Volume 23: 73–87
Publication date: 25 May 2020
dx.doi.org/10.7751/telopea14104

TELOPEA
Journal of Plant Systematics

The Royal Botanic Gardens & Domain Trust

plantnet.rbgsyd.nsw.gov.au/Telopea • escholarship.usyd.edu.au/journals/index.php/TEL • ISSN 0312-9764 (Print) • ISSN 2200-4025 (Online)

Eucalyptus calidissima (Myrtaceae), a new ironbark species from the Hunter Valley of New South Wales, Australia

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Abstract

Eucalyptus calidissima (Myrtaceae), a new and highly restricted ironbark species from the Hunter Valley of New South Wales is described and illustrated. The new species had previously been included in *E. nubilis* Maiden & Blakely (syn. *Eucalyptus nubila* L.A.S.Johnson, orth. var.), but differs in the ribbed hypanthium, hemispherical to bluntly-conical calyptra which is shorter than the hypanthium, and the slightly larger, globular or occasionally obconical, ribbed fruit. At present, *E. calidissima* is known only from a single population occurring across *c*. 200 ha and is considered rare, but it is not under immediate threat. Amendments to relevant sections of the New South Wales and Australian identification keys are provided.

Introduction

Vegetation surveys undertaken across parts of the Broken Back Range near Pokolbin in the Hunter Valley of New South Wales over recent decades have struggled to satisfactorily place a population of broad-leaved ironbarks with glaucous branchlets and buds within currently circumscribed species (described herein as *Eucalyptus calidissima*). Initial collections made by Ian Brooker in the 1970s (AD 97642512, MEL 1611550A) were considered by him to represent *Eucalyptus nubilis* Maiden & Blakely [*E. nubila* L.A.S.Johnson, *orth. var.*; *Eucalyptus fibrosa* subsp. *nubilis* (Maiden & Blakely) L.A.S.Johnson; *Eucalyptus fibrosa* subsp. *nubila* L.A.S.Johnson, *orth. var.*], albeit well outside of its known geographical range. One further replicate from this same gathering in 1976 (NSW 307956) is attributed to *E. nubila* x *sideroxylon*. During the mid-1980s, an unpublished manuscript by the late Terry Tame (detailing his field observations within the Hunter Valley during the early 1970s and 80s; Tame 1984), records the grey-green leaved *E. nubilis* for Manobalai Nature Reserve and the Wybong area (*c*. 110 km north-west of Pokolbin), and near Ulan (*c*. 200 km north-west of Pokolbin). Additionally, hand drawn distribution maps associated with that work (provided by T. Tame to the first author in *c*. 2006) show this taxon tentatively marked for a location near Pokolbin, with the note "(*E. nubila* x *sideroxylon*)" inscribed adjacent. It is possible that this annotation refers to the population (probably also represented by NSW 307956) which is the focus of this paper, although some uncertainty in the identity of eucalypts at this Pokolbin location may be inferred. There are no further indications in Tame (1984) exactly where it was that he recorded these possible hybrid plants, and the associated map is too coarse to provide clarification. However, given the putative parents nominated by Tame (*E. nubilis* and *E. sideroxylon*), it is assumed that what he recorded was the new species described in this paper. Three specimens from this same

area later lodged at NSW by Tame in 1999 and identified by him as *E. nubilis* (NSW 437310, NSW 437313, NSW 437315) places it well within the population described here and corroborates this explanation.

Sixteen years after the initial collections of Brooker, Tunstall *et al.* (1992) were the next to encounter and voucher *E. calidissima* during surveys of the Commonwealth-owned Singleton Training Area (STA). In the absence of any other alternative they attributed trees growing in the southern sections of the STA affronting the Broken Back Range to *E. nubilis*. A specimen lodged by Isobel Crawford and Joan Graham from this area (CANB 418772.1, November 1991), and determined by Brooker as *E. nubilis*, came out of that survey and supports this view. Tunstall *et al.* (1992) noted that the occurrence of *E. nubilis* at this location represented the extreme south-eastern limit of this otherwise more western taxon, and that the closely related *E. fibrosa* (syn. *E. fibrosa* F.Muell. subsp. *fibrosa*) was more prevalent across the site. Later, Thomas (1998) and Bell (2001) also referred these trees to *E. nubilis*, yet recognised the disjunct nature of this population, cognisant of the considerable distance (> 200 km) between these plants and the bulk of the species distribution west and north from Dunedoo. Targeted threatened species surveys across the STA by Hunter (2005) later revealed important new information on threatened taxa, including other eucalypt species (summarised in Copeland and Hunter 2005), noting the presence of *E. nubilis* but providing no comment on its significance. Most recently, Klaphake (2010) and Bell and Carty (2012) have recognised the STA population of ironbarks as potentially representing a new taxon of restricted distribution, given morphological differences between specimens occurring there and typical *E. nubilis*, and the disjunct nature of the stand in a region otherwise dominated by *E. fibrosa* and *E. crebra*, both members of *E.* ser. *Siderophloiae*.

