Conservation Assessment of *Eucalyptus canobolensis* (L.A.S.Johnson & K.D.Hill) J.T.Hunter

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Eucalyptus canobolensis (L.A.S.Johnson & K.D.Hill) J.T.Hunter (Myrtaceae)

Distribution: Endemic to NSW
Current EPBC Act status: Endangered
Current NSW BC Act status: Vulnerable

Proposed listing on NSW BC Act as Endangered.

Summary of Conservation Assessment

Eucalyptus canobolensis is eligible for listing as Endangered under Criteria A2(c) and B1ab(iii) +B2ab(iii).

The reasons for the species being eligible for listing in the Endangered category are that (i) the species has undergone a large reduction in population size within a three generation timespan of 210 years through loss of habitat due to past land clearing; (ii) the species has a highly restricted geographic range with an area of occupancy (AOO) estimated to be 104 km^2, and extent of occurrence (EOO) estimated to be is 171 km^2; (iii) the species is found at only one location; and (iv) continuing decline in the quality of habitat, due to post-fire increases in blackberries, has been observed and is predicted to continue.

Description and Taxonomy

New South Wales (NSW) Flora Online (PlantNet, accessed March 2022) state that *Eucalyptus canobolensis* (L.A.S.Johnson & K.D.Hill) J.T.Hunter is a “Tree 8–12, rarely to 18 m high; bark smooth to base, shedding in ribbons. Juvenile leaves opposite, broad-ovate to orbiculate, glaucous. Adult leaves disjunct, lanceolate, mostly 10–18 cm long, 1.5–3.5 cm wide, green or grey-green, dull, concolorous. Umbellasters 3-flowered; peduncle distinctly flattened, 6–9 mm long; pedicels absent. Buds ovoid, glaucous or pruinose, 5–9 mm long, 3–5 mm diam., scar present; calyptra conical or hemispherical, slightly shorter than and as wide as hypanthium. Fruit cup-shaped, 5–9 mm long, 6–8 mm diam.; disc flat; valves exserted."

Eucalyptus canobolensis was first described as a subspecies of *Eucalyptus rubida* by Hill and Johnson (1991). It was separated from *E. rubida* on the basis of its large juvenile leaves and quadrangular coppice shoots. Its status as a separate entity was confirmed following a morphological phylogenetic analysis (Chappill and Ladiges 1996). In 1998 Hunter described *Eucalyptus canobolensis* as a separate species (Hunter 1998a).

Eucalyptus canobolensis is still recognised as a subspecies of *Eucalyptus rubida* by some authorities (e.g. Nicolle 2021) however is currently recognised at the species level on EUCLID (Slee *et al.* 2000) and by the Australian Plant Census (CHAH 2005).

Distribution and Abundance

Eucalyptus canobolensis is restricted to high altitude areas around Mount Canobolas south west of Orange on the Central Tablelands of NSW, which is within the South Eastern Highlands Bioregion (NSW Threatened Species Scientific Committee 2008; Department of Agriculture, Water and Environment 2012). The species dominates parts of the Mount Canobolas State Conservation Area (MCSCA) with mixed aged stands occurring predominantly above 1,000 m altitude and being most common between 1,200 to 1,300 m, however plants are also found as low as 900 m (Hunter 1998a; NSW OEH 2019; Zimmer *et al.* 2021). Above 1,300 m, *E. canobolensis* becomes less common as *Eucalyptus pauciflora* is prominent (Hunter 1998b). Occurrences are typically on soils derived from Canobolas Volcanic Complex basalt and trachyte, the main geology of the mountain, with plants more common on ridges than in valleys (Hunter 1998a; Scott 2012).

Although the current distribution of *Eucalyptus canobolensis* is predominantly within the MCSCA, a number of remnant trees have been recorded in the surrounding area down to 900 m elevation, and it is highly likely that *E. canobolensis* was much more common on shallow basalt-derived soils down to this altitude in the past (Scott 2012). Notes accompanying past collections of the species also indicate it may have been more widespread, with the collection of Debenham in 1963 suggesting the taxon to be "throughout the Canobolas, Orange distr." (NSW325558) and Garden in 1949 noting a "Pure strand [sic] for a fair distance down the mountain" (NSW325552). Isolated individuals and small stands are currently known from Black Sallee Reserve on the southern outskirts of Orange (*c.* 9 km east of Mount Canobolas), Canobolas State Forest at Cadia (*c.* 14 km southeast), Ridgeway Hill/Tunbridge Wells (*c.* 9 km south) and in Glenwood State Forest (*c.* 4 km west), all separated from the core occurrences in MCSCA by significant areas modified for agricultural and forestry use (Resource Strategies Pty. Ltd. 2012; Scott 2012; ALA 2022).

