



Three new species segregated from *Phebalium squamulosum* subsp. *squamulosum* (Rutaceae) based on morphological and phytochemical data

Ian R. H. Telford^{1,4}, Nicholas J. Sadgrove^{2,3}, Jeremy J. Bruhl¹

1. Botany and N.C.W. Beadle Herbarium, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia

2. School of Science and Technology, University of New England, Armidale, NSW 2351, Australia

3. Current address: Jodrell Laboratory, Royal Botanic Gardens, Kew, Richmond TW9 3DS, UK

4. Author for correspondence: itelford@une.edu.au

Introduction

The genus *Phebalium* Vent. is widespread through southern and eastern Australia with 28 species recognised in the 'Flora of Australia' (Wilson 2013) and 30 recognised by APC (2016). Several species, in particular *Phebalium squamulosum* Vent., exhibit considerable morphological variation. In the last major revision of the genus, Wilson (1970) recognised nine subspecies, with eight of these maintained in his treatment for 'Flora of Australia' (Wilson 2013). Telford and Bruhl (2014) subsequently raised *P. squamulosum* subsp. *verrucosum* Paul G. Wilson to the rank of species.

The type specimen of *P. squamulosum* was taken from a plant cultivated in Empress Josephine's garden at Malmaison, France, from a collection from the Sydney area, "originaire de la Nouvelle Galles, et croissant sur les montagnes" (Ventenat 1805). A lectotype was selected by Callmander *et al.* (2017), which includes an image of an isoelectotype.

In his treatment of *P. squamulosum* subsp. *squamulosum*, Wilson (1970) included lowland plants of the Sydney Basin as well as plants from south-eastern Queensland and high altitudes of the New England Tableland,

Abstract

Phebalium graniticola I. Telford & J.J. Bruhl, *P. stellatum* I. Telford & J.J. Bruhl and *P. sylvaticum* I. Telford & J.J. Bruhl are segregated as new species from *Phebalium squamulosum* Vent. subsp. *squamulosum*. Essential oil data support the recognition of these species as distinct. Distributions of the new species are mapped, and their habitat and conservation status discussed. A table comparing selected morphological attributes of the new species with *P. squamulosum* subsp. *squamulosum* is provided.

Key words: biodiversity, conservation, essential oils, plant systematics, taxonomy

New South Wales, noting (Wilson 1970: 82): "This subspecies, as here delimited, includes several different forms which may warrant recognition, but as some of these forms are known only from single collections it appears unwise at the moment to further fragment the species." Extensive, additional material collected since then allows critical reassessment of delimitation of the subspecies.

Investigation of the *P. squamulosum* complex in Queensland by Forster (2003) has shown that additional collections have allowed a clearer pattern of discontinuous variation to emerge. Forster used morphological discontinuities, and geographic and ecological disjunctions to argue for raising several subspecies to specific rank within *Phebalium* (Forster 2003) and *Philotheca* Rudge (Forster 2005). Forster (2003) segregated *Phebalium distans* P.I.Forst. from *P. squamulosum* subsp. *squamulosum*, and reinstated *P. longifolium* S.T.Blake as a species. He also drew attention to two groups of populations from near Dorrigo, New South Wales and Mount Ballow, Queensland in need of further study. Here we investigate the status of these populations.

Leaf essential oil composition has provided insights into relationships in *Phebalium* (Brophy *et al.* 2006; Pala-Paul *et al.* 2009; Sadgrove *et al.* 2013, 2014). The first analysis of essential oils from *P. squamulosum* was undertaken by Batey *et al.* (1971), with a novel sesquiterpene ketone that they named squamulosone found to be the major constituent. Although no subspecies was specified in that study and no voucher cited, the locality of collection (Narrabeen, Sydney) places it as *P. squamulosum* subsp. *squamulosum*.

Brophy *et al.* (2006) reported no squamulosone present in oils from samples from Queensland assigned to *P. squamulosum* subsp. *squamulosum*; major components were elemol/hedycaryol and isomers of eudesmol. The two related sesquiterpenes elemol and hedycaryol were first reported in *Phebalium* by Southwell (1970) from a Blue Mountains sample of *P. ozothamnoides* F.Muell., currently referred to *P. squamulosum* subsp. *ozothamnoides* (F.Muell.) Paul G.Wilson (Wilson 2013). Southwell (1970) demonstrated that elemol is the heat product of hedycaryol formed in hydrodistillation, yielding an essential oil with a mixture of the two. Elemol and hedycaryol are generally

reported together in analyses because they are not effectively separated in chromatography.

In curating *Phebalium* in herbarium NE, we assigned the plants from the unallocated populations referred to by Forster (2003) as putative new species. Composition of the essential oils of these, *P. stellatum* I.Telford & J.J.Bruhl from near Dorrigo New South Wales, and *P. sylvaticum* I.Telford & J.J.Bruhl from Gibraltar Range, New South Wales, was assessed by Pala-Paul *et al.* (2009) but no comparisons were made with oils from other populations currently assigned to *P. squamulosum* subsp. *squamulosum*. In their analyses, the oils of *P. stellatum* and *P. sylvaticum* show a similar composition; both lack squamulosone and contain some measure of hedycaryol/elemol, but major components and proportions of chemicals differed. *Phebalium stellatum* yielded essential oils characterised by a significantly higher proportion of monoterpenes, where α -pinene and myrcene represented the major monoterpenes. In contrast, the chemical character of volatiles from *P. sylvaticum* demonstrated collectively higher proportions of hedycaryol/elemol, eudesmol isomers and other oxygenated sesquiterpenes such as guaial and bulnesol (Table 1).

