

Morphological data indicate the subspecies of *Leionema elatius* (Rutaceae) are not conspecific and both should be treated as species

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Abstract

Morphological data show that the two subspecies currently assigned to *Leionema elatius* (Benth.) Paul G. Wilson (Rutaceae), namely *L. elatius* subsp. *elatius* and *L. elatius* subsp. *beckleri* (F. Muell.) Paul G. Wilson, are not conspecific and both should be treated as species. *Leionema elatius* subsp. *beckleri* is reinstated to the rank of species as *L. beckleri* (F. Muell.) I. Telford & J. J. Bruhl. The distributions of both species are mapped and their conservation status discussed. Images comparing the morphological attributes of the two species and a table comparing selected attributes of the species and the newly described *L. praetermissum* P. R. Alvarez & Duretto are presented. Modifications to a key to species of *Leionema* found in New South Wales and south-eastern Queensland are provided.

Introduction

Leionema (F. Muell.) Paul G. Wilson is an Australasian genus of Rutaceae consisting of 28 named species (Wilson 1998; Alvarez and Duretto 2019). The Australian species are confined to south-eastern Australia except for a single species restricted to a mountain in northern Queensland. The only extra-Australian species, *L. nudum* (Hook.) Paul G. Wilson, occurs on Aotearoa/New Zealand's North Island (Wilson 1998).

The type of *Eriostemon elatior* F. Muell. (Mueller 1875), basionym of *Leionema elatius* (F. Muell.) Paul G. Wilson (Wilson 1998), was collected by Charles Stuart during the first extensive collections in New England in the 1850s for Ferdinand Mueller. Mueller (1875) also named *Eriostemon beckleri* F. Muell., based on a collection by Herman Beckler from the Clarence River catchment. In his revision of *Phebalium*, Wilson (1971) treated these taxa as conspecific, the view maintained when they were transferred to *Leionema* (Wilson 1998). In his treatment of *Leionema* for the 'Flora of Australia' project, Wilson (2013) referred all collections of *L. elatius*, except for those from Mount Lindesay, McPherson Range, on the Queensland–New South Wales border, to *L. elatius* subsp. *elatius*, and the Mount Lindesay population to *L. elatius* subsp. *beckleri* (F. Muell.) Paul G. Wilson.

During field work in 2006 on Roberts Range, west of Tenterfield on the north-western edge of the New England Tableland, a population of *Leionema elatius* had been found that was morphologically different from the common variant of more humid habitats to the east. The site lay c. 3 km to the north-east of 'Clifton', the homestead where Stuart was gardener at the time of his collection of the type of *Eriostemon elatior*.

Investigation of morphological variation in *L. elatius* was undertaken over the range of the species to test the current application of infraspecific nomenclature.

Materials and methods

The study is largely based on specimens held in the N.C.W. Beadle Herbarium (NE). Type specimens were viewed online at JSTOR Global Plants (<https://plants.jstor.org>; accessed 7 Oct 2020). Images of critical collections from Mount Lindesay and Mount Ernest that display variation in leaf morphology were provided by the Queensland Herbarium. Micromorphology of specimens at NE was examined using a Wild MZ8 stereomicroscope with a 1.0× Leica planapo lens and Leica LED light source.

In the taxonomy of Australian Rutaceae, a morphological or phenetic species concept has generally been applied, with species defined by suites of covarying attributes (Stuessy 1990). The rank of subspecies is often conferred on a group of populations within a species that “show slight and often intergrading morphological differences as well as some geographic, ecological, and/or phylogenetic distinctions” (Simpson 2010: 660). Standardisation of the application of rank in closely related genera in Rutaceae tribe Boronieae, particularly the use of subspecies, was initiated by Forster (2013a, 2013b). In assessing the application of rank in *Leionema elatius sens. lat.*, the same criteria for defining rank are followed here, and we use morphology to identify discontinuities that indicate species’ boundaries, consistent with the unified species concept (De Queiroz 2007).

Distributional data for the taxa are recorded in bioregions following the Department of the Environment (2013) *Australia’s bioregions (IBRA)*, IBRA7, Commonwealth of Australia (<http://www.environment.gov.au/land/nrs/science/ibra#ibra>; accessed 20 July 2019) to convey biogeographical information. Whereas, in the citation of specimens, botanical or pastoral districts in use by the relevant herbaria are used to facilitate curation.

