Thysanotus juncifolius*** (Salisb.) Willis & Court, *Muelleria* 1: 45 (1956).

Chlamysporum juncifolius Salisb., Parad. Londin. t. 103 (1808).

Type: R.A. Salisbury *loc. cit.*, t. 103. No specimen is known, so the type is the illustration accompanying the original description of cultivated plants whose origin was "Sponte nascentum prope Port Jackson, legit A. Gordon" and sent to England via E.J.A. Woodward.

Thysanotus junceus R.Br., Prodr.283 (1810). *Chlamysporum junceum* (R.Br.) Kuntze, Revis. Gen. Pl. 708 (1891).

Lectotype (Brittan 1981, p. 123): Port Jackson, New South Wales, *R. Brown* [*Bennett 5684*], without date (BM *n.v.*, isolectotypes E *n.v.*, K *n.v.*, MEL) (see Notes below).

Perennial herb with rhizomatous rootstock. *Roots* fibrous, not tuberous. *Plant* leafless when flowering, aerial stems (scapes) to c. 60 cm tall. *Scapes* ascending, branching monopodially, rarely with 2 or 3 branches per node, ridged, smooth; node bracts lanceolate, 2–5 mm long. *Umbels* terminal, 1–5 flowered, bracts ovate, membranous, outer ones c. 1.4 mm long. *Pedicels* erect in flower and fruit, articulated near the base. *Perianth* segments to c. 12 mm long, outer three linear-oblong, c. 1.3 mm wide, inner three narrowly elliptical, 3.5–4 mm wide, fimbriate, fimbriae c. 1.5 mm long. *Stamens* 6, dehiscing by posteriorly extended terminal pores, outer 3 anthers 2.2–2.8 mm long, purple (sometimes yellow), straight, slightly twisted, inner 3 anthers 6–8 mm long, purple, curved, twisted; *Ovary* sessile, globular, ovules 2 per locule. *Capsule* globose, 3–5 × 2–3 mm, enclosed in persistent perianth segments which form a short tail. *Seeds* globose, black, c. 1 mm diam., aril straw-coloured (Fig. 2).

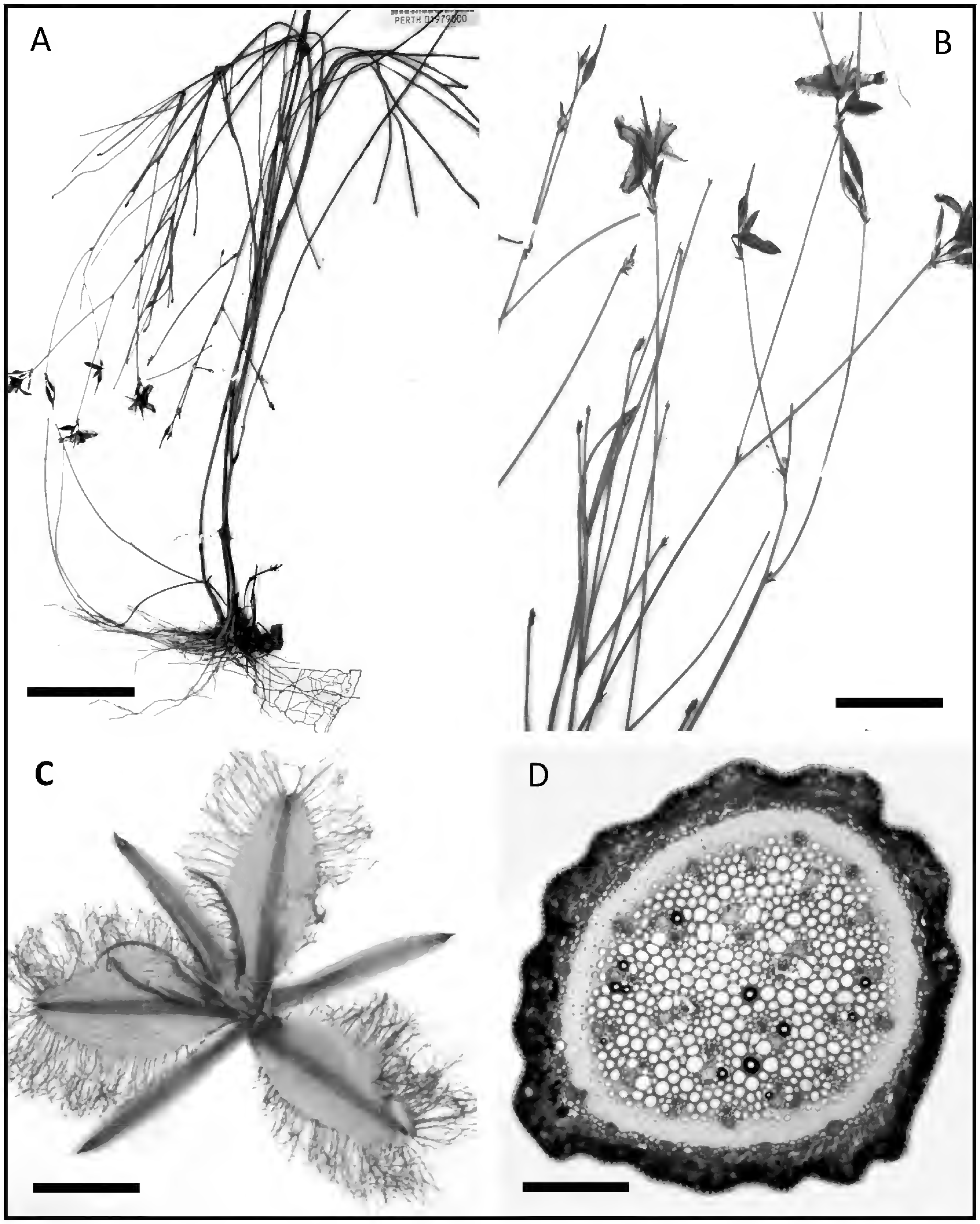

Fig. 2. *T. juncifolius* A. Habit. B. Absence of sessile umbels below the terminal umbel. C. Flower. D. Transverse stem section. (Specimens – A&B. PERTH1979000; C. PERTH3000516; D. *Dalby 94/09.* Scale bars: B = 2 cm; C = 7 mm; D = 500 µm. Photos - Udani M. Sirisena)

Flowering period: October–early November.

Habitat: *Thysanotus juncifolius* grows in very shallow, loamy soils in the Blue Mountains and sandy gravels over Hawkesbury sandstone in New South Wales and on coastal sands in eastern Victoria (Brittan 1981).

Distribution: The distribution is East Gippsland, Victoria and southern and central coastal New South Wales (Fig. 3).

Notes: The species epithet *Thysanotus junceus* R.Br. is here regarded as legitimate, supporting the conclusion of Brittan (1981), contrary to the listing as an illegitimate name in APC (2013) and APNI (2013).

Proposed Conservation status: Currently listed as 'not threatened' under Conservation Codes for NSW and Victoria, and this seems appropriate to the modified circumscription of the species.