Elsewhere in the Hunter region several other collections of *E. nubilis* were made between 1960 and 1990. These include two collections gathered in 1968 (MEL 1611551A; CANB 445515.1) and 1976 (NSW 307948; MEL 1611549A; CANB 445543.1; AD 97647168) from the Gungal district (c. 100 km north-west of Pokolbin), one in 1974 (AD 97639088) from near Singleton (c. 20 km north-north-west of Pokolbin), and one in 1985 (NSW 205289-91; CANB 449914.1; MEL 2294720A) from Towarri National Park (c. 100 km north-north-west of Pokolbin). The 1974 collection from near Singleton was later re-determined by Brooker as *E. fibrosa*, but for all others field inspections were made by us in September 2018 to verify their identities. These showed *E. nubilis* to dominate the upper slopes of sandstone hills, with trees possessing the characteristic ironbark trunk, grey-green to bluish leaves, glaucous buds with conical calyptras, and rounded fruit with strongly exserted valves.

A further possible collection of *E. calidissima*, tentatively identified at the time as *E. nubilis* (CANB 474433.1), was made from Milbrodale (c. 15 km west of Pokolbin) in 1991. Inspection of that location in October 2018 showed only open forest dominated by *Eucalyptus crebra* and *Callitris endlicheri*, with scattered individuals of *E. moluccana, E. punctata* and *E. fergusonii* subsp. *dorsiventralis*. Viewing of nearby slopes and hills from vantage points on this escarpment failed to detect any grey-green or bluish eucalypts, with only *Acacia bulgaensis* providing such colour tones. Notes accompanying the 1991 collection state '*bark tessellated halfway up trunk then smooth and cream. Light green buds with small brown caps; leaves with slight bluish tinge*'. These traits are consistent with field characteristics of *E. fracta* rather than *E. nubilis*, and the former species was in fact collected by the first author from this same escarpment approximately 5 km to the north-west in 2006 (NSW 862264). Viewing of a scanned image of the 1991 collection, showing buds but no fruit, is inconclusive but is suggestive of *E. fracta*. Given only a tentative determination was made of the 1991 collection by Brooker in 1998 (as '*Eucalyptus fibrosa*? subsp. *nubila*'), it is plausible for this specimen to represent *E. fracta*, a species only described in 1997, rather than *E. calidissima*.

Given the long and ongoing confusion over the identity of the grey-green and glaucous Pokolbin ironbarks, and their close affinity to the locally dominant yet apparently mutually exclusive *E. fibrosa*, resolution of this 40-year anomaly is required. Consequently, we have investigated this population by examination of numerous individuals in the field within its known range and compared these to other reported stands of *E. nubilis* from the Sydney Basin. Additionally, study of populations within the Goonoo State Conservation Area near Dubbo, the type locality for *E. nubilis*, have provided a framework within which the new species can be placed. We conclude that the Pokolbin population warrants recognition as a new species, described here as *E. calidissima*. Clear morphological differences in the buds and fruit, together with the disjunct distribution of the new species relative to the inland and more widely distributed *E. nubilis*, argue against its placement as a subspecies of the latter, as the two entities appear to comprise a topographical and geographical replacement pattern with *E. fibrosa* and another unnamed taxon (*E.* sp. '*Yarrawa*') (outlined in Discussion). Following Brooker & Slee (2000), the term 'glaucous' is used in this paper to refer to a fine whitish surface wax or bloom that is easily rubbed off (also known as 'pruinose'), rather than colour alone.

Taxonomy

Eucalyptus calidissima S.A.J.Bell ***sp. nov.***

Differs from *Eucalyptus nubilis* predominantly in the 4-ribbed hypanthium, the shorter, rounded to bluntly conical calyptra that is equal in length, or shorter than, the hypanthium, and the slightly larger, slightly to strongly ribbed, globular to slightly obconical fruit.

Type: Australia: New South Wales: North Coast: Pokolbin State Forest, off De Beyers Road, c. 4.2 km SW of Pokolbin, Hunter Valley (32°47'10"S 151°15'37"E), *S.A.J. Bell 5597*, 20 Oct 2018 (holo: NSW 1061184; iso: BRI, CANB, DMHN, K, MEL, NE, SYD).

Fig. 1. *Eucalyptus calidissima*; a, flowering and fruiting branch; b, adult leaf, adaxial (upper) surface; c, seed; d, juvenile leaf, adaxial (upper) surface; e-h, bud variation; i-m, fruit variation. Scale bar: a = 20 mm; b = 15 mm; c = 0.5 mm; d = 15 mm; e-m = 8 mm. Artwork: Chris Rockley (a-d, from isotype) and Van Klaphake (e-m, unvouchered specimens from within population at type locality).

Tree to 25 m tall. *Bark* built up in layers, thick, persistent to small branches (*c.* 4 cm diam.), grey, black or grey-brown, inner layers yellowish ('ironbark'), smallest branches smooth. *Branchlets* green with a strong glaucous covering. *Juvenile growth* (coppice) with stems terete or weakly square in cross section, strongly glaucous; *juvenile leaves* petiolate, opposite for several pairs then alternate, ovate, 8–11 cm long, 4.5–7 cm wide, slightly discolorous, grey-green and glaucous. *Adult leaves* alternate, *petiole* 2.5–3 cm long; *lamina* broadly-lanceolate to lanceolate or narrow-lanceolate, 9–20(–24) cm long, 1.5–3.5 cm wide, base tapering to petiole, concolorous, dull, strongly grey-green, sometimes glaucous, side-veins *c.* 45° to midrib, tertiary venation densely to very densely reticulate, *intramarginal vein* parallel to and *c.* 1 mm from margin. *Inflorescence* in terminal panicles, 7–11-flowered; *peduncles* terete to angled, 0.8–1.8 cm long; *buds* sessile or on *pedicels* to 0.5 cm long. *Mature buds* ovoid, moderately to strongly glaucous, 0.7–1.3 cm long, 0.3–0.6 cm wide, scar present; *hypanthia* angular, 4-ribbed; *calyptra* smooth, hemispherical to bluntly conical, as long as or shorter than hypanthium. *Flowers* white. *Fruit* sessile or on pedicels to 0.5 cm long, hemispherical or globular to occasionally obconical, 0.5–1.1 cm long, 0.7–0.9 cm wide, slightly to strongly ribbed longitudinally; *disc* narrow, level or sunken; *valves* 4, rarely 3 or 5, enclosed or slightly exserted. *Seeds* flattened-ovoid, brown, *c.* 2 mm long. Figs 1–3.