Assessment of the conservation status of species involved the IUCN Standards and Petitions Subcommittee (2019) Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. <http://www.iucnredlist.org/documents/RedListGuidelines.pdf> (accessed 10 Sep 2020).

Results and Discussion

Leionema elatius subsp. *elatius*, *L. elatius* subsp. *beckleri* (Wilson 1998) and the morphologically similar and newly described *L. praetermissum* P.R.Alvarez & Duretto (Alvarez and Duretto 2019) can be unambiguously distinguished on the basis of stem, leaf, flower, fruit and seed characters. Vegetative features alone allow effective separation of the three taxa: verrucose stems and petioles appressed to the stem in *L. elatius* subsp. *elatius* and *L. praetermissum*, while *L. elatius* subsp. *beckleri* has stems that are not verrucose and petioles that are spreading from the stem. Each of the taxa has distinctive leaf apices: obtuse to rounded in *L. elatius* subsp. *elatius*, emarginate in *L. elatius* subsp. *beckleri*, and acute in *L. praetermissum*. We also report novel, diagnostic characters for the three taxa: presence versus absence and form (when present) of a tuft of stellate hairs at the apex of the leaf midrib (Table 1). Figure 1 allows comparison of the two currently recognised subspecies of *Leionema elatius*. The weight of morphological differences, geographic separation and lack of intermediates indicate that *Leionema elatius* subsp. *beckleri* should be reinstated to the rank of species.

Images of collections from Mount Lindesay that were regarded by Wilson (2013) as the only extant *Leionema elatius* subsp. *beckleri*, and a specimen from the neighbouring Mount Ernest, allowed comparison with the type. Leaves exhibited by these McPherson Range collections were ovate, 4–15 mm long. Similar small-leaved specimens have been collected from several exposed, higher altitude sites on the Northern Tablelands escarpment in New South Wales including Hamburger Rock, Guy Fawkes River National Park, and Paradise Rocks, Oxley Wild Rivers National Park. Such foliar morphology is consistent with Beckler’s type collection. There appears to be clinal variation with reduction in leaf size, plant stature and inflorescence complexity with increasing exposure.

The presence of intergrading forms (Stebbins 1950) and grouping of populations with distinct regional facies (Stace 1989) are important criteria for the use of the rank of subspecies. We have seen specimens from across the geographical and ecological range of *L. elatius sens. lat.*, with some gatherings displaying considerable variation in leaf size—including the type of *L. beckleri*—but we have not seen specimens that would reasonably be interpreted as intermediate between *L. elatius* and *L. beckleri*.

In the protologue of the *L. praetermissum* P.R.Alvarez & Duretto (Alvarez and Duretto 2019), the authors suggested *L. elatius* as the probable closest relative. From Table 1, it is apparent that *L. praetermissum*, *L. elatius sens. str.* and *L. beckleri* are morphologically very similar. A comprehensive molecular phylogeny of the genus, including these species, is needed to test hypotheses based on morphological similarity.

Table 1. Comparison of selected morphological attributes of *Leonema elatius* subsp. *elatius*, *L. elatius* subsp. *beckleri* and *L. praetermissum*.

Character	<i>L. elatius</i>	<i>L. beckleri</i>	<i>L. praetermissum</i>
Stem surface	verrucose	not verrucose	verrucose
Stem indumentum	dense minute stellate and simple hairs	dense minute stellate hairs	sparse minute stellate and simple hairs
Petiole orientation	appressed to stem	spreading	±appressed to stem
Leaf width (mm)	2–3(–4)	3–11.5	2–3
Leaf apex	obtuse–rounded	emarginate	acute
Leaf midrib apex	with a tuft of short, stout stellate hairs	with a tuft of long stellate hairs	glabrous (epidermals colliculate)
Petal orientation	slightly incurved	reflexed, the apex incurved	±slightly incurved
Coccus length (mm)	3.5–3.7	2.8–3.2	3–4
Seed length (mm)	2.8–3.2	1.8–2.3	c. 3