Sadgrove *et al.* (2014) found populations from the New England Tableland, therein assigned to *P. squamulosum* subsp. *squamulosum* – below named as a new species, *P. graniticola* I.Telford & J.J.Bruhl – yielded elemol and eudesmol as major components but also lacked squamulosone (Table 1). Comparison with other samples of *P. squamulosum* subsp. *squamulosum* indicates the name encompasses several chemotypes, and probably constitutes a heterogeneous species aggregate. The two sesquiterpene rich oils from *P. sylvaticum* and *P. graniticola* are differentiated by elemol/hedycaryol, with a lower proportion in the latter species, together with moderate to high concentrations of globulol. Ledol (the epimer of globulol) was observed in trace quantities in *P. sylvaticum*, but generally this azulenic group only occurs in *P. squamulosum* subsp. *squamulosum* sampled in the study by Sadgrove *et al.* (2014).

In this paper, we are not presenting a full revision of the species, or even of the subspecies *P. squamulosum* subsp. *squamulosum*. Although we value highly comprehensive taxonomic revisions, we are publishing

Table 1. Comparison of major essential oil components of leaves of *Phebalium graniticola*, *P. stellatum* and *P. sylvaticum*. Data for *P. stellatum* and *P. sylvaticum* from Pala-Paul et al. (2009); for *P. graniticola*, from Sadgrove et al. (2014).

Essential oil component	<i>P. stellatum</i>	<i>P. sylvaticum</i>	<i>P. graniticola</i> ~
α-pinene	-	7.1–8.9	0.2–3.4
camphene	0.5–3	1.6–2.6	-
γ-3-carene	4.4–13.7	8.0–11.5	-
myrcene	0.1–2.8	10.6–23.0	0.9–6.0
limonene	1.3–1.7	2.1–2.5	-
β-phellendrene	5.2–10.8	0.5–14.8	0.2–7.1
geijerene	0.1–0.2	0.1	-
bicyclogermacrene	1.8–2.7	0.9–1.6	0–0.5
elemol/hedycaryol*	29.1–40.6	18.7–23.9	5.7–18.7
globulol	-	-	6.3–33.3
ledol	-	0.1–0.3	-
guaiol	1.7–6.1	0.7–1.4	1.5–3.9
bulnesol	2.5–5.9	0.7–1.0	2.3–3.1
γ-eudesmol	5.4–8.2	2.2–3.5	1.5–13.1
β-eudesmol	6.1–10.0	6.7–9.1	1.4–16.3
α-eudesmol	5.5–8.6	2.8–3.8	1.9–9.8
Monoterpenes #	24.3–31.4	50.1–58.5	1.4–23.0
Oxygenated monoterpenes #	0.2–0.4	1.3–2.5	0.2–1.8
Sesquiterpenes #	3.4–4.4	1.6–3.0	2.6–7.3
Oxygenated sesquiterpenes #	61.1–69	33.9–43.7	58.9–91.4

* Different chromatographic methods were employed across the studies summarised here. Where a DB-WAX column was used, separation of elemol and hedycaryol was achieved (Pala-Paul et al. 2009) but not where a HP-5MS was used (Sadgrove et al. 2014). Owing to the interchangeability of elemol/hedycaryol in hydrodistillation (Southwell 1970), the two are combined to aid comparison.

These values are taken from Pala-Paul et al. (2009) and raw data included as supplementary material in the study by Sadgrove et al. (2014).

~ Treated in Sadgrove et al. (2014) as *P. squamulosum* subsp. *squamulosum*.

three distinct species from northern New South Wales and southern Queensland to address immediate conservation and management concerns. In this regard, we agree with Messina and Walsh (2019) and point to the constructive conservation outcome for *Phebalium speciosum* L.Telford (Telford 2013) that was segregated from the *P. nottii* (F.Muell.) Maiden & Betche complex without a full revision of that group. It has since been gazetted as “Critically Endangered” (NSW Scientific Committee report; <https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=20320>) and is subject to active management under the Saving Our Species program of the Office of Environment and Heritage (pers. comm. James Brazill-Boast).

Materials and methods

Morphological data

Morphological data was derived from herbarium specimens held in BRI, CANB, CFSHB, NE and NSW

(codes follow Index Herbariorum; <http://sweetgum.nybg.org/science/ih/>). Images of seeds were taken using a Nikon SMZ25 microscope, 1.0x objective, with bright field illumination. The plate (Figure 1) was constructed using paint.net v.4.0.13 and Inkscape v.0.91.

Essential oil data

Data on essential oil composition are from Pala-Paul et al. (2009) and Sadgrove et al. (2014) and we tabulate combined, selected results below.