Specimens examined: New South Wales: *North Coast:* West of Tilligery creek, *H. van Rees s.n.*, 6 Nov 1979 (MEL620710); Yambulla creek, *N.A. Wakefield s.n.*, 21 Dec 1948 (MEL541193); Bullahdelah, *Anonymous s.n.*, Nov 1923 (MEL2214370); Car park of headland south of Grants Head, *B. Rann 72 and and M. Kennedy*, 19 Oct 1993 (NSW278942); Tomago Sand Beds Tanilba Station No. 16/17. Zone 4. R22, *D.L. McNair 9184*,15 Mar 2002 (NSW712982); Peats Ridge, where Newcastle Expressway is crossed by Gosford water supply pipeline, *D.F. Blaxell 1289*, 6 Mar 1974 (NSW599673);

Central Coast: Port Jackson district, *Robert Brown s.n.*, 1802, (MEL244288–Isolectotype); Lane Cove, *Anon.*, Oct 1910, (MEL2214365); Port Jackson district, *Anon.*, Oct 1897 (AD96021075, AD96028166); Sydney, *J.B. Cleland s.n.* Oct 1897 (AD96021076); Belrose, *R. Coveny 11059 and P. Hind*, 12 Nov 1981 (NSW 599674, PERTH1979000); Princes Highway, c. 1 mile S of Sutherland, *N.H. Brittan 59/105-4*, 29 Dec 1959 (PERTH3000664); Princes Highway, c. 1 mile S of Sutherland, *N.H. Brittan 59/105-2*, 29 Dec 1959 (PERTH3000516); Hornsby, *W.F. Blakely s.n.*, 28 Feb 1995 (NSW50431); Near Sydney, Port Jackson, *E. Betche s.n.*, 30 Sep 1886 (NSW50434); Bundeena Drive, c. 100 m towards Bundeena from Sir Bertram Stevens Drive, *J.M. Dalby 94/09, T.D. Macfarlane and S.W.L. Jacobs*, 24 Nov 1994 (NSW363144, PERTH); Oatley, *J.H. Camfield s.n.*, 30 Nov 2002 (NSW50435); Waterfall, 8 miles (12.9 km) SSW of Sutherland, *R.G. Coveny 3413 and M.H. Zerk*, 4 Dec 1970 (NSW599678); Frenchs Forest, *M. Mills s.n.*, 22 Oct 1939 (NSW599679); Roseville Chase, *H. Salasoo 1296*, 2 Feb 1952 (NSW50437);

South Coast: Heathy flat near 'Pacific City', Jervis Bay, *F.A. Rodway 8929*, 15 Feb 1931 (NSW599681); plains by the east coast, Green Cape, *S. Mossman 210*, 1850 (E, photo seen).

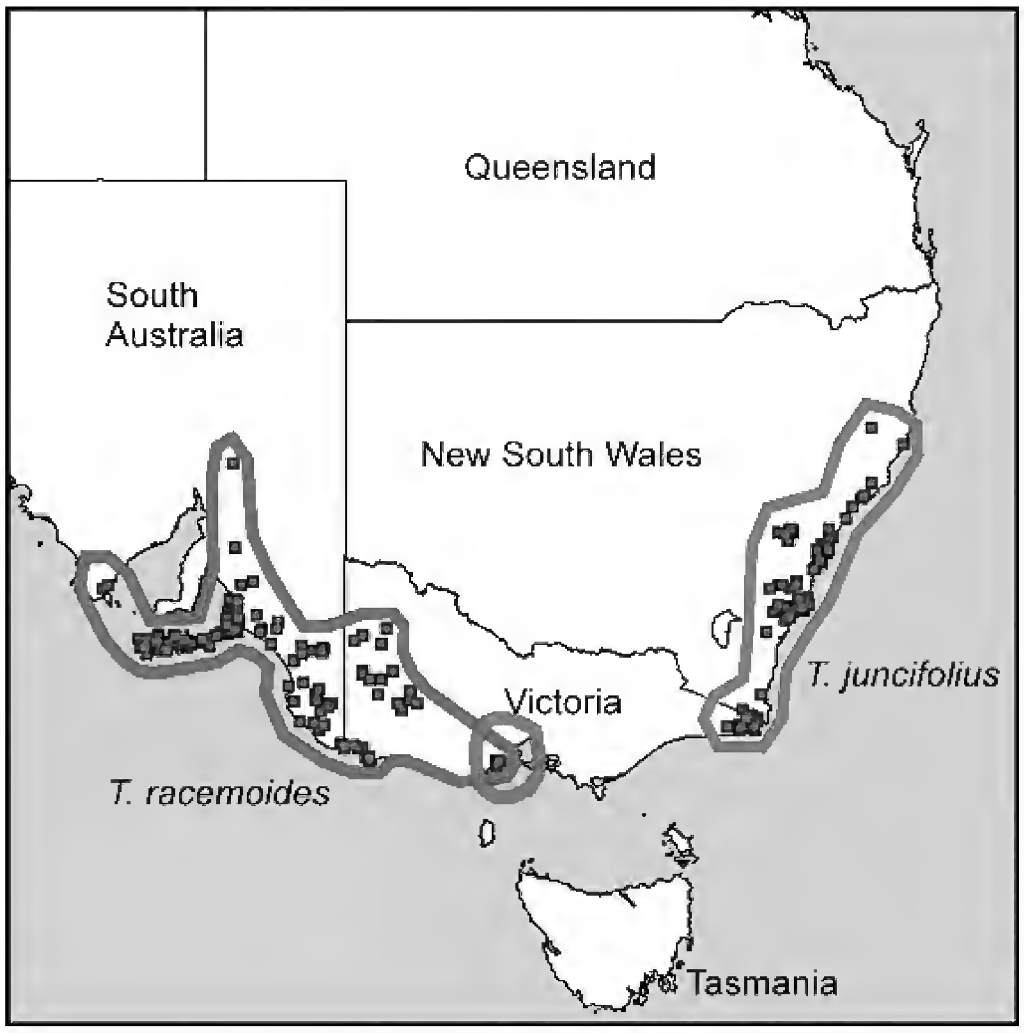

Fig. 3. Distribution of the *Thysanotus juncifolius* complex in south eastern Australia. *Thysanotus racemoides* encircled in blue, with Anglesea population encircled in green; *T. juncifolius* encircled in red.

Central Tablelands: Near Bowens Creek, Mount Wilson-Bilpin, *N.H. Brittan 59/108-1*, 31 Dec 1959 (PERTH3000834); Butlers Swamp, Tourist Road c. 7 km N of Robertson, *T.A. James 1427 and P.G. Kodela*, 9 Jan 1993 (NSW273284); Catherine Hill Bay, Lake Macquarie, *J.W. Dwyer1057*, 31 Jan 2000 (NSW50432); Belrose, *R.G. Coveny 11059 and P.D. Hind*, 12 Nov 1981 (NSW599674); Butler's Swamp, 11.7 km along Tourist Road from Bowral - Robertson Road, *A.N.L. Doust 421*, 19 Jan 1993 (NSW264192);

Victoria: *East Gippsland:* Princes Highway between Mount Drummer and Genoa, *N.H. Brittan59/ 94,* 20 Dec 1959 (PERTH2934728); *Beauglehole 31977* and *E.W. Finck*,22 Nov 1969 (MEL535886); Tobins Creek, *D.L. Jones* 18118 and *B.E. Jones*, 15 Nov 2001 (MEL2283147). Princes Highway, between Mount Drummer and Genoa, between 318 and 319 mile pegs [c. 22 km E of Genoa], *N.H. Brittan 59/94-2*, 20 Dec 1959 (PERTH2934744); Maramingo Creek, Princes Highway, 4 miles [6.4 km] E Genoa (329 mile peg), *N.H. Brittan 59/96*, 20 Dec 1959 (PERTH2934701); Maramingo Creek, Princes Highway, 4 miles [6.4 km] E Genoa (329 mile peg), *N.H. Brittan 59/96-2*, 20 Dec 1959 (PERTH2934736); Mallacoota Inlet National Park, Spotted dog mine area, *A.C. Beauglehole 32469* and *E.W. Finck*, 16 Dec 1968 (MEL535885); Mallacoota Inlet National Park, ½ mi [0.8 km] south of Marshmead property, *A.C. Beauglehole 31602* and *J.H. Willis*, 8 Nov 1969 (MEL535884); Glue Pot Creek, near Genoa, *R. Melville* 2705 and *N. Wakefield*, 7 Jan 1953 (MEL537755, NSW599686); Marramingo Creek, *N.A. Wakefield s.n.*, 19 Dec 1947 (MEL2214345); Lower Reedy Creek, *N.A. Wakefield* 2868, 11 Dec 1948 (MEL541195); Cicada Trail, midway between Mueller and Wingan rivers, *A.C. Beauglehole 31977 and E.W. Finck*, 22 Nov 1969 (MEL535886); at intersection of Stony Peak Road and the Betka River, *R.K. Humphries and G.E. Earl s.n.*, 12 Nov 1989 (MEL119208).