Additional specimens examined (scans viewed only): New South Wales: North Coast: Shoulder N end of Broken Back Range, WNW of Pokolbin, *M.I.H. Brooker 5153*, 28 Jun 1976 (AD 97642512, MEL 1611550A); Quarry 1.1 km at 22 degrees from Broken Back Trig., *I. Crawford & J. Graham 1472*, 28 Nov 1991 (CANB 418772.1); Foothills of the Broken Back Range, Pokolbin, *T.M. Tame 5840*, *5841a, 5841b*, 18 Apr 1999 (NSW 437313, NSW 437310, NSW 437315). Additionally, extensive unvouchered material collected independently by both authors from throughout the type population over several years has also been examined.

Illustrations: As *Eucalyptus* sp. Pokolbin, on page 96 of *Eucalypts of the Sydney Region* (Klaphake 2010) and page 77 of *Endemic Plants of the Hunter: Trees and Larger Shrubs* (Bell *et al.* 2019).

Fig. 2. Mature *Eucalyptus calidissima* trees, on moderately sloping foot slope of the Broken Back Range, showing grey-green canopy.

Fig. 3. *Eucalyptus calidissima* habitat, the new taxon dominating exposed upper slopes, Broken Back Range.

Distribution: Known only from the lower North Coast of New South Wales, near Pokolbin in the Hunter Valley (Fig. 4), where it occurs on the northern foot slopes of the Broken Back Range. Considerable survey effort has been expended in this part of the Hunter Valley since the mid-1990s, but no other stands of similar ironbarks have been reported. Surveys of Pokolbin State Forest (Binns 1996), Yengo National Park (Bell *et al.* 1993; NSW DECC 2008) and Wollemi National Park (Bell 1998; NSW OEH 2012) have failed to reveal additional populations. Further afield, no collections or observations have been reported for Goulburn River National Park (Hill 1999), Munghorn Gap Nature Reserve (Hill 1999; NSW DEC 2004), Manobalai Nature Reserve and adjacent crown lands (Bell 1997; Peake 1999), or the Myambat army base near Denman (Fallding *et al.* 1997; Jacobs 2014).

Flowering: Probably sporadic. Buds have been collected in April and August, and flowers have been observed in September.

Habitat: *Eucalyptus calidissima* is a community dominant on the steep eastern foot slopes of the northern face of the Broken Back Range. The geology in this area and elsewhere along the southern rim of the Hunter Valley comprises the Wollombi Coal Measures of Permian age, where the lithology is organic rich rocks including coal seams, tuffaceous claystones, siltstones, sandstones and conglomerate (Glen and Beckett 1993). Much of the surface rock in the area supporting *E. calidissima* is highly fossilised, and other eucalypts of restricted distribution occur in this same general area (*E. castrensis,* Hill and Stanberg 2002; *E. fracta,* Hill 1997; *E. pumila*, Cambage 1919). This same geological type also outcrops further north-west along the southern rim of the Hunter Valley and extends an additional 60 km to the Yarrawa locality near Denman. Triassic Narrabeen sandstones occur immediately above these Permian slopes, often forming near-vertical cliff lines. Associated species within *Eucalyptus calidissima* habitat include *Corymbia maculata, Acacia amblygona, A. elongata, Pultenaea spinosa, Dillwynia sieberi, Dianella revoluta, Rytidosperma pallidum* and *Entolasia stricta*. At lower elevations in this area, the related *E. fibrosa* replaces *E. calidissima*, with no apparent intergradation. Further afield (<2 km distant), *Eucalyptus crebra* dominates the landscape with *C. maculata* and occasional individuals of *E. crebra* can also be found within habitat dominated by *E. calidissima*. Figures 2 and 3 show views of habitat on these talus slopes.

Ecology: *Eucalyptus calidissima* forms part of a distinctive topo-sequence with other more-or-less mutually exclusive eucalypts that is replicated across several locations along the eastern end of the Broken Back Range. Between approximately 170 and 320 m above sea level, *E. calidissima* occupies a distinct band along the mid-slopes where it dominates the canopy. At lower elevations, the species is progressively replaced firstly by *E. fibrosa*, where there is no evidence of inter-breeding, and then by *E. crebra* and *E. moluccana* on the valley floor.