Results and discussion

Trichome form and distribution appear to be taxonomically informative in defining taxa in *Phebalium*. All material currently assigned to *Phebalium squamulosum* subsp. *squamulosum* have peltate, lepidote trichomes in varying degrees. Lepidote trichomes in the study group exhibit more or less entire, erose and fimbriate scale margins, and variation in

rufous colouration. Only in populations near Cascade, New South Wales such rufous lepidote trichomes are sparse, while colourless stellate trichomes constitute most of the indumentum on the abaxial surface of leaves. Specimens from the Bucketty to Mogo Creek area, Central Coast, New South Wales, possess some stellate trichomes, but in other leaf and seed characters are more like *P. squamulosum* subsp. *squamulosum* s. str., and may represent a new taxon. The variation, development and evolution of trichomes merits further study (cf. Lander 1984).

Vegetative and floral differences (Table 2), together with the differences in seed morphology of size, shape and ornamentation (Figure 1) indicate new species are merited to accommodate three groups of populations from northern New South Wales and adjacent Queensland, which we name below.

Segregation of three putative new species from *P. squamulosum* subsp. *squamulosum* on this morphological evidence is corroborated by phytochemical data (Table 1). Species recognised here are sampled for phytochemistry from at least two individuals (Pala-Paul *et al.* 2009; Sadgrove *et al.* 2014) and up to five individuals from one or two populations. The high level of similarity of chemical profiles within a taxon and the obvious dissimilarity between taxa provides confidence that this line of evidence is congruent with discontinuities in morphology across taxa, that we recognise here as species.

The sesquiterpene ketone, squamulosone, was isolated from essential oils in high yield from the type variant of *P. squamulosum* (Batey *et al.* 1971). All three of

the new species lack squamulosone as a component of their essential oils.

The three new species differ in the proportion of their essential oil components (Table 1). In Sadgrove *et al.* (2014) samples from Bluff Rock and Donnybrook, near Tenterfield, New South Wales, were referred to *P. squamulosum* subsp. *squamulosum* Chemotype B, but are here named as the new species, *P. graniticola*.

Total monoterpenes are substantially higher in *P. sylvaticum* compared with those from *P. stellatum* and *P. graniticola*. Globulol is present in oils from *P. graniticola* in moderate to high amounts but absent in *P. stellatum* and *P. sylvaticum*. *Phebalium graniticola* has substantially less elemol/hedycaryol than *P. stellatum* and *P. sylvaticum*.

The morphological and phytochemical evidence together provides strong support for the segregation from *P. squamulosum* subsp. *squamulosum* of the three species described below as new: *P. graniticola*, *P. stellatum* and *P. sylvaticum*.

This paper is the second in an ongoing study of *Phebalium squamulosum*. Our field, herbarium and laboratory studies indicate that *P. squamulosum* subsp. *squamulosum* is restricted to the Sydney Basin and that the other currently recognised subspecies each represents at least one species. In addition, there are entirely new entities we have segregated at the N.C.W. Beadle Herbarium, including those currently assigned to *P. squamulosum* subsp. *squamulosum* in central and southern New South Wales, Victoria and South Australia. A student has commenced a PhD candidature in April 2019 in Botany and the N.C.W. Beadle Herbarium,

Table 2. Comparison of selected morphological attributes of *Phebalium graniticola*, *P. stellatum*, *P. sylvaticum* and *P. squamulosum* subsp. *squamulosum* s.str.

Attribute	<i>P. graniticola</i>	<i>P. stellatum</i>	<i>P. sylvaticum</i>	<i>P. squamulosum</i> subsp. <i>squamulosum</i> s. str.
Habit	shrub to 3 m	shrub or tree to 8 m	shrub or tree to 7 m	shrub to 2.5 m
Leaf shape	elliptic	lanceolate	lanceolate, rarely elliptic	elliptic
Leaf lamina length (mm)	4.3–27.5	(35–)50–85(–117)	(17–)30–70(–80)	8–34
Trichomes of leaf abaxial surface	lepidote	stellate and lepidote	lepidote	lepidote
Leaf margin	irregularly dentate	entire	entire to sinuate	entire
Calyx surface	lepidote and verruculose	lepidote	lepidote	lepidote
Petal length (mm)	2.8–3.5	2.5–3	3.5–4.2	3–4
Seed length (mm)	2.2–2.6	2.0–2.3	2.2–2.7	2.4–2.6