Notes: Morphologically, anatomically and genetically there is a clear distinction between *T. racemoides* and *T. juncifolius* (Sirisena 2010). The presence of subterminal, sessile umbels towards the stem apex has sometimes led South Australian collectors to misidentify *T. racemoides* as *T. baueri* R.Br., as the latter may also possess sessile umbels towards the apex. However, the branched perennial habit, rhizomes and lack of tuberous roots clearly distinguish *T. racemoides* from *T. baueri.*

Thysanotus juncifolius lacks sessile subterminal umbels, which seems to be the most obvious distinguishing character separating it from the new species. Furthermore, the stems of *T. juncifolius* are always ridged and the anthers and perianth segments are shorter than those of the new species (Table 1). Anatomically there are differences in the chlorenchyma of the scape in transverse section (See table below). Molecular and combined data analyses indicate a close relationship between *T. racemoides* and the Western Australian *T. sparteus* R.Br., whereas *T. juncifolius* is distant and instead more closely related to *T. asper* Lindl. and *T. arenarius* Brittan, both also from Western Australia (Sirisena 2010).

Brittan (1981, 1987) reported the occurrence of *T. juncifolius* in south-east Queensland based on. *Mossman 210* which was colelcted from Green Cape, New South Wales (cited above). This record is maintained, in error, in the current census of the Queensland flora (Bostock and Holland 2010, p. 94). The specimen, of which we have seen a scan, has two labels, but they bear the same number; the words 'Moreton Bay', in different ink from the other writing, was presumably added in error. Samuel Mossman's Australian collections that we have found reference to are all from the Green Cape and Twofold Bay area of southern NSW and from Tasmania. There is no evidence of *T. juncifolius* occurring in Queensland.

Table 1. Character comparison of *Thysanotus racemoides* and *T. juncifolius*

Character	***T. racemoides***	***T. juncifolius***
Nodes with 2–3 branches	Common	Rare
Subterminal sessile umbels	Present	Absent
Number of flowers per umbel	Mostly 2 occasionally 3 or 4	1–5
Length of perianth segments (mm)	12–15	Mostly <12
Outer anther length (mm)	2–6	<4.0
Inner anther length (mm)	7–12	6–8
Chlorenchyma shape	Always elongate (Fig. 1)	Mostly irregular (Fig. 3)

Amended key to species of *Thysanotus*

The published *Flora of Australia* key by Brittan (1987) is amended to accommodate *T. racemoides* by inserting a new couplet after couplet 51. Amendments are indicated with asterisks.

48: Stems terete, smooth to ridged

49 Stems strongly ridged, with short, dense, simple or tuberculate hairs

50 Stems with tuberculate hairs; umbels to 8-flowered; perianth segments 7–8 mm long...................... **T. brachiatus**

50: Stems with short, dense, simple hairs, at least basally; umbels 1–3 flowered; perianth segments 10–12 mm long.............. **T. virgatus**

49: *Stems rounded or slightly ridged, glabrous at least distally

51 *Subterminal umbels absent, all umbels terminal .... **T. juncifolius**

51: *Subterminal umbels always present below terminal umbels

52 *Subterminal umbels always sessile ....**T. racemoides**

52: *Subterminal umbels pedunculate, rarely sessile..............**T. sparteus**

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A new combination and lectotypification in *Xanthosia* (Apiaceae)

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Abstract

Platysace kochii (E.Pritzel) L.A.S.Johnson is here transferred to *Xanthosia* as *X. kochii* (E.Pritzel) J.M.Hart and Henwood *comb. nov.* (Mackinlayoideae, Apiaceae). *Xanthosia bungei* Keighery is reduced to the synonymy of *X. kochii*. A lectotype for *X. kochii* is chosen and the typification of *X. fruticulosa* adjusted. Descriptions *of X. kochii* and *X. fruticulosa*, a distribution map, and diagnostic images are provided.

Introduction

Xanthosia bungei Keighery was erected to resolve the taxonomy of the *X. fruticulosa* species complex (Keighery 1989). Prior to Keighery's work, *X. fruticulosa* was considered to be a geographically and ecologically widespread species within the Perth region. When dealing with an undescribed segregate of *X. fruticulosa*, Keighery examined an image of the type of *X. fruticulosa* and found that the name should be applied to what was then considered to be an undescribed species, whereas what was recognised as *X. fruticulosa* required a new name. He subsequently published *Xanthosia bungei* and applied it to what he described as a woody species with erect peduncles and white- to cream-coloured flowers. He restricted the application of *X. fruticulosa* to small herbs with reflexed peduncles and yellow-green flowers.

During the revision of Australian *Trachymene* (Hart and Henwood 2006) and *Platysace* (in prep.) we encountered a species endemic to Western Australia originally described as *Trachymene kochii* by Pritzel (1911) and subsequently transferred to *Platysace* (Johnson 1962). Examination by us of type material of *Platysace kochii* (E.Pritzel) L.A.S.Johnson, as held at NSW, found that the specimen has 9-veined mericarps; auriculate, petaloid sepals; petals with an inflexed apical appendage and an inflorescence that is a compound umbel, with two or three peripherally inserted, petaloid bracteoles on each umbellule. This suite of characters conforms to *Xanthosia*, and requires the species to be transferred from *Platysace* to *Xanthosia*.

Platysace (=*Xanthosia*) *kochii* was confirmed to be conspecific with the type of *X. bungei* that had been examined as part of a broader revision of *Xanthosia* (Hart 1998). Within *Xanthosia*, this perennial species is distinctive for its restriction to semi-arid habitats of Western Australia (the remaining species in this genus occur in temperate forest and heath communities) and for shedding its leaves following flowering. Individuals generally remain leafless during the hotter and drier months of the year. It is perhaps understandable, given that the species has a similar life history to *Platysace cirrosa*, that it was mistakenly placed in *Platysace*

(Johnson 1962). *Xanthosia bungei* is a relatively recent name, and has not appeared in any floras or published major revisions. Since Pritzel's epithet has priority over Keighery's (1989), a new combination in *Xanthosia* is here made for the species. In doing so, we provide descriptions of *X. fruticulosa* and *X. kochii* in order to further clarify these species and to assist in their recognition in the field and herbarium. It should be noted that *X. fruticulosa* has sepals with a truncate base, not auriculate as described by Keighery (1989), thereby providing another morphological character to distinguish these closely related species. The specimen of *X. fruticulosa* at K designated as the holotype (Keighery 1989) is adjusted to lectotype. The duplicate specimens of *Drummond 118* (BM, G, MEL239079A and NSW409406), not cited by Keighery (1989), are further isolectotypes.

The distribution of each species and the listing of selected specimens examined are presented according to Australia's bioregions (IBRA 2012).