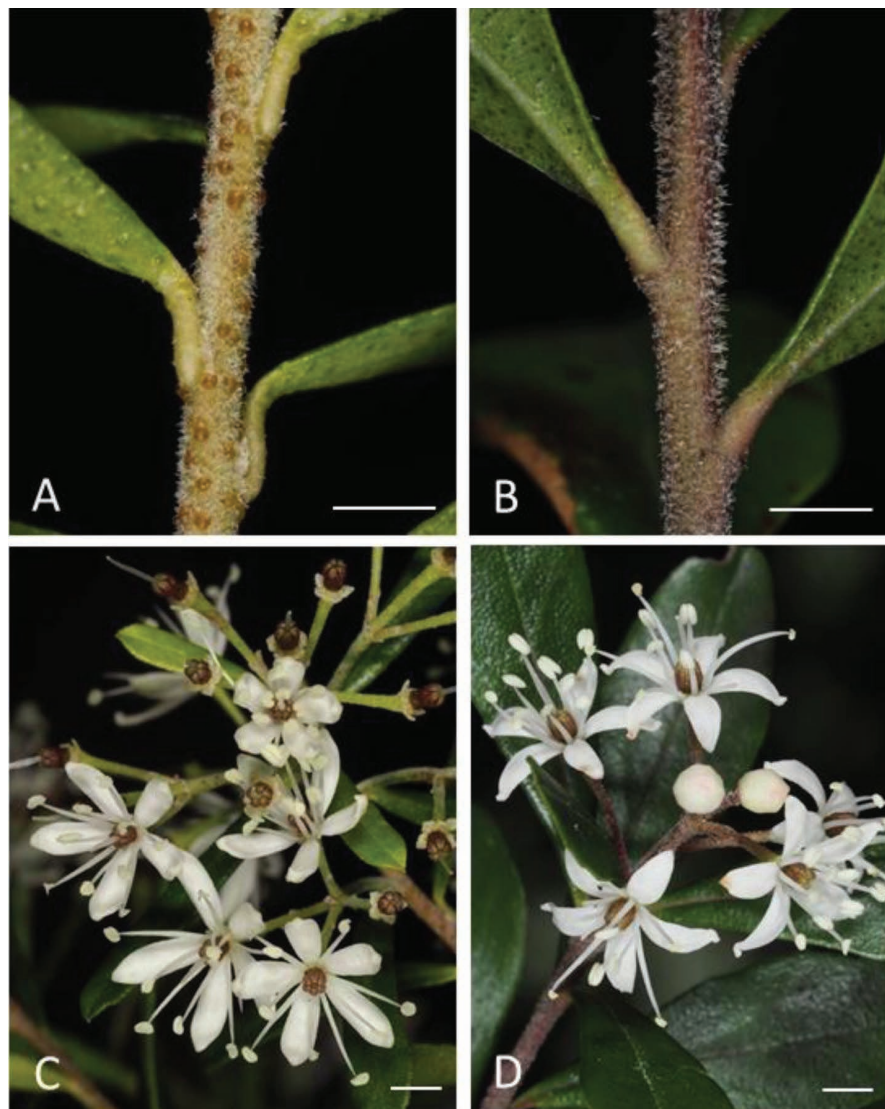


Fig. 1. Branchlets and flowers of *Leonema elatius* and *L. beckleri*. **A, C** *L. elatius* (from Telford 13518 & Rose); **B, D** *L. beckleri* (from Telford 13529). Scale bars=2 mm. Images by J.J. Bruhl.

Taxonomy

Leionema elatius (F.Muell.) Paul G.Wilson, *Nuytsia* 12: 273 (1998)

Basionym: *Eriostemon elatior* F.Muell. *Fragmenta phytographiae australiae* 1(8): 181 (1859)

Phebalium elatius (F.Muell.) Benth. *Flora australiensis* 1: 340 (1863).

Type citation: “In tractu elato New England prope Tenterfield. C.St.”

Type: New South Wales: New England, C. Stuart 153; lectotype (here corrected from holotype): MEL 4700 (image seen); probable isolectotypes: K (K 000717345, K 000717346 [excluding fruiting specimen, which we treat as a residual syntype], MEL (MEL 4698) (images seen).