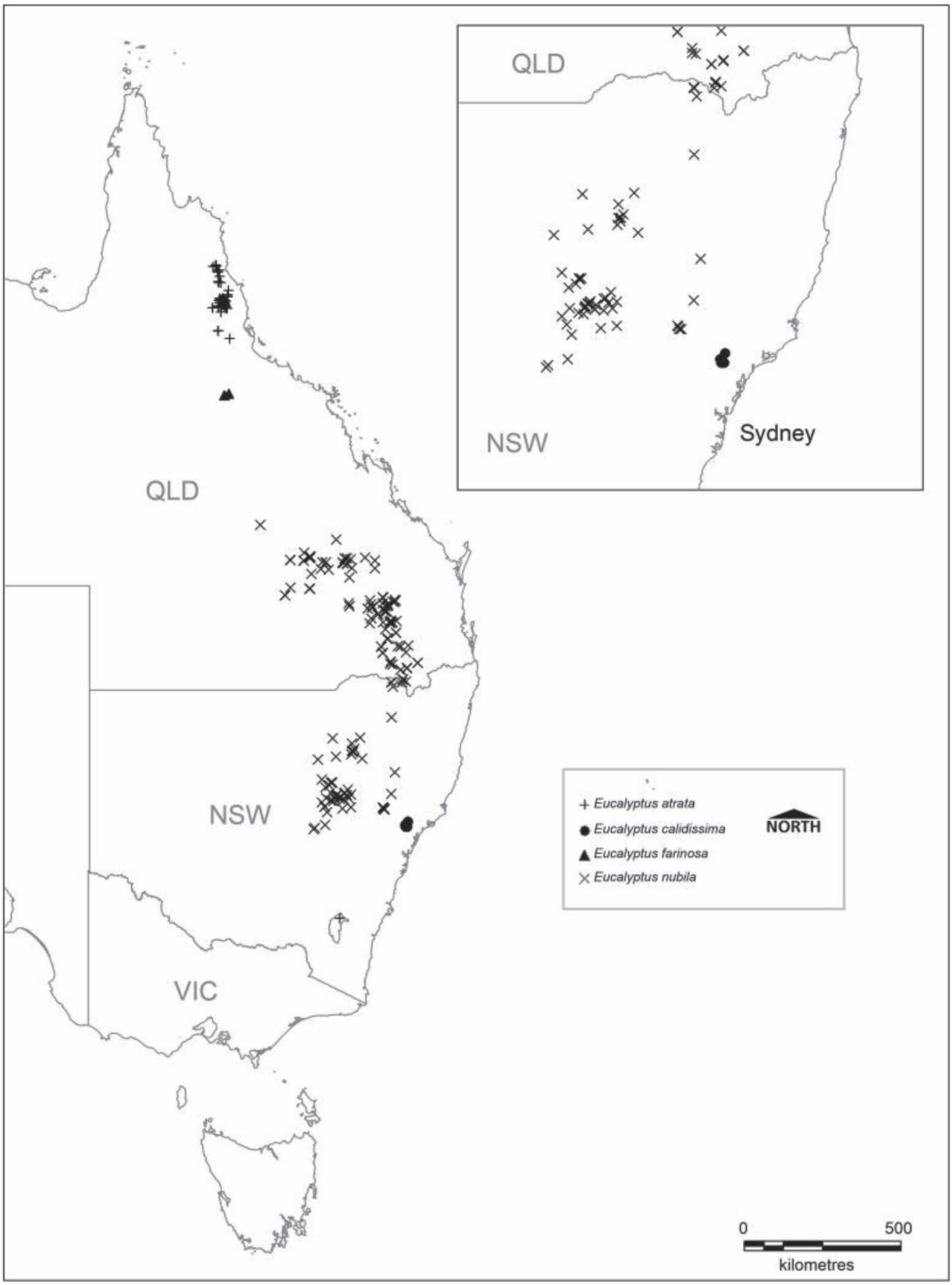

Fig. 4. Distribution of *Eucalyptus calidissima* and morphologically similar species in eastern Australia. Inset: magnified view of NSW collections. Source: AVH (accessed 23 August 2018, duplicate and dubious records removed).

At higher elevations, *E. calidissima* is replaced by low woodland of *Corymbia eximia* and *E. squamosa*, which then gives way to open forest of *E. fergusonii* subsp. *dorsiventralis, E. punctata* and *E. sparsifolia* prior to the rugged cliffs of the Broken Back escarpment. This sequence of eucalypt replacement provides strong patterning to the landscape in this area.

Population size: Approximately 200 ha of habitat occupied by *E. calidissima* occurs at Pokolbin. Given observations that two to three mature individuals of *E. calidissima* were present within 0.04 ha sample plots, an estimated population size in the range of 10 000 to 15 000 individuals has been calculated for the species.

Conservation status: *Eucalyptus calidissima* is known from a single population which is currently not under threat. Much of the population occurs within the STA managed by the Commonwealth Department of Defence, together with adjacent lands in the Pokolbin Flora Reserve, Pokolbin State Forest and small areas of private property. Following Briggs and Leigh (1996), a conservation risk code of 2RC is here proposed, recognising the restricted distribution of the species (<100 km), and the number of plants (<1000) present within Pokolbin Flora Reserve.

Using the Geospatial Conservation Assessment Tool (GeoCAT: http://geocat.kew.org), an Extent of Occurrence (EOO) of 3.710 km^2 and Area of Occupancy (AOO) of 20 km^2 has been calculated. As recommended by IUCN (2017), for situations where EOO is smaller than AOO the metric for EOO is altered to that of AOO (i.e. EOO is also 20 km^2) to ensure consistency with the definition that AOO is an area within EOO.