Taxonomy

Xanthosia kochii (E.Pritzel) J.M.Hart & Henwood *comb. nov.*;

Trachymene kochii E.Pritzel, *Repertorium specierum novarum regni vegetabilis* 10: 133 (1911).

Platysace kochii (E.Pritzel) L.A.S.Johnson, *Contributions to the National Herbarium of New South Wales* 3: 101 (1962).

Lectotype (here designated): Australia. Western Australia: Watheroo rabbit fence, Sept. 1905, *M. Koch 1459*; lecto NSW442786; isolecto NSW442785

Xanthosia bungei Keighery, *Nordic Journal of Botany* 8: 445 (1989).

Holotype: Australia. Western Australia: Summit of Mt. Singleton, 7 Sept 1973, *J.S. Beard 6453*; holo: PERTH1597787, iso: CANB359698, K, NSW409407, PERTH (n.v. *fide* Keighery).

Erect, perennial shrub, 0.3–1.0 m high. Taproot woody with a flaky or corky surface. Plants hirsute. Leaves cauline, trifoliolate. Petiole sheathing, 2–4 mm long. Leaflets cuneate, the segments equal, 3–20 mm long, 1–6 mm wide, margins tridentate, rarely entire. Inflorescence a compound umbel with (3 or)4(or 5) rays, (2–)6–15 flowers per ray, and up to 6 flowers between the rays; flowers all female or bisexual and male. Rays terete, 1–6 mm long. Involucral bracts 3–5, linear, foliaceous, green, equal to the rays, 2–6 mm long, c. 1 mm wide, apex acute. Bracteoles (2 or) 3, ovate, petaloid, green or yellow, shorter or equal to the flowers, 2.4–2.9 mm long, 0.6–1.3 mm wide, apex acute, the lateral bracteoles asymmetrical. Inflorescences pedunculate; peduncles erect, 8–40 mm long. Flowers pedicellate. Sepals narrowly elliptic to ovate, 1–1.5 mm long, c. 0.8 mm wide, white or yellow, base auriculate, apex acute, glabrous. Petals c. 1.1 mm long, c. 0.7 mm wide, white, midrib adaxially keeled and bridged, apex obtuse, appendage smooth. Stamens longer than perianth; filaments c. 1.9 mm long; anthers c. 0.5 mm long, yellow; staminodes present in female flowers; small, inconspicuous, about the same height as the nectaries with a short filament c. 0.2mm long and distinct, sterile anthers c. 0.2mm long. Nectaries slightly raised, c. 0.4 mm high, glabrous. Styles c. 2 mm long at female anthesis. Ovary glabrous. Male flowers differ from the female fertile flowers in having an undeveloped inconspicuous ovary, with styles barely protruding above the nectaries. Female flowers differ from bisexual flowers in lacking stamens, instead having inconspicuous staminodes. Fruit brown, ovoid, 2.2–2.7 mm long, 1.8–2.3 mm wide, 0.6 mm broad. Mericarps glabrous, minutely papillate, 9-ribbed: ribs keeled (Fig. 1).

Distribution: Endemic to Western Australia (Fig. 3). Tallering (Yalgoo region) and Merredin (Avon Wheatbelt), occurring from Jibberding north to Tardun, east to Mt Gibson and west to Yandanooka.

Representative Specimens: Western Australia: Yalgoo: Tallerang: Summit of Mt Gibson, *W.G. Henderson & M.H. Henderson s.n.*, 14 Sep 1972 (PERTH3619265); Avon Wheatbelt: Merredin: Koolanooka road near Morawa, *J.S. Beard 6701*, 27 Sep 1973 (PERTH); Between Mullewa and Morawa, *W.E. Blackall 2788*, 24 Sep 1932 (PERTH); Wanarra road, 31 km from the Great Northern Highway, N of Wubin, *J.M. Hart 95053*, 27 Oct 1995 (PERTH, SYD); Koolanooka Hills 18 km E of Morawa, *G.J. Keighery 2031 & J.J. Alford*, 15 Aug1990 (PERTH)

Flowering: August to September.

Ecology: Found under thickets dominated by species of *Allocasuarina*, *Melaleuca* and *Acacia* on red loam or yellow sand. Grows tangled in the bases of taller shrubs. Appears to drop its leaves when fruiting (around October) to become dormant over summer months.

Affinities: Morphologically similar to *X. fruticulosa* from which it differs by its compound umbels on erect peduncles (Fig. 1a), its auriculate sepal bases (Fig. 1k) and in being a larger shrub.

Notes: NSW442786 and NSW442785 bear reproductive and vegetative material, with NSW442786 having