Shrub to 3.5 m. *Branchlets* with dense minute stellate and simple hairs, conspicuously verrucose with brown oil glands. *Leaves* with petiole c. 1 mm long, appressed to stem; lamina narrowly elliptic or narrowly obovate, 4–18 mm long, 2–2.8 mm wide, base cuneate, apex rounded to obtuse, mucronate with a tuft of short, stout, stellate hairs, margins minutely crenulate towards apex, discolorous, adaxial surface shiny dark green, abaxial surface paler green, both surfaces punctate with oil glands. *Inflorescence* of 2–5-flowered umbels and solitary flowers in the upper leaf axils, the leaves subtending the umbels slightly reduced, the solitary flowers in the extreme upper axils subtended by elliptic bracts 1.5–3 mm long; peduncles 3.5–8 mm long, with minute white stellate and simple hairs and sparsely verrucose with brown oil glands; pedicels 3–4.4 mm long, with minute white stellate and simple hairs subtended by elliptic bracts 1.3–2 mm long; the solitary flowers with scapes 5–5.7 mm long bearing 2 elliptic bracteoles similar to the bracts subtending the pedicels of the umbels (probably indicating a reduced umbel). *Flowers* 5-merous. *Calyx* shallowly cup-shaped, 5-lobed; lobes broadly triangular, c. 0.5 mm long, ciliate with simple white hairs, abaxially sparsely verrucose. *Petals* free, ascending to spreading, narrowly elliptic, 3.7–4.3 mm long, 1.2–1.5 mm wide, slightly incurved, apex mucronate, incurved, margins incurved, white, green glandular punctate abaxially. *Stamens* 10, opposite and alternating with the petals, slightly spreading; filaments terete, 4–5.2 mm long, glabrous; anthers elliptic, 0.6–0.8 mm long, white. *Disc* cylindroidal, c. 1 mm long, 0.7 mm diam., red–purple. *Ovary* subglobose, 0.8–1 mm long, c. 0.8 mm diam., red–purple, 5-locular, the locules erect, mostly free, fused at their bases, minutely glandular punctate; style terete, 3.5–3.7 mm long, white; stigma scarcely enlarged, green. *Fruit* of up to 5 spreading cocci; coccus ± ellipsoidal, 3.5–3.7 mm long, 2–2.2 mm wide, sometimes with an apical lateral obtuse beak c. 0.3 mm long, green with brown punctate oil glands. *Seeds* compressed ellipsoid–obovoid, 2.8–3.2 mm long, ± smooth, black; elaiosome c. 1 mm long, white.

Distribution: *Leionema elatius* is known from a single extant population in the New England Tableland Bioregion (Department of the Environment 2013) on the Donnybrook Plateau, Roberts Range, c. 30 km WNW of Tenterfield, New South Wales. This site is c. 3 km from where Charles Stuart lived and worked. The only known gatherings of this species are Stuart’s and ours. Whether they were one and the same site is unknown, but if not, they are most likely from the same range.

Habitat: the only known population occurs in a rocky gully at 1000 m altitude where the species grows in *Eucalyptus scoparia* shrubby woodland with *Bertya cunninghamii* subsp. *rupicola*, *Allocasuarina littoralis* and *Prostanthera* sp. Bald Mountain (M.S. Clemens AQ336575) on metasediments.

Specimens examined: AUSTRALIA: New South Wales: Northern Tablelands: New England, *leg. ign.* [probably C. Stuart] (NSW 69930); Roberts Range, c. 27 km WNW of Tenterfield, c. 5.8 km SW of Donnybrook trig, 20 Dec 2006, Telford 13131, Bruhl, Badham & Caldwell (BRI, CANB, NE, NSW); *ibid.*, Oct 2012, Sadgrove 305 & Telford (MEL, NE, NSW); CULTIVATED: Armidale, N.S.W. ex Roberts Range, c. 27 km WNW of Tenterfield, 20 Sep 2017, Telford 13518 & Rose (BRI, CANB, CHR, MEL, NE, NSW).

Phenology: flowering September. Fruit collected December.