Under IUCN (2017) guidelines, *E. calidissima* does not qualify as Critically endangered, Endangered or Vulnerable, as on current information none of the five criteria can be met. There is no data available to determine if there has been a reduction in population size consistent with Criterion A, and indeed field observations suggest that populations are stable. The calculated EOO places it well within the threshold for Critically endangered (<100 km^2) under Criterion B, however only one of the three sub-criteria can be met (number of locations). The estimated minimum population size of *c.* 10 000 mature individuals arguably places it on the threshold of Criterion C (Vulnerable level only), but none of the relevant sub-criteria are met. Similarly, the minimum population size of *c.* 10 000 individuals excludes Criterion D from consideration for any threat level. Under this criterion, the AOO of 20 km^2 and number of locations (<5) suggests that Criterion D2 may be enacted, however despite the small and restricted population there is an absence of plausible threats that may '*drive the taxon to CR or EX in a very short time*'. No quantitative analysis of data has been undertaken, so Criterion E cannot apply. Additionally, the long lifespan of eucalypts and the clear absence of any significant threats argues against a determination of Near Threatened (IUCN 2017): the species is therefore considered rare (not an IUCN category) on the basis of its highly restricted distribution.

Etymology: The specific epithet is based on the Latin *calidus* (warm or hot) and *–issimus* (very) and is a reference to the wine growing locality of Pokolbin where this species occurs. The origin of the name 'Pokolbin' is uncertain, but is thought to be either from the native Darkinjung language meaning 'very hot place', or was a term used to describe the working conditions in the area by early Hungarian immigrants during the 1800s, which they referred to as being 'in the hell' (Geographical Names Board of New South Wales 2018). Either reference is applicable to the chosen epithet.

Common name: 'Pokolbin Ironbark' is suggested as a suitable common name for this taxon, as has been used in Klaphake (2010) and Bell *et al.* (2019).

Similar species: Within the Hunter region, *E. calidissima* has historically been confused with *E. nubilis* due to the glaucous branchlets, buds, and juvenile leaves; the grey-green adult leaves; and the general shape and size of the fruit. However, the buds of *E. nubilis* have non-ribbed hypanthia and conical and acute calyptra, in contrast to the 4-ribbed hypanthia and the hemispherical to bluntly conical calyptrae of *E. calidissima* (Fig. 5). Also, the fruit valves of *E. nubilis* are almost always strongly exserted while those of *E. calidissima* are sunken or only marginally exserted above rim level. *Eucalyptus fibrosa*, which occurs adjacent and sometimes within stands of *E. calidissima*, is also superficially similar but does not have grey-green leaves or glaucous branchlets, the juvenile leaves are generally considerably broader and more rounded, and the buds are green and have calyptra that are longer than the hypanthia (Fig. 6). An additional putative taxon currently under study, *E.* sp. 'Yarrawa' (*sensu* Klaphake 2010), occurs across northern Wollemi National Park and adjacent areas, but can be distinguished on the basis of its obconical rather than globular to hemispherical fruit (rarely obconical in *E. calidissima*) with a broad rather than narrow disc and strongly exserted valves, and the non-glaucous branchlets and buds. Some populations of *E.* sp. 'Yarrawa' have distinctly grey-green leaves (such as in the hills behind Bulga), but the branchlets and buds on these specimens are not glaucous and the fruit are always obconical with strongly exserted valves. The glaucous branchlets in *Eucalyptus calidissima* have been observed to persist until branches are at least 2 cm in diameter, assisting recognition of the species.

Fig. 5. Upper: *Eucalyptus calidissima* buds (fresh, showing variation in glaucous trait) and juvenile leaf (Pokolbin SF type location). Lower: *Eucalyptus nubilis* buds (dried) and juvenile leaf (Goonoo State Conservation Area, between Dubbo and Mendoran).

Fig. 6. *Eucalyptus fibrosa* buds (fresh), adult leaves and single juvenile leaf (Columbey National Park, Clarencetown).

The ribbed or winged hypanthia and fruits of *E. fergusonii* subsp. *dorsiventralis* may be confused with the buds and fruits of *E. calidissima*, particularly as this taxon occurs on the upper escarpment slopes of the Broken Back Range above *E. calidissima*. However, *E. fergusonii* subsp. *dorsiventralis* is part of *E.* ser. *Rhodoxyla*, and can be easily distinguished from *E. calidissima* by the longer, fusiform non-glaucous buds, flowers supporting staminodes, the long-pedicellate, barrel-shaped fruits (to 1.3 cm long, always longer than wide), the non-glaucous branchlets, the discolorous and green adult leaves, and the unlayered bark.

Given historical confusion and the superficial resemblance of *Eucalyptus calidissima* to *E. nubilis*, inspections of populations in the vicinity of the type location of *E. nubilis* have been undertaken to more confidently diagnose differences. The type for *E. nubilis* was collected from the 'Dubbo district' in November 1897 (NSW 129812), specifically on the Dubbo to Coonamble road (Bean 2009). Subsequent examination of a number of populations of *E. nubilis* in this area (particularly in Goonoo State Conservation Area) in November 2018 revealed plants with the distinctive blue-green foliage, and although no fresh reproductive material could be found, fallen buds displayed terete (non-ribbed) hypanthia with conical calyptra, consistent with the type description of *E. nubilis* (Maiden 1933). Fruit at all inspected locations had strongly exserted valves, although those at one stand along Old Mendoran Road were only slightly exserted. Neither Maiden (1933) nor more contemporary descriptions of *Eucalyptus nubilis* (e.g. Johnson 1962; Boland *et al.* 2006; Slee *et al.* 2015) document buds with ribbed hypanthia and hemispherical calyptra characteristic of *E. calidissima*.