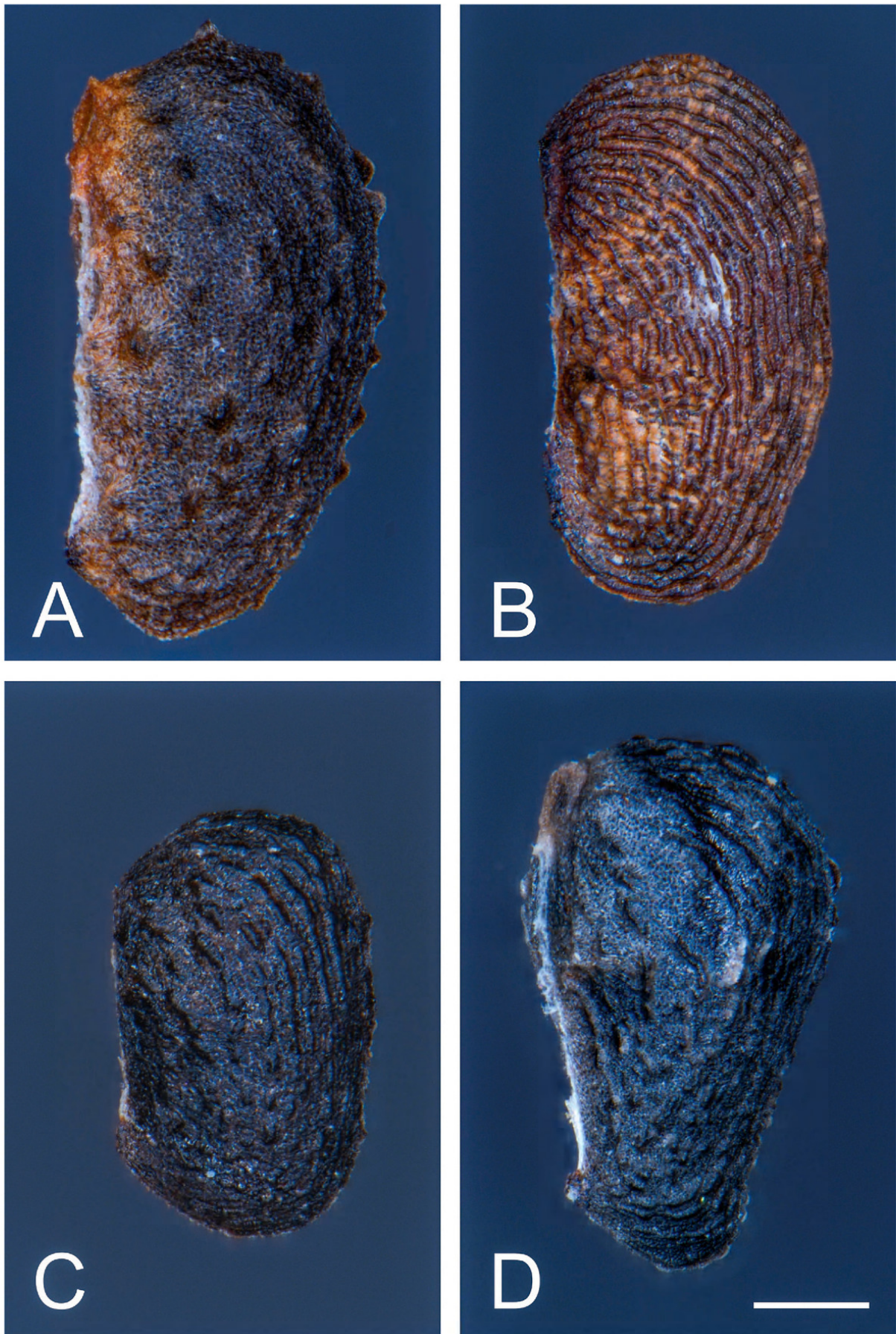


Figure 1. A: Seed of *Phebalium graniticola* (I.R. Telford 13122, NE). B: Seed of *P. squamulosum* subsp. *squamulosum* (J.B. Williams s.n., NE28996). C: Seed of *P. stellatum* (J.J. Bruhl 3513, NE). D: Seed of *P. sylvaticum* (J.J. Bruhl 3514, NE). Scale bar = 0.5 mm.

University of New England. This research project will add molecular data as well as more morphological and phytochemical data, leading to a comprehensive revision of the group as part of systematic study of *Phebalium* in eastern Australia.

Taxonomy

In this section, citation of specimens follows regional categories used by respective State herbaria, while distributional data follow IBRA Bioregions (<https://www.environment.gov.au/land/nrs/science/ibra>).

Phebalium graniticola I.Telford & J.J.Bruhl, sp. nov.

P. squamulosum subsp. *squamulosum* auct. non Vent.: Wilson (1970, 2013) p.p., excluding all populations other than those from the Granite Belt of Qld and the North Western Slopes and Northern Tablelands (not including Barrington Tops) of N.S.W.; Weston & Porteners (1991: 258) p.p. *ibid.*; Weston & Harden (2002: 303) p.p. *ibid.*

Type: NEW SOUTH WALES: Northern Tablelands: alongside Blather Creek near Blatherarm Road, Torrington State Recreation Area (now Torrington State Conservation Area), J.R. Hosking 1610 & G.R. Hosking, 7 Oct. 1998; *holo:* NSW; *iso:* BRI, CANB, MEL (MEL283130), NE (NE68575), NSW.

Diagnosis: differing from *P. squamulosum* Vent. subsp. *squamulosum* s. str. in its leaf margins (irregularly dentate vs entire), calyx rim (broad triangular lobes vs truncate), seed ornamentation (verruculose with few longitudinal ridges vs not verruculose and with many longitudinal ridges), and its leaf essential oil (the absence of squamulosone). *Shrubs*, stems erect, to 3 m tall. *Bark* ±smooth, red-brown to grey-brown with paler longitudinal lenticels. *Branchlets* densely silvery and rufous lepidote. *Leaves*: petiole 1.2–3.5 mm long, densely silvery and rufous lepidote; lamina elliptic, 4.3–27.5 mm long, 2.2–6.0 mm wide, apically rounded or truncate, mucronate, margins irregularly dentate, ±recurved, adaxial surface with midrib impressed, silvery lepidote on young leaves, glabrescent, glossy green, sparsely scabridulous with remnant bases of scales and the epidermis raised into obtuse to acute protuberances above the glands, abaxial surface silvery and rufous lepidote. *Inflorescence* terminal, of a single (3–)5–8(–13)-flowered umbel, sessile or peduncle to