Much of the land above 900 m altitude within a 14 km radius of the Mt Canobolas summit (the distance to the furthest confirmed extant record) is currently used for native production forestry, softwood (pine) plantation forestry and agriculture (Fig 1). Within this radius, there are *c.* 24,000 ha above 900 m elevation of which 1,672 ha is the MCSCA managed by NSW National Parks and Wildlife Service. Production forestry takes up much of the rest of the mountain's slopes, most of which is softwood *Pinus radiata* plantations within Canobolas and Glenwood State Forests (Fig. 2) with the remainder mostly used for agriculture and a small amount for mining. The plantation forests occupy a combined area of *c.* 10,200 ha above the 900m contour, or about 42% of the area. Although it is unlikely that *Eucalyptus canobolensis* occurred at similar densities down to the 900 m contour in the past, it is highly likely that a substantial reduction in area of occurrence, available habitat and number of mature individuals has occurred due to this change in land use and associated clearing within 3 generations in a long-lived eucalypt, as this would predate European settlement in the region (Fensham *et al.* 2020).

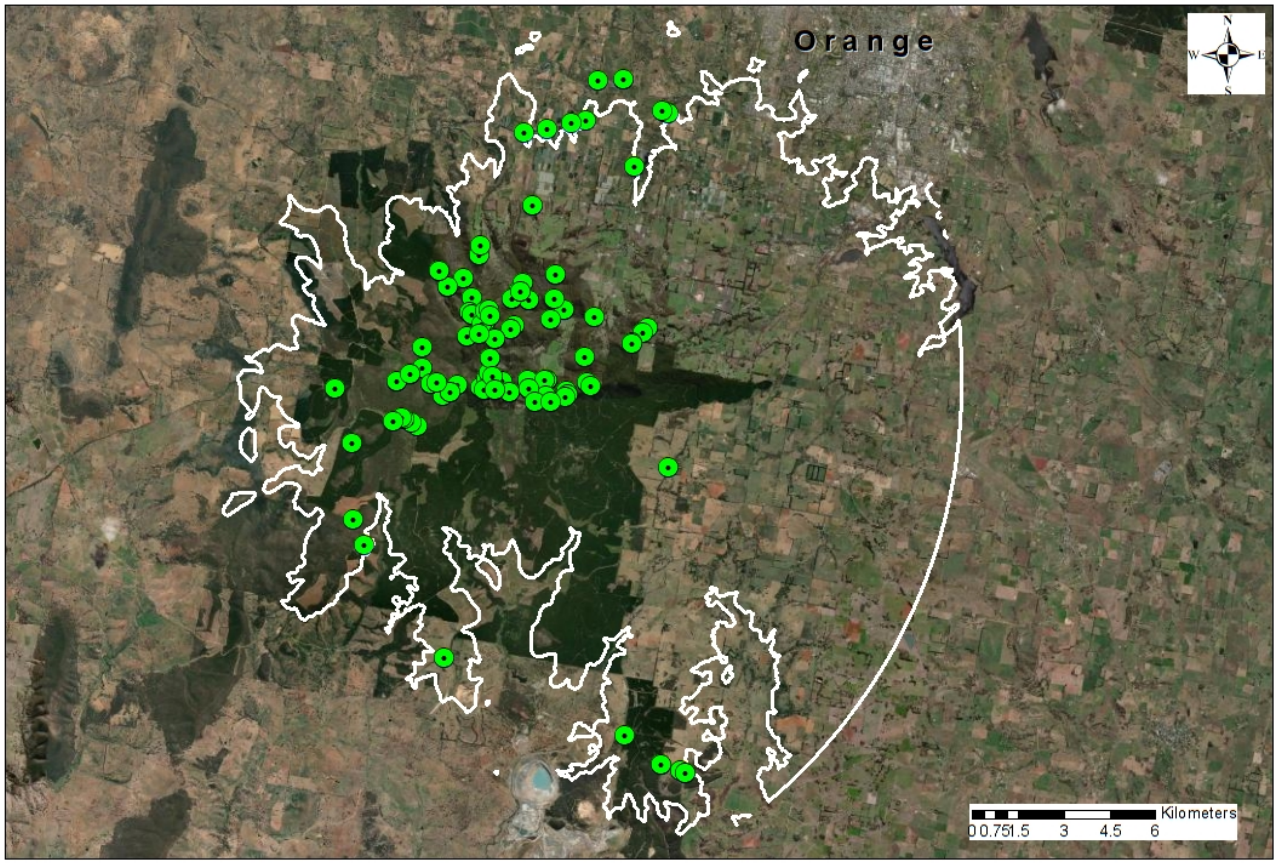

Figure 1 – Accepted records of *Eucalyptus canobolensis* (green) above 900 m altitude within a 14 km radius of the summit of Mount Canobolas, this being the distance to the furthest confirmed extant record.