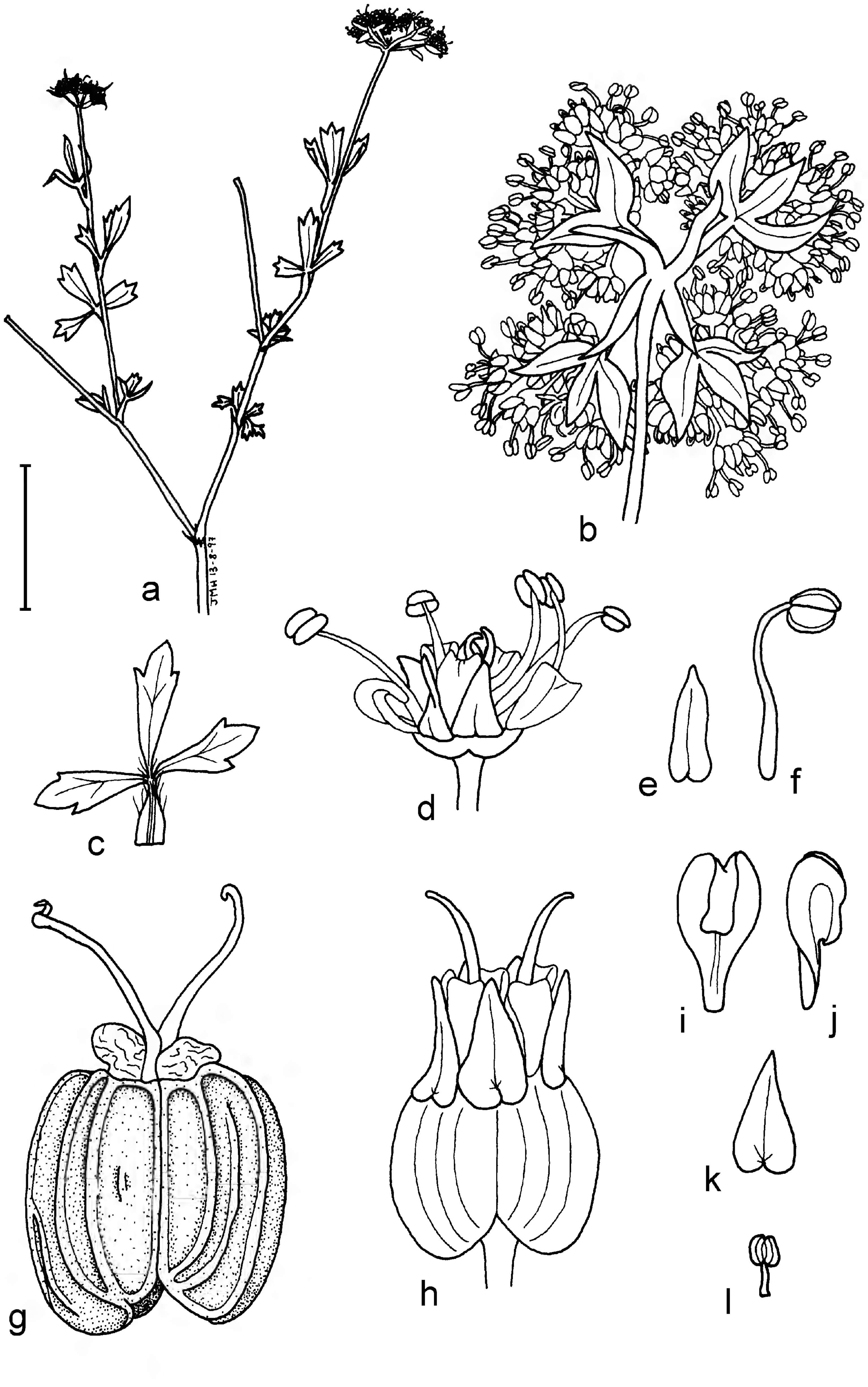

Fig. 1. ***Xanthosia kochii*: a,** branchlet; **b,** underside of inflorescence; **c,** leaf; **d,** male flower in male anthesis; **e,** sepal from male flower; **f,** stamen from male fertile flower; **g,** fruit; **h,** female flower in female anthesis; **i-j,** petals, **i,** adaxial view, **j,** side view; **k,** sepal from female fertile flower; **l,** staminode from female flower. **a–f,** drawn from *G.J. Keighery 2031* (PERTH), **g,** drawn from *J.M.Hart* 95033 (PERTH, SYD), **h-l,** drawn from *W.G and M.H Henderson* (PERTH). Scale bar: a = 40 mm; b = 4 mm; c = 20 mm; d–g = 1.5 mm; h, k = 2 mm; i, j, l = 1 mm.

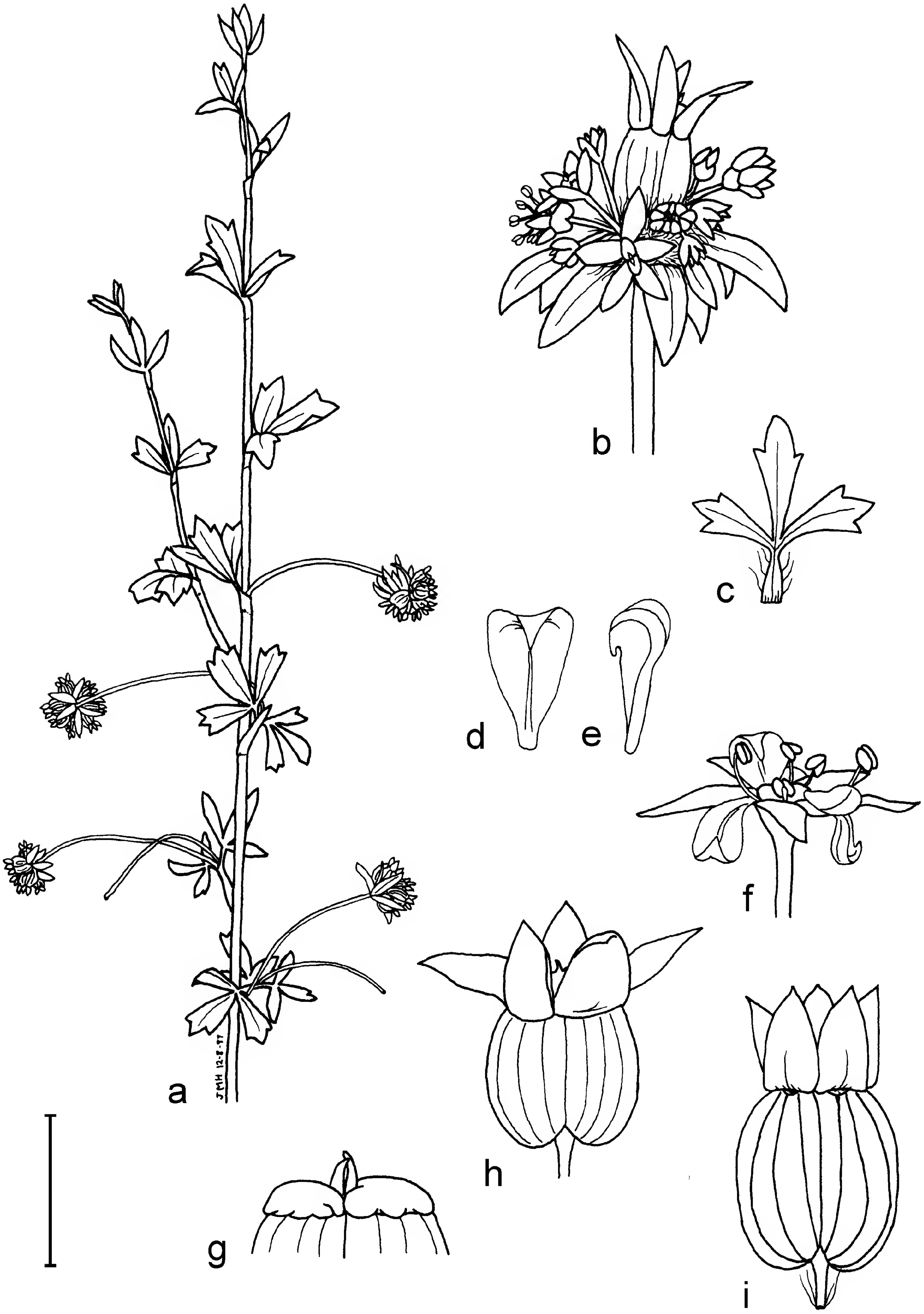

Fig. 2. ***Xanthosia fruticulosa*****: a,** branchlet; **b,** inflorescence; **c,** leaf; **d-e,** petals, **d,** adaxial view, **e,** side view; **f,** male flower in male anthesis; **g,** summit of fruit showing nectaries and styles; **h,** bisexual flower in female anthesis, petals and stamens shed; **i,** fruit. Drawn from *J.M.Hart 95060* (CANB, PERTH, SYD). Scale bar: a, c = 20 mm; b, h = 3 mm; d, e = 1 mm; f, g, i = 2.5 mm; h = 2 mm.

most material. For this reason NSW442786 was chosen as lectotype. NSW442785 and excess material are designated as isolectotypes. We were unable to locate the additional sheet at PERTH designated by Keighery (1989) as isotype for *X. bungei*.

Xanthosia fruticulosa Benth., *Flora Australiensis* 3: 361 (1867).

Lectotype: Between Moore and Murchison rivers, Western Australia, *J. Drummond 6th coll. no. 118*; lecto: K686317, isolecto: MEL0239079A, NSW409406, BM582873, G367417 (n.v.).

Erect, perennial subshrub to 0.2 m high. Taproot woody with a flaky or corky surface. Plants sparsely hairy; the stem excorticating when aged. Leaves cauline, trifoliolate. Petiole sheathing shortly at the base, sheaths 1.3–2.1 mm long. Petiole 1–6 mm long, flattened. Leaflets cuneate, the segments equal, 5–22 mm long, 1.5–8 mm wide, sessile; margins tridentate sometimes entire. Inflorescence a simple umbel with 16–40 flowers, flowers all bisexual or bisexual and male. Involucral bracts 5–8, lanceolate, irregularly inserted and not clearly whorled, foliaceous, green, approximately equal to the flowers, 3.5–5.7 mm long, 1.7–2.1 mm wide, apex acuminate. Inflorescences pedunculate; peduncles reflexed, 6–22 mm long at flowering. Flowers pedicellate. Sepals lanceolate, 1.7–2.7 mm long, c. 0.8 mm wide, green, base truncate, apex acuminate, glabrous or rarely ciliate. Petals 0.7–0.9 mm long, c. 0.5 mm wide, white or pink, midrib adaxially keeled and bridged, apex acute, appendage smooth. Stamens approximately equal to the perianth. Nectaries slightly raised, c. 0.4 mm high, glabrous. Styles 0.4–0.6 mm long. Ovary glabrous. Male flowers differ from the bisexual flowers in having an undeveloped inconspicuous ovary, with the styles barely protruding above the nectaries. Fruit brown, ovoid, 2.5–3.2 mm long, 2.1–2.8 mm wide, 0.6 mm deep. Mericarps glabrous, smooth, oblong in transverse section, 5–7 ribbed: the ribs not elevated (Fig. 2). Chromosome number n=10 (Keighery 1982).