1.5 mm long; pedicels 4.5–7(–15) mm long, densely silvery and rufous lepidote. *Calyx* shallowly cup-shaped, 0.8–1.0 mm long, 1.6–2.8 mm diam., verruculose and lepidote with 5 broadly triangular lobes often obscured by lepidote trichomes. *Corolla* of 5 free petals; petals elliptic, 2.8–3.5 mm long, 1.3–2.0 mm wide, shortly acuminate, adaxial surface glabrous, yellow, abaxial surface densely silvery and rufous lepidote. *Stamens* 10; filaments filiform, 5.0–5.8 mm long, glabrous; anthers elliptic, c. 1.2 mm long; apical gland minute, globose. *Ovary* subglobose, c. 1 mm diam., of 5 carpels, silvery lepidote; style c. 3 mm long, terete, glabrous; stigma minutely capitate. *Fruit* a capsular schizocarp of up to 5 erect cocci; cocci compressed obovoid, 3–3.5 mm long, 2–2.4 mm wide, truncate with an apical beak c. 1.5 mm long, silvery and ferruginous lepidote. *Seeds* compressed ovoid, 2.2–2.6 mm long, 1.3–1.6 mm wide, verruculose and with few discontinuous, longitudinal ridges on the outer face, dull dark grey. (Figs 1A, 2)

Specimens examined (selection): QUEENSLAND: Darling Downs: Amiens, 10 miles NW of Stanthorpe, L. Pedley 1488A, 30 Oct. 1963 (BRI); Slopes near summit of Mount Norman, Girraween National Park, J.M. Powell 1062 & J.A. Armstrong, 27 Sep. 1977 (BRI, NSW). NEW SOUTH WALES: Northern Tablelands: Bald Rock State Park, 23 km N of Tenterfield, R.G. Coveny 5728 & N.Lander, 3 Oct. 1974 (CANB, NE, NSW); Roberts Range, c. 27 km WNW of Tenterfield, 5 km along track to Donnybrook Plateau from Back Creek Road, I.R. Telford 13122, J.J. Bruhl, M. Badham & D. Caldwell, 20 Dec. 2006 (BRI, CANB, HO, NE, NSW); Jonquil Knob, Torrington State Recreation Area, off Duck Creek Trail, P.I. Forster 27439, 12 July 2001 (BRI, MEL, NE, NSW); 2.3 km along Blatherarm Road from Torrington to Silent Grove road, Torrington State Recreation Area, R. Johnstone 1499 & A.E. Orme, 31 Dec. 2004 (K, NE, NSW); Bluff Rock, 13 km S of Tenterfield, N.J. Sadgrove 303, 28 Oct. 2012; Cathedral Rock, 10 km N of Ebor, J.B. Williams NE51584, Oct. 1974 (NE); North Western Slopes: The Barbs, c. 20 km ESE of Ashford, B.J. Lepschi 5007 & A. Whalen, 15 Sep. 2003 (AUA, CANB, DAO, NE, NSW, NY); 'Willows', Bonshaw road, c. 43 km WNW of Glen Innes, G.J. White NE56114, 19 Aug. 1992 (NE); 'Rockview South', E of Barraba, J.T. Hunter s.n. & V.H. Hunter NE105028, 22 Apr. 2017 (BRI, NE, NSW).

Distribution: *Phebalium graniticola* is widespread through the New England Bioregion from Amiens, NW of Stanthorpe, Queensland, south to Cathedral Rock, near Ebor, New South Wales, west to near Barraba and Inverell, New South Wales.

Habitat: *Phebalium graniticola* grows in dry heath and *Eucalyptus* woodland mostly on granite, rarely on



Figure 2. Isotype of *Phebalium graniticola* I. Telford & J.J. Bruhl (NE).

metasediments (Donnybrook Plateau, Severn River Gorge). This species occurs at 580–1550 m altitude, mostly on high rocky sites, following suitable habitats near streams to the lower altitudes. Associated species include *Acacia neriifolia* A.Cunn. ex Benth., *A. torringtonensis* Tindale (Torrington only), *Callitris endlicheri* (Parl.) F.M.Bailey, *Calytrix tetragona* Labill., *Eucalyptus andrewsii* Maiden, *E. prava* L.A.S.Johnson & K.D.Hill, *E. youmanii* Blakely & McKie, *Leptospermum brevipes* F.Muell., *L. trinervium* (Sm.) Joy Thomps., *Prostanthera petraea* B.J.Conn (Bald Rock only) and *Styphelia triflora* Andrews.

Phenology: *Phebalium graniticola* flowers August–October; fruits December–January.

Conservation status: The species is widespread and common with populations of many individuals and thus is considered to be of “Least Concern” (IUCN 2017). It is conserved in Girraween National Park in Queensland, Bald Rock and Cathedral Rock National Parks, Torrington State Conservation Area and Bolivia Hill Nature Reserve in New South Wales.

Etymology: The epithet is from the Latin *granitum* (granite) and *-cola* (a dweller), referring to the species preference for granitic habitats.