Conservation Status: *Leionema elatius* is currently known from a single population of three mature individuals (pers. obs.). Since Stuart’s type collection in the 1850s, only two additional specimens, both in fruit, have been made until our rediscovery in 2006. One specimen is at Kew and was made by Stuart (see above), and there is a second at NSW, formally from Mueller’s Herbarium at MEL, that was collected from New England but has no collector or date information. This collection was likely made by Charles Stuart from the same population as the earlier flowering type material and may be a duplicate of the residual syntype material at Kew. As discussed above, the type locality was probably close to this site, making the species extremely restricted. No collections from the wild other than the type collections and Telford 13131 and Sadgrove 305 are known. We cautiously suggest that the species meets the criteria for listing as “Critically Endangered” (IUCN 2019). We do not know whether the population has been diminished by recent drought or whether it has been subjected to fire since 2006. Clearly, anthropogenic climate change is a threat to the species. The population lies on freehold property

adjacent to Donnybrook State Forest and the species is not known to be represented in any conservation reserve. Searches should be conducted in similar habitats along Roberts Range and in the nearby Sundown National Park, Queensland, as a matter of priority.

Lectotypification: Two sheets made of collections by C. Stuart are held in MEL. One sheet (MEL 4700) with one branch has Stuart's field tag attached with "Phebalium ? 153 6–8 ft Mts 1000 ft" and another label with "Eriostemon elatior F von Mueller New England C. St." in Mueller's handwriting. This sheet was annotated as "holotype" by P.G. Wilson, 7 May 1965. Here we correct the status of 'holotype' to 'lectotype' according to the Code, Art. 9.10 (https://www.iapt-taxon.org/nomen/pages/main/art_9.html). A second sheet (MEL 4698) with two branches has a possible field tag with "153 *Phebalium elatior* F.M." and a label in Mueller's handwriting with "*Eriostemon elatior* F. M. New England C. St.". This sheet was annotated as "isotype" by P.G. Wilson, 7 May 1965, which we correct to isolectotype. One sheet with two accession numbers and three separate sprigs is held in K. K000717345 has a single flowering sprig demarcated by pencil lines on the sheet. K000717346 has one flowering and one fruiting sprig. It appears that the two flowering sprigs are likely one gathering, and duplicates of the C. Stuart collection held at MEL and discussed above, and the fruiting sprig represents a later collection.

Leionema beckleri (F.Muell.) I.Telford & J.J.Bruhl **comb. et stat. nov.**

Basionym: *Eriostemon beckleri* F.Muell., *Fragm.* 9: 109 (1875)

Phebalium beckleri (F.Muell.) Engl. in Engl. & Prantl (eds) *Nat. Pflanzenfam.* III 4: 141 (1896)

Phebalium elatius subsp. *beckleri* (F.Muell.) Paul G. Wilson *Nuytsia* 1: 106 (1970)

Leionema elatius subsp. *beckleri* (F.Muell.) Paul G. Wilson, *Nuytsia* 12: 273 (1998)

Type citation: "Prope origineni fluminis Clarence-River, *H. Beckler*".

Type: New South Wales: McLennans Creek, Clarence River, *H. Beckler*; lecto (here designated): MEL 4589 (image seen); isolecto: NSW 69929 *n.v.*

Shrub to 3.5 m. *Branchlets* densely white stellate hairy, raised oil glands absent. *Leaves* with petiole 1.5–3.5 mm long, spreading; lamina spatulate, narrowly obovate or obovate, (4–)15–40 mm long, 3–11.5 mm wide, base cuneate, distally crenulated; emarginate, rarely rounded with a tuft of long, stellate hairs at tip of midrib, discolorous, adaxial surface shiny dark green, abaxial surface paler green, both surfaces punctate with oil glands. *Inflorescence* terminal, of 6–14-flowered simple or compound umbels in the upper axils, the subtending leaves becoming reduced; peduncles 4–15 mm long with white stellate hairs; pedicels 2.3–4.5 mm long with white stellate hairs. *Flowers* 5-merous. *Calyx* shallowly cup-shaped, 5-lobed; lobes broadly triangular, c. 0.5 mm long, ciliate with simple white hairs, abaxially sparsely verrucose. *Petals* free, spreading to reflexed, narrowly elliptic, 3.5–4.3 mm long, c. 1.2 mm wide, plane, with an incurved apiculate apex, white to cream, green glandular punctate abaxially. *Stamens* 10, opposite and alternating with the petals, slightly spreading; filaments terete, 3.8–5.2 mm long, white; anthers elliptic, 0.6–0.8 mm long, white. Disc cylindrical, c. 0.7 mm long, c. 0.7 mm diam, reddish. *Ovary* subglobose, 0.8–1 mm long, c. 0.8 mm diam., pale green or tinged red, 5-locular, the locules erect, mostly free, fused at their bases, minutely glandular punctate; style terete, 2.5–2.8 mm long, white; stigma scarcely enlarged, green. *Fruit* of up to 5 spreading cocci; coccus compressed spherical, 2.8–3.2 mm long 2.6–3 mm wide, with an apical lateral acute beak c. 1 mm long. *Seeds* compressed ellipsoid-obovoid, 1.8–2.3 mm long, ±smooth, black; elaiosome c. 1 mm long, white.