Distribution: Endemic to Western Australia (Fig. 3). Katanning (Avon Wheatbelt), Lesueur Sandplain (Geraldton Sandplain), Perth (Swan Coastal Plain) and Northern Jarrah Forest (Jarrah Forest), found around Lesueur National Park, Dandaragan - Moora area, Chittering Valley and Serpentine River.

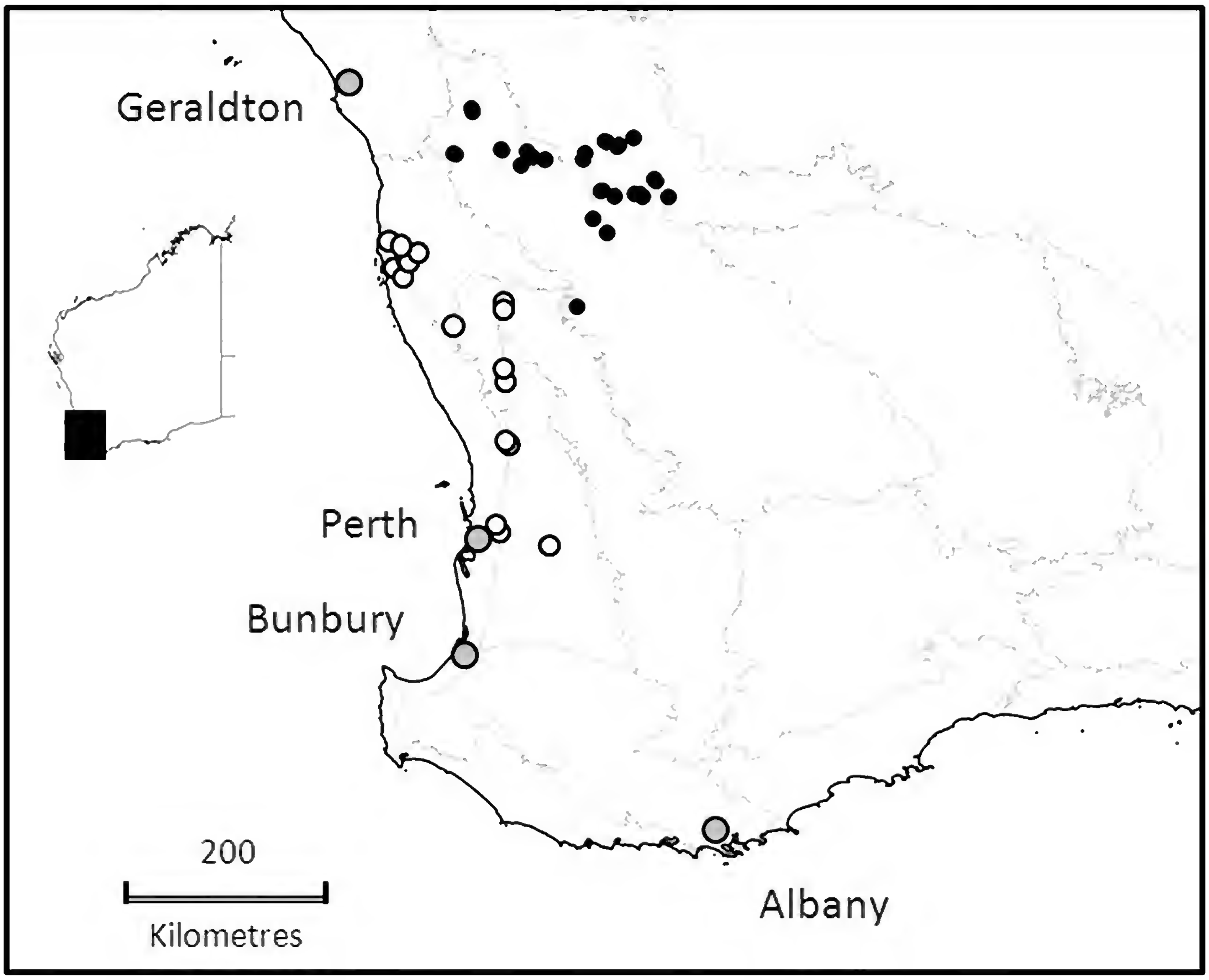

Fig. 3. Map of known localities of *Xanthosia fruticulosa* (○) and *Xanthosia kochii* (●) in south western Western Australia, overlaid on IBRA (2012) version 7.0 sub-regions indicated in grey.

Representative Specimens: Western Australia: Avon Wheatbelt: Katanning: 11 km N of Moora along Midlands road, *R. Cranfield 8173 and P. Spencer*, 16 Oct 1991 (PERTH); Geraldton Sandplain: Lesueur Sandplain: Mt Lesueur, *A.S. George s.n.*, 13 Oct 1974 (CANB352275.1, K, PERTH3620417); Mt Misery W of Dandaragan, *E.A. Griffin 5046*, 11 Sep 1988 (PERTH); Swan coastal plain: Perth: Serpentine River, *W.V. Fitzgerald s.n.*, Sep 1900 (NSW52403, PERTH3620174); 7.5 km from Bullsbrook end on Chittering Valley road, *J.M. Hart 95060*, 28 Oct 1995 (CANB, PERTH, SYD).

Flowering: September to November.

Acknowledgments

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Actinotus repens Keighery ex Henwood (Apiaceae): A new species from south-west Western Australia

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Abstract

Actinotus repens Keighery ex Henwood (Mackinlayoideae, Apiaceae) is here described as a new species from south-west Western Australia. A key to Western Australian species of *Actinotus* is included.

Introduction

Actinotus comprises 19 described species, with two centres of species richness: one in south-west Western Australia (8 endemic spp.) and the other in eastern Australia (6 endemic spp.). *Actinotus schwartzii* F.Muell. is restricted to the Macdonnell ranges (Northern Territory), and three species (*A. bellidioides* (Hook.f.) Benth., *A. moorei* F.Muell., and *A. suffocates* (Hook.f.) Rodway) are currently restricted to Tasmania. One species, *A. novae-zelandiae* (Petrie) Petrie, is endemic to Te Waipounamu, Aotearoa–New Zealand.

Placement of *Actinotus* within Apiaceae has, until relatively recently, been somewhat equivocal. Maximum parsimony analysis of nucleotide sequences from chloroplast and nuclear genomes has consistently placed *Actinotus* as a well-supported member of Mackinlayoideae (Plunkett and Lowry, 2001; Nicolas and Plunkett, 2009). Relationships between *Actinotus* and other Mackinlayoideae, however, remain unresolved with the genus either supported as sister to the New Caledonian endemic shrub, *Apiopetalum* or in a weakly supported sister relationship to the Australian endemic genera, *Xanthosia*+*Chlaenosciadium,* and the South African centred genus, *Centella* (Nicolas and Plunkett, 2009).