***Phebalium stellatum* I.Telford & J.J.Bruhl sp. nov.**

P. squamulosum subsp. *squamulosum* auct. non Vent.: Wilson (1970; 2013) *p.p.*, excluding all populations other than those in the vicinity of Cascade near Dorrigo, N.S.W.; Weston & Porteners (1991: 258) *p.p. ibid.*, and all illustrations except 2a, right hand leaf only; Weston & Harden (2002: 303) *p.p., ibid.*

Type: NEW SOUTH WALES. North Coast: Wild Cattle Creek State Forest, 200 m along Callitris Rd from Morora Rd, 2.5 km ENE of Cascade, I.R. Telford 12938 & J.J. Bruhl, 10 Sep. 2006; holo: NSW; iso: BRI, CANB, HO, K, MEL (MEL2380142), MO, NE (NE88775), PERTH.

Diagnosis: differs from *P. squamulosum* Vent. subsp. *squamulosum* s. str. in the presence of stellate trichomes on branchlets and leaves, larger, lanceolate leaves (35–117 vs 8–34 mm long), smaller flowers (petals 2.5–3 vs 3–4 mm long), smaller seeds (2–2.3 vs 2.4–2.6 mm long) with fewer longitudinal ridges, and the absence of squamulosone from its leaf essential oil.

Shrubs or trees, stems erect to 8 m tall. *Bark* grey-brown,

±smooth roughen slightly by paler lenticels. Branchlets densely white lepidote to stellate hairy. *Leaves*: petioles 2–5 mm long; laminae narrowly lanceolate, (35–)50–85(–117) mm long, (3.5–)7.5–10(–15) mm wide, acute, margin straight or shallowly crenate, flat or slightly recurved; adaxial surface with midrib impressed, sparsely stellate, glabrescent, dull; slightly raised and rounded above the glands, abaxial surface densely white stellate hairy and rufous lepidote becoming predominately white stellate hairy at maturity. *Inflorescence* terminal, of up to five 4–8-flowered umbels, the adjacent upper axils with solitary umbels; peduncles 3–10 mm long, densely silvery lepidote; pedicels 3–7.4 mm long, densely silvery lepidote. *Calyx* broadly cup-shaped, c. 0.8 mm long, c. 1.5 mm diam., truncate or scarcely 5-lobed, densely silvery lepidote. *Corolla* of 5 free petals; petals elliptic, 2.5–3 mm long, 1.2–1.5 mm wide, apiculate, the adaxial surface glabrous, cream–pale yellow; abaxial surface densely silvery and ferrugineous lepidote. *Stamens* 10; filaments filiform, 3.5–5.5 mm long, glabrous; anthers elliptic, c. 0.6 mm long, apical gland minute, globose. *Ovary* subglobose, 1–1.2 mm diam., of 5 carpels, silvery lepidote and stellate hairy; style filiform, c. 3.5 mm long, with sparse stellate trichomes towards base; stigma truncate. *Fruit* a capsular schizocarp of up to 5 erect cocci; cocci compressed obovoid, 2.2–2.8 mm long, 1.8–2.5 mm wide, truncate, silvery and rufous lepidote. Seeds compressed obovoid, 2.0–2.3 mm long, 1.3–1.5 mm wide, with discontinuous longitudinal ridges mainly on the outer face, glossy black. (Figs 1C, 3, 4)

Specimens examined (selection): NEW SOUTH WALES: North Coast: Wild Cattle Creek State Forest, Mobong Rd, 2.5 km from junction with Measuring Hut Rd, S. Griffith s.n., 3 Sep. 1991 (BRI, NE, NSW); Wild Cattle Creek State Forest, 8.5 km along Moses Rock Rd from Cascade, I.R. Telford 12945 & J.J. Bruhl, 10 Sep. 2006 (BRI, CANB, HO, MEL, NE, NSW, PERTH); Morora Rd, 4.4 km E of Cascade via Dorrigo, A.R. Bean 16875, 10 Sep. 2000 (BRI, CANB, MEL, NSW); Dorrigo State Forest, hillsides above Wild Cattle Creek, C. White 7561, 4 Oct. 1930 (BRI); Urumbilum River, Orara West State Forest [now Bindari National Park], A. Floyd s.n., 9 Sep. 1972 (CFSHB).

Distribution: *Phebalium stellatum* is restricted to the mountainous country within 20 km of Cascade, N of Dorrigo, in the New South Wales North Coast Bioregion, New South Wales.

Phenology: The species flowers August–September; fruits December.



Figure 3. Isotype of *Phebalium stellatum* I.Telford & J.J.Bruhl (NE).

Habitat: *Phebalium stellatum* grows in wetter open forest on clay soils derived from metasediments at 600–700 m altitude adjacent to closed forest and with a dense small tree and shrub understorey. Dominant tree species are *Eucalyptus saligna* Sm., *E. microcorys* F.Muell., *E. pilularis* Sm. and *Lophostemon confertus* (R.Br.) Peter G.Wilson & J.T.Waterh. with an understorey including *Callicoma serratifolia* Andrews, *Acacia binervata* DC., *Allocasuarina littoralis* (Salisb.) L.A.S.Johnson, *Schizomeria ovata* D.Don, *Alphitonia excelsa* (A.Cunn. ex Fenzl) Benth., *Archirhodomyrtus beckleri* (F.Muell.) A.J.Scott, *Rubus moluccanus* L. and *Trimenia moorei* (Oliv. ex Benth.) W.R.Philipson.