Distribution: *Leionema beckleri* occurs in the SE Queensland, NSW North Coast and New England Tablelands Bioregions (Department of the Environment 2013) from the McPherson Range, Queensland, southwards along and to the east of the Northern Tablelands escarpment to near Bulahdelah, New South Wales.

Habitat: the species grows in a variety of vegetation communities including shrubby open forest with *Eucalyptus campanulata*, *E. oreades* or *E. pilularis* dominant, often adjacent to rain forest, and in shrub communities with *Leptospermum* spp. on the more exposed sites on a variety of substrates including basalt, acid volcanics, granite and metasediments at 300–1150 m altitude.

Selected specimens examined: AUSTRALIA: Queensland: Moreton District: McPherson Range, Binna Burra–Coomera Falls track, c. 5 km from Binna Burra, 3 Sep 1973, *Telford 3340* (CBG); Springbrook, Canyon Lookout, 23 Jul 2003, *Dare 134* (BRI, CANB, NE); summit of Mount Lindesay, 10 Oct 1932, *Stewart* (BRI image seen); Mount Lindesay, base of cliff lines, 26 Oct 1992, *Forster PIF12173* & *Leiper* (BRI image seen, MEL *n.v.*); 1.5 km WSW of Mount Ernest, 7 Aug 1999, *Halford Q3826* (BRI image seen). New South Wales: Northern Tablelands: Paradise Rocks, 300 m NE of trig point, on ridge, Oxley Wild Rivers National Park, 10 Nov 2015, *Duretto 4030* & *Collins* (CANB *n.v.*, NE, NSW *n.v.*); Oxley Wild Rivers National Park, 1.2 km ESE of "The

Rocks, 1.5 km NE of Green Gully, 31 Jan 2007, *Copeland 4163 & Thomas* (BRI *n.v.*, CANB *n.v.*, NE, NSW *n.v.*). North Coast: Minyon Falls, at lookout, Nightcap National Park, 25 Oct 2005, *Johnstone 1577* (K *n.v.*, NE, NSW *n.v.*); Nymboi–Binderay National Park, Nymboida River, Cod Hole, 9 Sep 2006, *Telford 12940 & Bruhl* (BRI, CANB, CHR, EIU, HO, MO, NSW, PERTH); Guy Fawkes River National Park, Hamburger Rock, Chaelundi Road, 23 Sep 1995, *Metcalf NE105237* (BRI *n.v.*, CANB *n.v.*, MEL *n.v.*, NE, NSW *n.v.*); Coorabakh National Park, Big Nellie Road, c. 20 km NW of Cooperbrook, 29 Aug 2000, *Bruhl 1908*, *Telford & Fatemi*, 29 Aug 2000 (MEL, NE, NSW); Tapin Tops National Park, Rowleys Rock Lookout, 10 May 2014, *Telford 13453 & Bruhl* (BRI, NE, NSW); Barrington Tops National Park, Gloucester Tops, Gloucester Falls, 30 Dec 2017, *Telford 13527* (BRI, CANB, MEL, MO, NE, NSW).

Phenology: Flowering May–September; fruit collected October–January.

Conservation Status: *Leionema beckleri* is widespread and common and considered to be of “Least Concern”. Conserved in Queensland in Lamington, Springbrook and Mount Barney National Parks, and in New South Wales in Border Ranges, Nightcap, Washpool, Nymboi-Binderay, Guy Fawkes River, Dorrigo, New England, Werrikimbe, Oxley Wild Rivers, Tapin Tops, Coorabakh and Barrington Tops National Parks.

Notes: The herbarium label of the sheet designated as lectotype above, MEL 4589, has “McLennans Creek, Clarence River” in Mueller’s handwriting.