Outside of New South Wales, *Eucalyptus calidissima* appears most similar to *E. farinosa* and *E. atrata*, both of which are trees of smaller stature (*c.* 12 m in height) from restricted distributions in north Queensland (Slee *et al.* 2015), more than 1500 km north of Pokolbin. The ovate to orbicular adult leaves of *E. farinosa* (Slee *et al.* 2015) distinguish that species from *E. calidissima*, which has broadly lanceolate to narrow-lanceolate leaves. Additionally, the barrel-shaped fruit of *E. farinosa* retain their glaucous covering (Slee *et al.* 2015) which is not evident in the globular fruit of *E. calidissima*, and both buds and fruit are more strongly 4-ribbed than *E. calidissima*. For those *E. calidissima* specimens lacking 4-ribbed buds, morphological features separating this species from *E. atrata* are more difficult to discern, as both support broadly similar juvenile and adult leaves which are comparable in colour and can be glaucous. However, as *E. atrata* is part of the 'hard-barked' *E. crebra* group of ironbarks, the thick layered bark of *E. calidissima* (of the 'slab-barked' *E. fibrosa* group, in which layers or slabs can be easily prized off: Fig. 7) can be used to differentiate the two. Individual trees of *E. calidissima* can also be considerably taller than *E. atrata* (up to 25 m cf. 12 m in *E. atrata*). The buds of *E. atrata* are also often slightly beaked or nippled (not observed in *E. calidissima*), while most specimens of *E. calidissima* examined in the field support some ribbing of the hypanthia (absent in *E. atrata*). Additionally, buds and fruit of *E. calidissima* are generally sessile or on pedicels to 5 mm long, while pedicels may be up to 7 mm long in *E. atrata* (Slee *et al.* 2015). A third glaucous species from northern Queensland (*E. whitei*) has smaller juvenile and adult leaves than *E. calidissima*, non-ribbed hypanthia often with an acute rather than rounded

calyptra, and barrel-shaped fruit. *Eucalyptus paedoglauca*, also from northern Queensland, bears similarities to *E. calidissima* in juvenile leaf and fruit morphology, but the glaucous trait on branchlets is short-lived and buds are non-glaucous (Slee *et al.* 2015).

Fig. 7. Bark of *Eucalyptus calidissima*, showing layered grey-black outer bark (partly artificially removed revealing yellowish inner-bark).

A diagnostic key to *E. calidissima* and morphologically similar species of ironbarks within Australia is presented below, modified from Nicolle (2016) and commencing at lead 14 in that work. New entries accommodating *E. calidissima* have been inserted as 19a and 33a, reflecting stands exhibiting the common 4-ribbed buds and smooth buds respectively. For New South Wales, a slight modification to the digital *Flora of New South Wales* key (http://plantnet.rbgsyd.nsw.gov.au/floraonline.htm) from lead 18 will sufficiently diagnose *E. calidissima*. The addition of couplets here designated 19a (for specimens with slightly exserted valves) and 22a (valves not distinctly exserted) will lead to *E. calidissima*.

Partial Key to *Eucalyptus* ser. *Siderophloiae* and ser. *Rhodoxyla* (adapted from Nicolle 2016)

14. Trunk bark rough, hard and deeply fissured (ironbark)
    15. Crown composed mostly or entirely of sessile juvenile leaves
        16. Fruits 3–7 mm long; crown leaves 20–50 mm wide ..... ***E. melanophloia***
        16: Fruits 6–10 mm long; crown leaves 30–100 mm wide ..... ***E. shirleyi***
    15: Crown composed mostly or entirely of petiolate adult leaves
        17. Buds and fruits 4-ribbed and square in cross section
            18. Branchlets, buds and immature fruits pruinose (glaucous)
                19. Pedicels >6 mm long ..... ***E. caleyi***
                19: Pedicels <6 mm long

19a. Adult leaves ovate to orbicular, 6-10 cm long, 3-6 cm wide ..... ***E. farinosa***

19a: Adult leaves broad- to narrow-lanceolate, 9–24 cm long, 1.5–3.5 cm wide ..... ***E. calidissima***

18: Branchlets, buds and immature fruits not pruinose (glaucous)

20. Pedicels <7.5 mm long; Qld ..... ***E. quadricostata***

20: Pedicels >7.5 mm long; NSW ..... ***E. tetrapleura***

17: Buds and fruits smooth, terete in cross section

21. Opercula elongated, longer than hypanthia

22. Buds and fruits not pruinose (glaucous) ..... ***E. fibrosa***

22: Buds and/or fruits pruinose (glaucous) ..... ***E. nubilis***

21: Opercula equal to or shorter than hypanthia

23. Adult leaves distinctly glossy

24. Flowers with all filaments fertile (having anthers)

25. Fruit valves at or below rim level ..... ***E. granitica***

25: Fruit valves exserted above rim level ..... ***E. ophitica***

24: Flowers with outer filaments lacking anthers (staminodes)