Conservation status: Six populations have been recorded in the area within 20 km of Cascade. The population at the type locality consists of hundreds of individuals of mixed size classes (pers. obs., 27 May 2019). At this site, the disturbed roadside site suggests regeneration is promoted by opening of the forest canopy. Other populations have not been assessed. Under the IUCN (2017) risk categories, the species must be regarded as “Data Deficient”. More detailed consideration to its conservation status will be given in the broader study under way. The species is conserved in Bindari National Park.

Etymology: The epithet is from the Latin *stella* (star), in reference to trichome shape of the indumentum on branchlets and abaxial leaf surfaces, and the starry appearance of the inflorescences.

Notes: Specimens from the Bucketty to Mogo Creek area, Central Coast, New South Wales, possess some stellate trichomes, but in other leaf and seed characters match neither *P. stellatum* nor *P. squamulosum* subsp. *squamulosum* s. str.

***Phebalium sylvaticum* I.Telford & J.J.Bruhl sp. nov.**

Phebalium squamulosum subsp. *squamulosum* auct. non Vent.: Wilson 82 (1970; 2013) p.p., excluding all populations except for North Coast (other than Cascade area) and Gibraltar Range, N.S.W.; Weston & Porteners 258 (1993) p.p., *ibid.*; Weston & Harden 303 (2002) p.p., *ibid.*

Type: **NEW SOUTH WALES.** Northern Tablelands: Gibraltar Range National Park, 2 km north-east of turn-off to Washpool National Park along Gwydir Highway, L.M. Copeland 40846, 6 Sep 2006; holo: NSW; iso: BRI, CANB, K, MEL (MEL2380138), MO, NE (NE88815).

Diagnosis: differs from *P. squamulosum* Vent. s. str. in larger, usually narrowly lanceolate leaves (17–)30–70(–80) × (3.5–)5–10 vs 8–34 × 2.5–5.5 mm), seed ornamentation (verruculose with few longitudinal ridges on outer face vs many longitudinal ridges), and the absence of squamulose from its leaf essential oil.

Shrubs or trees, stems erect to 6 m tall. *Bark* grey-brown, ±smooth roughened slightly by paler lenticels. *Branchlets* densely scaly with rufous lepidote trichomes. *Leaves*: petiole 2–4.5 mm long; lamina narrowly lanceolate to narrowly elliptic, (17–)30–70(–80) mm long, (3.5–)5–10 mm wide, obtuse to acute, margin entire to sinuate, flat to slightly recurved; adaxial surface with midrib impressed, glabrous, glossy green, slightly raised and rounded above the glands; abaxial surface densely silver and silver-rufous lepidote. *Inflorescence* terminal, of up to five 3–6-flowered umbels, the several adjacent upper axils with solitary umbels; peduncle 1.5–4 mm long, silvery lepidote; pedicels 5–10 mm long, silvery lepidote. *Calyx* broadly cup-shaped, c. 1.5 mm long, 2.5–2.8 mm diam.; very shallowly 5-lobed, silvery and rufous lepidote on abaxial surface. *Corolla* of 5 free petals; petals elliptic, 3.5–4.2 mm long, 1.8–2 mm wide, obtuse; adaxial surface glabrous, yellow; abaxial surface densely rufous lepidote with a narrow glabrous margin. *Stamens* 10; filaments filiform, 3.5–6.5 mm long, glabrous; anthers elliptic, 1–1.2 mm long; apical gland globose. *Ovary* subglobose, 1.5–1.8 mm diam., of 5 carpels, densely silvery lepidote; style 4–4.5 mm long, with stellate trichomes or rarely lepidote on lower half; stigma truncate. *Fruit* a capsular schizocarp of up to 5 erect cocci; cocci compressed obovoid, 2.3–3 mm long, 1.8–2.5 mm wide, truncate, silvery lepidote. *Seeds* compressed narrowly obovoid, 2.2–2.7 mm long, 1.3–1.5 mm wide, with a short reflexed apical beak and discontinuous longitudinal ridges appearing more or less warty mainly on the outer face, glossy black. (Figs 1D, 5)

Specimens examined (selection): **QUEENSLAND:** Moreton District: Mt Ballow, C.T. White 11101, 25 July 1937 (BRI); Durrumlee Peak, Mt Ballow area, McPherson Range, P.I. Forster PIF7440 & G. Leiper, 19 Sep. 1990 (BRI, CBG, MEL, NSW, PERTH); Double Peak, Mt Ballow area, G. Leiper s.n., 18 Aug. 1990 (BRI); Mowburra Peak, Mt Barney National Park, D.A. Halford Q7380, 10 Sep. 2002 (BRI, MEL). **NEW SOUTH WALES:** North Coast: Unungar State Forest [now Toonumbar National Park], Jones s.n. AQ 152704, Oct 1947 (BRI); Toonumbar State Forest [now



Figure 4. *Phebalium stellatum*; A: flowering tree and habitat at Wild Cattle Creek State Forest, N.S.W. (type locality); B: inflorescences after rain; scale bar=10 mm.