Plants show considerable variation in leaf morphology, apparently related to habitat. Collections from more exposed sites including Mount Lindesay, McPherson Range, on the Queensland – New South Wales border, adjacent Mount Ernest, and Hamburger Rock and Paradise Rocks on the eastern escarpment of the New England Tableland of New South Wales exhibit a reduced stature and smaller leaves (4–15 mm long) than most collections from over the range of the taxon (to 40 mm long). Some small-leaved specimens have been identified as *Leionema elatius* subsp. *elatius*.

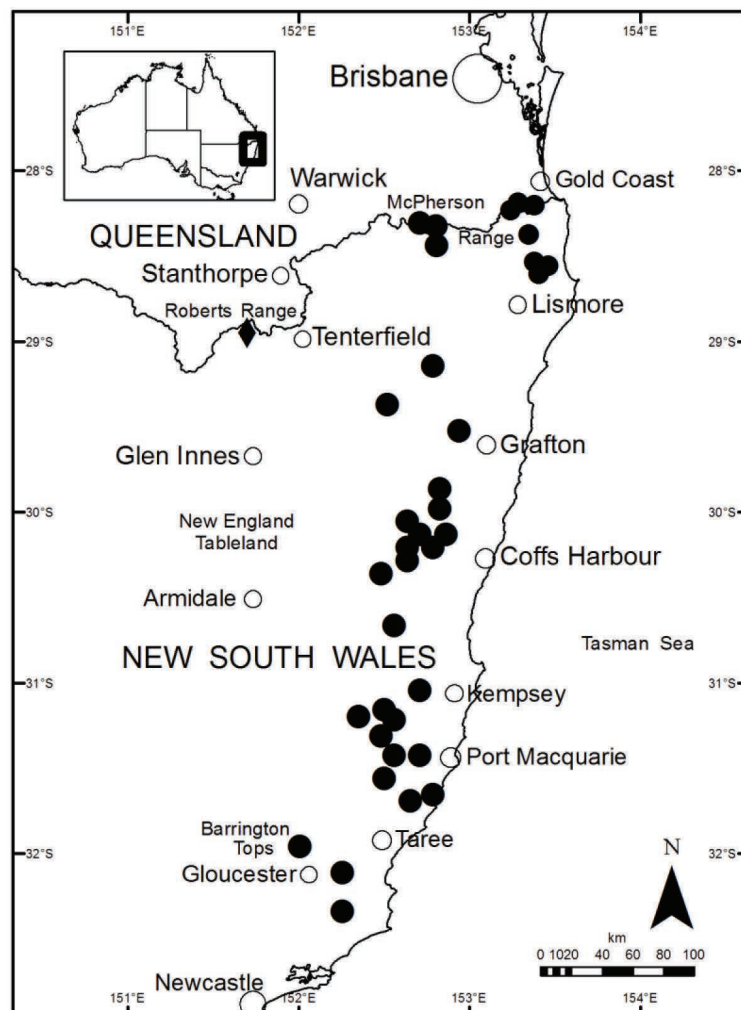


Fig. 2. Distributions of *Leionema elatius* ♦; *L. beckleri* •, based on Australasian Virtual Herbarium data (avh.chah.org.au; accessed 2 Oct. 2020)

Modification to the key to species of *Leionema* found in New South Wales and south-eastern Queensland, adapted from Alvarez and Duretto (2019)

17 Leaves >13 mm long 18
 17: Leaves <13 mm long 20
 18 Leaves 3–11.5 mm wide *Leionema beckleri*
 18: Leaves 2–3(–4) mm wide 19
 19 Stems densely hairy; leaf apex obtuse–rounded *Leionema elatius*
 19: Stems sparsely hairy; leaf apex acute *Leionema praetermissum*
 20 Stems pilose *Leionema gracile*
 20: Stems with stellate hairs 21
 21 Stems verrucose; leaves 2–4 mm wide *Leionema lamprophyllum*
 21: Stems not verrucose; leaves 4–6 mm wide 22
 22: Leaves distally crenulated; apex of midrib with a tuft of stellate hairs *Leionema beckleri*
 22: Leaves distally rounded; apex of midrib glabrous *Leionema rotundifolium*

Acknowledgements

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