26. Fruits hemispherical ..... ***E. virens***

26: Fruits obconic or barrel-shaped

27. Fruits 6–13 mm long x 5–10 mm wide

28. Fruits barrel-shaped; juvenile leaves linear to lanceolate ..... ***E. suffulgens***

28: Fruits obconic; juvenile leaves ovate to lanceolate ..... ***E. dura***

27: Fruits 4–7 mm long x 4–6 mm wide

29. Juvenile leaves ovate; adult leaves 15–35 mm wide ..... ***E. melanoleuca***

29: Juvenile leaves linear to narrow-lanceolate; adult leaves 7–16 mm wide ..... ***E. sicilifolia***

23: Adult leaves not glossy, ± dull

30. Branchlets, buds and immature fruits pruinose (glaucous)

31. Juvenile leaves linear to narrow-lanceolate; fruits 3–5 mm wide; WA and NT ..... ***E. jensenii***

31: Juvenile leaves lanceolate to orbicular; fruits 4–8 mm wide; NSW and Qld

32. Pedicels 5–12 mm long; fruits longer than broad ..... ***E. caleyi***

32: Pedicels 2–6 mm long; fruits about as long as broad

33. Juvenile leaves 35–80 mm wide; adult leaves 80–240 mm long x 14–35 mm wide; opercula rounded or slightly acute; Qld and NSW

33a. Opercula slightly beaked; bark compact and hard; small tree to 12 m ..... ***E. atrata***

33a: Opercula not beaked; outer bark layers easily levered off; tall tree to 25 m ..... ***E. calidissma***

33: Juvenile leaves 20–40 mm wide; adult leaves 60–120 mm long x 12–20 mm wide; opercula acute; inland plains from near Jericho to Hughenden area in Qld ..... ***E. whitei***

Amendment to NSW *Eucalyptus* Key in PlantNET (2018), from lead 18

18. Valves distinctly exserted (only weakly exserted in *E. calidissima*)

19. Buds not glaucous

20. Calyptra more than twice as long as hypanthium ..... ***E. fibrosa***

20: Calyptra less than twice as long as hypanthium

21. Disc flat ..... ***E. ophitica***

21: Disc depressed..... ***E. siderophloia***

19: Buds glaucous

19a. Hypanthium 4-ribbed, calyptra shorter than hypanthium ..... ***E. calidissima***

19a: Hypanthium not ribbed; calyptra as long or much longer than hypanthium..... ***E. nubilis***

18: Valves not distinctly exserted

22. Calyptra conical, acute; juvenile leaves orbiculate to broad-lanceolate

23. Buds glaucous ..... ***E. nubilis***

23: Buds not glaucous

24. Juvenile leaves broad-lanceolate to ovate, apex acute or obtuse..... ***E. siderophloia***

24: Juvenile leaves orbiculate, apex rounded..... ***E. fracta***

22: Calyptra rounded or obtuse; juvenile leaves linear to narrow-lanceolate or ovate

22a. Fruit 2-4 mm diameter, juvenile leaves linear to lanceolate ..... ***E. crebra***

22a: Fruit 7-9 mm diameter, juvenile leaves ovate to broad-lanceolate ..... ***E. calidissima***

Discussion

The presence or absence of a glaucous bloom on leaves, branchlets and buds is commonly used to distinguish different eucalypt taxa. Nicolle and Barrett (2018), for example, have used its presence to formalise two long recognised variants of the west Australian *Eucalyptus mooreana*, with the resulting taxa occupying overlapping yet rarely intergrading populations. Glaucousness in the eastern red gums (subseries *Erythroxyla*) has been extensively used for diagnosis in this group (Brooker & Slee 2000), and in certain white gums (series *Viminales*) (e.g. Rule & Walsh 2018). Use of this trait to aid discernment between superficially similar ironbark taxa is not unusual in eucalypt taxonomy, and when employed in combination with clear morphological features provides a strong tool for diagnosis readily implemented in the field.

The glaucous trait within *E.* ser. *Siderophloiae* (ironbarks) can occur (although variable and uncommon) in 14 of the 32 described taxa (*Eucalyptus atrata, E. caleyi* subsp. *caleyi, E. caleyi* subsp. *ovendenii, E. crebra*, *E. farinosa, E. jensenii, E. melanophloia* subsp. *melanophloia, E. melanophloia* subsp. *nana, E. nubilis, E. paedoglauca, E. quadricostata, E. shirleyi, E. staigeriana, E. whitei*), with two additional species in *E.* ser. *Melliodorae* (*E. sideroxylon, E. tricarpa*). However, within New South Wales only 4 of 13 ironbark taxa strongly possess this trait on leaves and buds (*Eucalyptus caleyi* subsp. *caleyi, E. caleyi* subsp. *ovendenii, E. melanophloia* subsp. *melanophloia, E. nubilis*), although four additional species can be slightly to strongly glaucous in some situations (*E. fracta, E. ophitica, E. sideroxylon, E. tricarpa*). In the absence of other alternatives, it is understandable that previous workers have determined specimens of *E. calidissima* from Pokolbin as *E. nubilis*.