Figure 5. Isotype of *Phebalium sylvaticum* I.Telford & J.J.Bruhl (NE).

Toonumbar National Park], W of Kyogle, *J.B. Williams s.n.*, 30 Aug. 1977 (BRI, CANB *n.v.*, MEL *n.v.*, NE, NSW *n.v.*); Gibraltar Range, c. 67 km NE of Glen Innes, *E.K. Winterhalder 629 & J.B. Williams*, Oct. 1961 (NE, NSW); Summit Mountain, Gibraltar Range National Park, *A.R. Bean 16846*, 8 Sep. 2000 (BRI); Clouds Creek, *H. Beckler*, [1859–1860] (MEL, image seen).

Distribution: *Phebalium sylvaticum* has been collected from four disjunct areas: the Mount Ballow area, McPherson Range, just north of the Queensland–New South Wales border north-east of Woodenbong and the Richmond Range south of Woodenbong, New South Wales, in the South East Queensland Bioregion, and the Gibraltar Range, north-east of Glen Innes, and Clouds Creek, New South Wales in the New South Wales North Coast Bioregion.

Phenology: The species flowers August–October; fruits December.

Habitat: *Phebalium sylvaticum* grows in closed forest, wetter open forest or shrubland on clay loams usually derived from basalt or other volcanics at 800–1200 m altitude. Most sites are dominated by *Eucalyptus saligna* Sm., *E. campanulata* R.T.Baker & H.G.Sm. and *E. obliqua* L'Her., usually adjacent to closed forest and with rain forest elements including *Acacia melanoxylon* R.Br. and *Callicoma serratifolia* Andrews in the understorey. Populations on the Gibraltar Range occur on the margins of *Ceratopetalum apetalum* D.Don and *Doryphora sassafras* Endl. closed forests on soils derived from metasediments or basalt. In the Mount Ballow area, the species is recorded in closed (simple microphyll moss) forest with *Nothofagus moorei* (F.Muell.) Krasser dominant on soils derived from trachyte, while on the nearby Double Peak it is in a tall shrubland with *Pomaderris argyrophylla* N.A.Wakef. and *Leptospermum*.

Conservation status: Six extant populations of this species are known, but numbers of mature plants per population have not been assessed. *Phebalium sylvaticum* must be regarded as “Not Evaluated” following the IUCN (2017) guidelines. More detailed consideration to its conservation status will be given in the broader study under way. The species is conserved in Mount Barney National Park, Queensland, and Toonumbar and Gibraltar Range National Parks, New South Wales.

Etymology: The epithet is from the Latin *sylva* (forest), in reference to the wet forest habitats of the species.

Notes: the first collection of *Phebalium sylvaticum*, by Hermann Beckler in 1859–1860, was sterile and

subsequently misidentified as *Phebalium billardieri* A.Juss., which is now a synonym of *Nematolepis squamea* (Labill.) Paul G.Wilson (Bentham 1863: 344), and also misidentified as *Phebalium squamulosum* var. *longifolium* (S.T.Blake) Paul G.Wilson, which is now treated as *Phebalium longifolium* S.T.Blake, a north Queensland endemic.

Vegetatively, *P. sylvaticum* may be superficially similar to *P. distans* and *P. longifolium*. The leaves of *P. sylvaticum* are generally shorter and wider than leaves of either *P. distans* (of southeastern Queensland) or *P. longifolium* (of northeastern Queensland); distinctly wider than in *P. distans*. Leaves of one specimen of *P. sylvaticum*, *L. Crooke s.n.* (NE 44919) are atypically smaller than other specimens. The lepidote trichomes appear to differ across these species, but further study is required to characterise the variation. Seed morphology appears to be diagnostic for species in *Phebalium* (e.g., Figure 1). In *P. longifolium*, seeds are considerably longer than in *P. sylvaticum*. Seed ornamentation differs with *P. longifolium* having fine longitudinal ridges, in contrast to the coarse broken ridges of *P. sylvaticum*.

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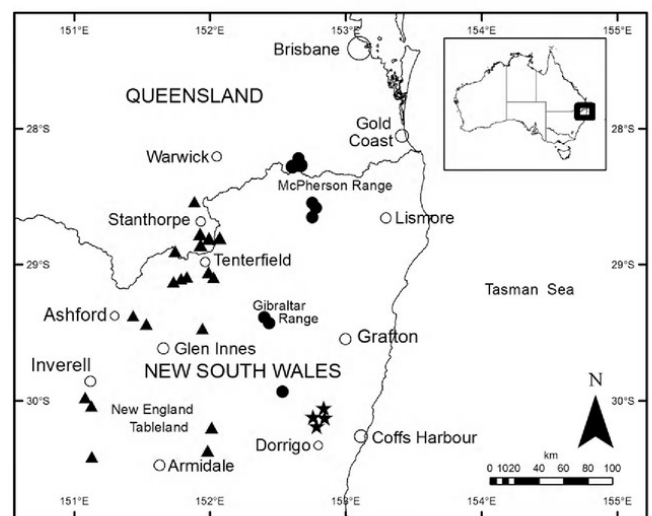


Figure 6. Distributions of (▲) *P. graniticola*; (★) *P. stellatum*; (●) *P. sylvaticum*.

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