As with the placement of *Actinotus* within Mackinlayoideae, the phylogenetic relationships within *Actinotus* await clarification. There are, however, several morphologically distinct groups within *Actinotus.* One of the most morphologically distinct groups contains *A. omnifertilis* (F.Muell.) Benth., *A. rhomboideus* (Turcz.) Benth. and *A. laxus* Keighery, all of which are restricted to south-west Western Australia. This group of species are readily distinguishable from other *Actinotus* by their simple, often toothed leaves; umbels of relatively few mostly co-sexual flowers subtended by relatively small, free bracts; clawed, ovate petals; more or less connate sepals, and basipetally swollen styles that cross at anthesis. It is with this group of species that the newly described *A. repens* Keighery ex Henwood has its strongest morphological similarities.

Taxonomy

Actinotus repens Keighery ex Henwood, ***sp. nov.***

Diagnosis: Differing from *A. laxus* and *A. omnifertilis* by its prostrate habit, robust indumented branches, and broadly ovate cauline leaves with c. 5-13 teeth. It differs from *A. rhomboideus* (Turcz.) Benth. by its prostrate habit and leaves with fewer teeth.

Holotype: Western Australia: Warren: Walpole-Nornalup National Park: Delta Road, 0.45 km from junction with Isle Road, *J.R. Wheeler 3786 & S.J. Patrick*, 27 Jan 1993 (*holo*: PERTH 4058488).

Informal names synonymous with *A. repens* Keighery ex Henwood:

Actinotus "walpole" (*Wheeler 3786*) in Wheeler et al., *Flora of the South West* 2: 477 (2002)

Actinotus sp. Walpole (*J.R.Wheeler & S.J.Patrick 3786*)* WA Herbarium [FloraBase accessed 2013]. *A miscitation of the type collection: *J.R.Wheeler 3786 & S.J.Patrick*

Actinotus repens Keighery ms WA Herbarium [FloraBase accessed 2013]

Suffrutescent, prostrate perennial, to 5 cm high, c. 20 cm wide. *Stems* glabrous, robust. *Leaves* alternate, estipulate; *petioles* (2–)4–15 mm long, pilose, terete to slightly canaliculated, bases alate; *lamina* entire, broadly ovate, (6–)9–10 × (6–) 10 (–15) mm long, glabrous or with scattered trichomes towards margin of younger leaves; margin coarsely dentate; venation pinnate, obscure; abaxial surface lighter green than adaxial surface. *Inflorescences* simple, umbellate, (3–)6–9-flowered; peduncles 4–21 mm long; *bracts* free, elliptic, foliose 0.7–0.8 × 2–5 mm; *pedicels* 0.5 mm long, apically articulated with ovary, retained after fruit is shed. *Calyx* tubular, distally with a 5-toothed rim 0.4 mm long, sparsely ciliate. *Petals* 5, ovate, 0.3 × 0.5 mm, white, with a single obvious vein. *Stamens* 5. *Styles* 2, often crossed at maturity, 0.5 mm long. *Fruit* uniloculate, turbinate, 0.5 × 0.7 × 1 mm, slightly compressed, 5-ribbed, pilose. Fig. 1.

Representative specimens listed by IBRA (2012) subregion: Western Australia. Northern Jarrah Forest: 2.8 km ENE of Mt William, near the intersection of Willowdale Road and Zigzag Road, Lane-Poole Conservation Reserve, *A.J. Perkins AJP-WA48*, 19 Oct 2003 (PERTH, NSW, SYD); **Southern Jarrah Forest:** 0.5 km W of the corner of Sues and Crouch roads, E of Margaret River (SWCC.WH.03a Plot SCRD01), *M. Morley 490*, 22 Oct 2007 (PERTH); **Warren:** Creek-line on Lane-Poole Road, 5.5. km E of the Wheatley Road, near Northcliffe, *R.W. Hearn* (*ARA 5886*), 12 Mar 1997 (SYD); Near Granite Peak, c. 20 miles [32 km] N of Walpole, *A.S. George 11122*, 3 Oct 1971 (PERTH); c. 2 km W of Walpole, north of the SW highway and & 500 m W of Walpole River, Edge of Walpole National Park, *J.R. Wheeler* 3779 & *S.J. Patrick*, 27 Jan 1993 (PERTH); Pemberton, *M. Koch 2613*, Dec 1921 (NSW); Delta Road, 0.5 km W of Isle Road, Walpole-Nornalup National Park, *A.J. Perkins AJP-WA54*, 22 Oct 2003 (PERTH, NSW, SYD).

Etymology: The specific epithet, *repens*, refers to the prostrate growth habit of this species.

Distribution and habitat*:* Endemic to south-west Western Australia (Fig. 2). It occurs on sandy clay and mud in valleys along creek-lines and edges of other water channels from the Waroona area south to Walpole, amongst *Eucalyptus* or *Melaleuca* dominated woodland.

Flowering period: January to March.

Fruiting period: January to March.

Conservation status: Western Australian Declared Flora priority 3, under the name *Actinotus* sp. Walpole (J.R. Wheeler & S.J. Patrick 3786) i.e. poorly known species including some populations that are not currently endangered (FloraBase, accessed 2013).