Identification of the broad-leaved ironbarks (i.e. *E. fibrosa s. lat., E. nubilis s. lat.*) has been problematic within the Hunter region for many years. As noted earlier, there has been ongoing confusion regarding the placement of the Pokolbin taxon, here described as *E. calidissima*. Additionally, the identity of stands of broad-leaved ironbark across the Triassic sandstone escarpment and hills comprising Yengo, Wollemi and Goulburn River National Parks (NPs) and adjacent areas has variously been attributed to either *E. fibrosa*, *E. nubilis* or both (e.g. Bell 1997, 1998; Hill 1999; OEH 2012). As early as the 1960s, Johnson (1962) described 'complete intergradation' between these two taxa in the Goulburn River Valley, influencing his decision to demote them to subspecies level. McRae and Cooper (1985) also noted the 'common' intergradation apparent between *E. fibrosa* and *E. nubilis* in their assessment of the vegetation around Merriwa. Apart from *E. calidissima*, another potential new entity has been documented within these broadly defined taxa. Klaphake (2010), NSW OEH (2012) and Bell *et al.* (2019) all refer to a non-glaucous entity from Wollemi NP as *Eucalyptus* sp. 'Yarrawa'. NSW OEH (2012) mapped over 23,000 ha of habitat where this taxon is thought to occur, implying that it is a widespread species. Taxonomic research into the affinities and status of *E.* sp. 'Yarrawa' is ongoing.

Further afield to the south-west, three 1994 collections of ironbarks from Port Macquarie Road in the Capertee Valley (outside of the Hunter, c. 110 km south-west of Pokolbin) are databased both to *E. nubilis* (NSW 361335, NSW 361337) and *E. fibrosa* (NSW 361338). This location is c. 150 km south-east of the main distribution of *E. nubilis*, and further study of these collections is required. Field inspections along this road in August 2018 (as far as the locked national park gate) revealed all observed ironbarks to be *E. fibrosa*, with no hint of

the glaucous branchlets and buds or bluish leaves typical of *E. nubilis*. However, it is unclear if populations of *E. nubilis* also occur in this area, or if specimens determined as that species represent *E.* sp. 'Yarrawa' (or indeed *E. calidissima*). For the wider Capertee area, NSW DEC (2006) document a vegetation community dominated by *E. nubilis* with *Callitris endlicheri* and *C. glaucophylla*, and discuss similarities of this vegetation to that in the Dubbo area. Given the delineation of similar vegetation including *E. nubilis* in the Bylong Valley (Bell & Driscoll 2014), c. 85 km to the north and on similar geology, there remains the possibility that *E. nubilis* might occur in the Capertee area.

Such uncertainty over the identity of broad-leaved ironbarks within the upper Hunter area over several decades is reflected in the extent to which both *E. fibrosa* and *E. nubilis* have been reported in the unpublished literature, with the two species often seemingly occurring within the same habitat and locations. For example, Bell (1997, 1998) documents both taxa as diagnostic in vegetation described as Narrabeen Ironbark Woodland and Narrabeen Goulburn Valley Ironbark Woodland, as does Peake (1999) for his *Allocasuarina* Scrub Complex on Sandstone and Box Woodland on Basalt, Hill (2000) for her Ironbark Open Forest on Sandstone, and NSW OEH (2012) for their Western Hunter Escarpment Ironbark Forest. Both entities are present on Narrabeen sandstone geology in the Bylong Valley, comprising distinct assemblages dominated by one or the other species (*E. fibrosa* in the east, *E. nubilis* in the west), but rarely occurring together (Bell & Driscoll 2014): resolution scale of defined communities may be informative here and requires further investigation.

Much of the indecision over the identity of ironbarks in this region is explainable by the paucity of reproductive material available at the time of field surveys, and on the ambiguity of taxonomic boundaries of taxa recognised at the time. As a result, it is unclear how extensive *E. fibrosa* and *E. nubilis* are within these lands, or if indeed new taxa are present. It seems logical that *Eucalyptus calidissima* and *E.* sp. 'Yarrawa' are closely related, and in turn both are related to *E. nubilis* and *E. fibrosa*, and all four taxa may exist in a geographical and/or topographical replacement pattern within the wider Hunter region such as has been recognised for other eucalypt taxa elsewhere (e.g. McDonald *et al.* 2009; Nicolle & French 2012). Geographically, the more easterly distributed *E. calidissima* is replaced firstly by *E.* sp. 'Yarrawa' and then *E. nubilis* further inland, while topographically *E. fibrosa* is replaced by *E. calidissima* at higher elevations. Formal recognition of *E. calidissima* here represents the first step in resolving these regional anomalies within this group, and ongoing work aims to further elucidate the seemingly more widespread *E.* sp. 'Yarrawa'.

Acknowledgements

Thanks to Roy Palmer for permission and company to inspect vegetation on his property at Milbrodale, and to Jo Palmer for information on her 1991 collection from that site. Joe Slupik from Pokolbin permitted access through his land to study the new species on adjacent lands. Thanks to Chris Rockley for preparing line drawings, and to Helen Vonow and Martin O'Leary (AD), Jo Palmer (CANB), Pina Milne (MEL) and Marco Duretto (NSW) for facilitating access to scans of eucalypt collections. Dean Nicolle provided advice and images of related eucalypts for assessment, particularly those taxa endemic to Queensland, and reviewed a draft of this paper. Referee comments and editorial input from Peter Wilson improved the quality of the manuscript and are gratefully appreciated. Research for this work was partially supported by the University of Newcastle through their Hunter endemics project.

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Manuscript received 28 September 2019, accepted 9 April 2020.