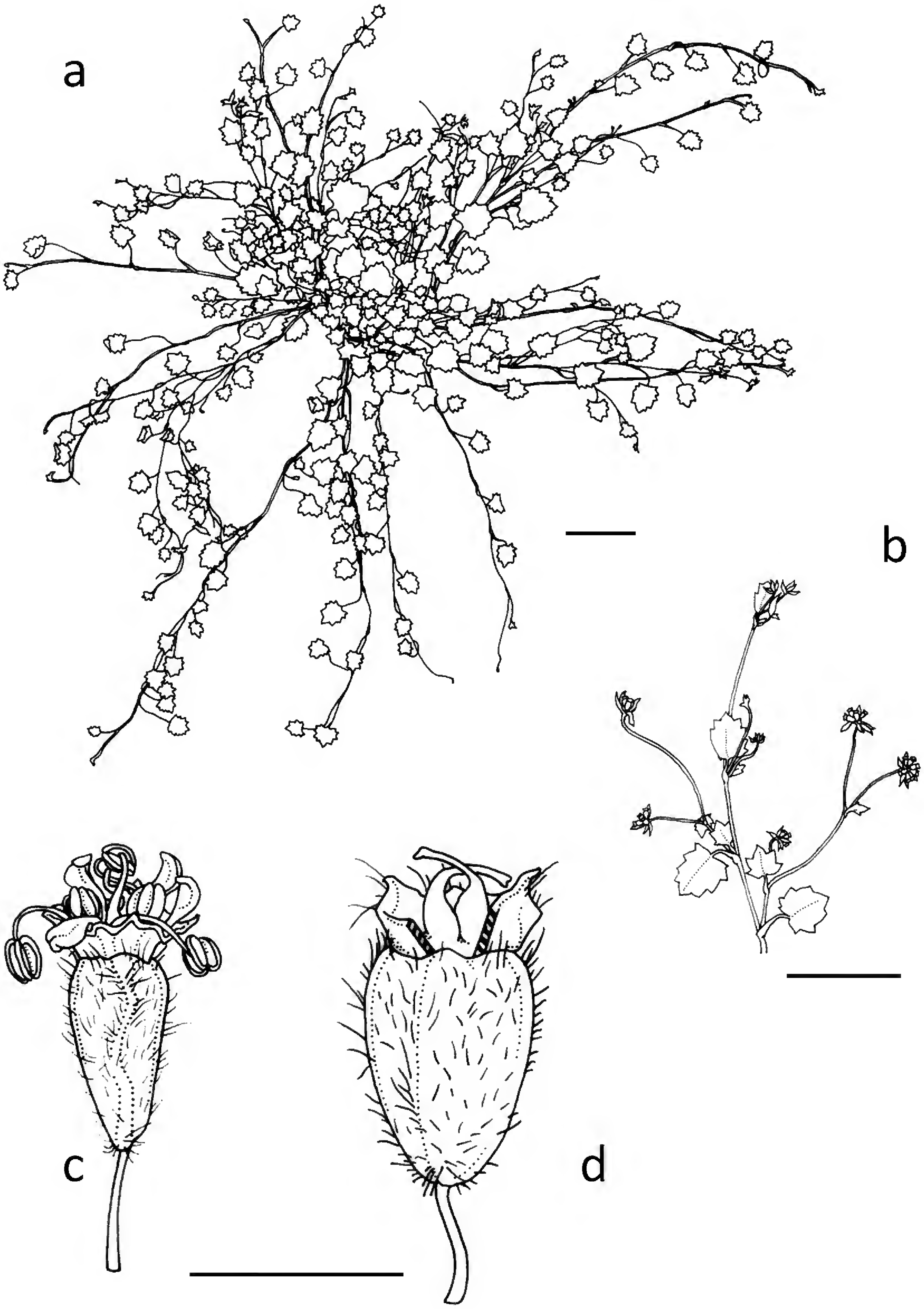

Fig. 1. Illustration of *Actinotus repens* Keighery ex Henwood: **a,** habit; **b,** flowering branch; **c,** flower; **d,** fruit with sepaline rim partially removed to show the crossed styles. Based on R.W Hearn *ARA 5886I*. Scale bar a & b = 15 mm, c & d = 1 mm

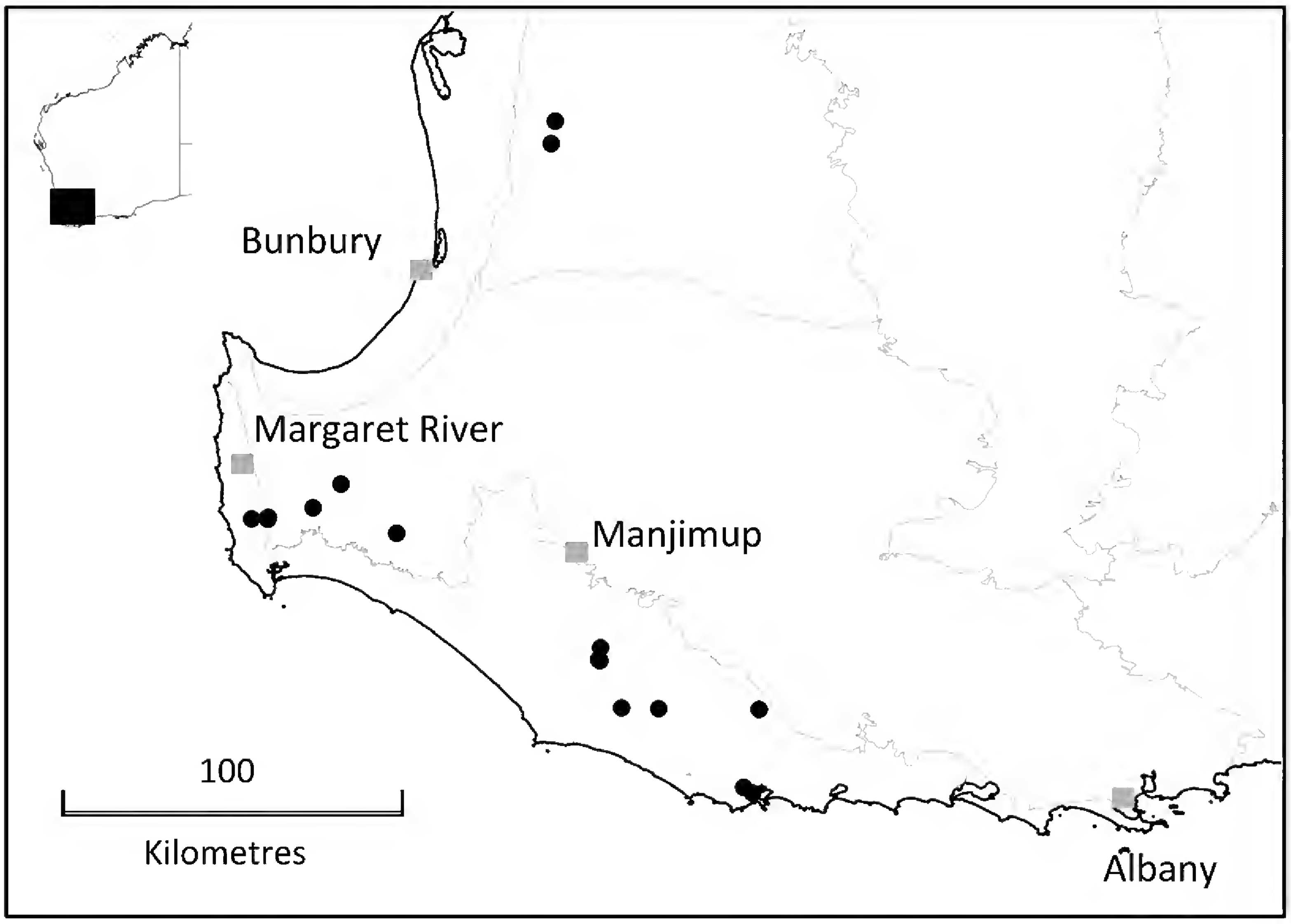

Fig. 2. Map of known localities of *Actinotus repens* Keighery ex Henwood in south-west Western Australia with v 7.0 IBRA sub-regions (Australian Government Department of the Environment, 2012, as provided by: Department of Sustainability, Environment, Water, Population and Communities) indicated in grey.

Key to Western Australian *Actinotus*

1 Leaves simple, toothed; styles crossed; petals ovate. 2

1: Leaves variously ternatisect; styles not crossed; petals spathulate or absent 5

2 Leaves cuneate; stems glabrescent with an indumentum of sparse, short, patent trichomes 3

2: Leaves orbiculate, rhomboidal or ovate; stems with a villous indumentum 4

3 Leaves mostly basal with more than three teeth on the margin; branches robust .... *A. omnifertilis*

3: Leaves scattered along branches, tridentate; branches weak .... *A. laxus*

4 Plants prostrate; leaf lamina ovate, glabrous or sparsely indumented .... *A. repens*

4: Plants ascending; leaf lamina orbiculate-rhomboidal, villous .... *A. rhomboideus*

5 Sepals free, elongated 6

5: Sepals connate forming an entire or shortly toothed rim 7

6 Leaf laminas 20–25 mm long; flowers numerous and arranged in an umbellate pseudanthium; stylopodium and nectary free from each other in fruit; peduncles 50–80 mm long .... *A. whicheranus*

6: Leaf laminas 4–12 mm long; flowers 3–5 per umbel; stylopodium and nectary connate, becoming swollen in fruit; umbels sessile or shortly pedunculate .... *A. glomeratus*

7 Anthers purple at maturity; involucral bracts 7 mm long .... *A. leucocephalus*

7: Anthers yellow at maturity; involucral bracts 15 mm long 8

8 Stems and inflorescences erect; involucral bracts 2–3 mm wide (appearing wider due to indumentum) .... *A. superbus*

8: Stems erect or spreading; inflorescences radiating; involucral bracts 5 mm wide .... *A. humilis*

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