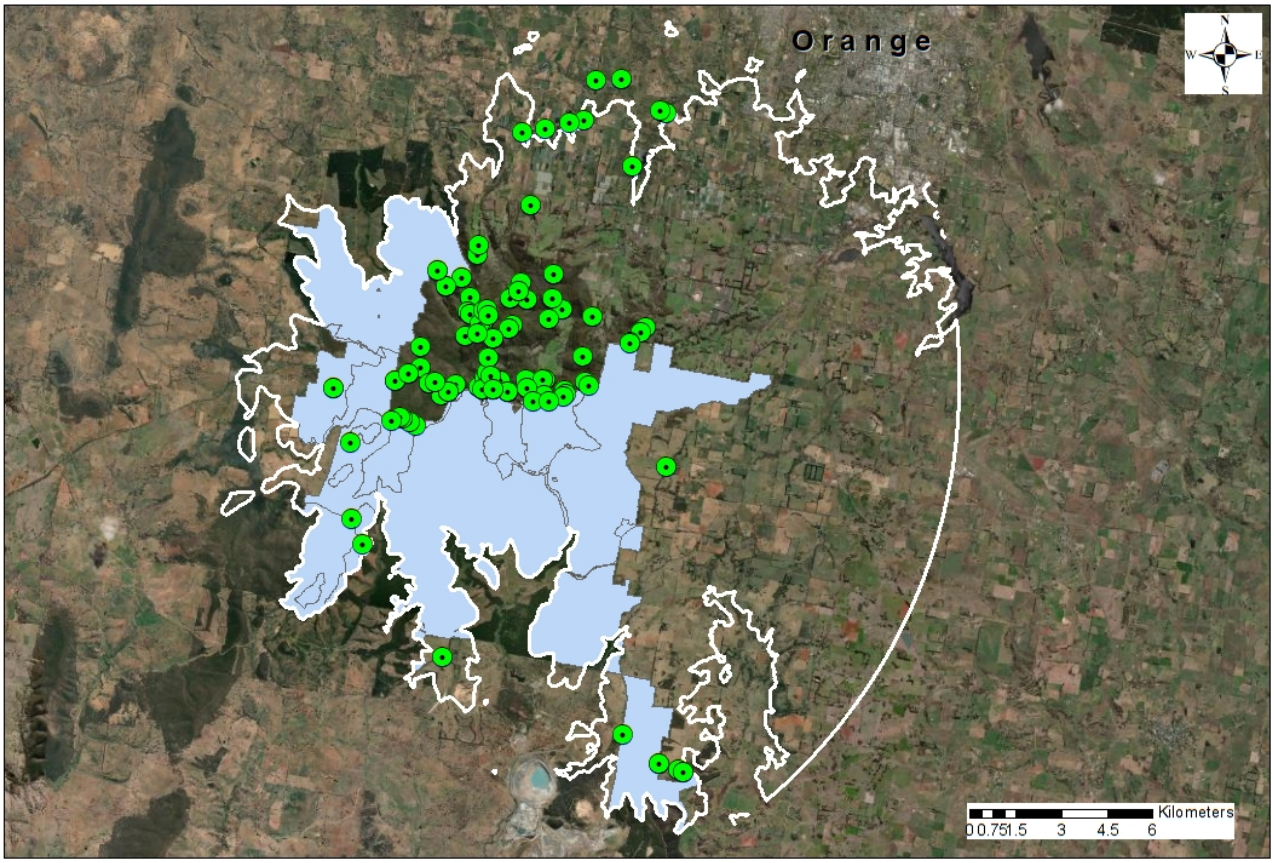

Figure 2 – Forestry Corporation of NSW management zones (blue shading) above 900 m altitude surrounding Mount Canobolas, 80% of which are softwood plantations of *Pinus radiata*. Included are accepted records of *Eucalyptus canobolensis* in green, mostly within the MCSCA.

Hunter (1998b) estimated the total population of *Eucalyptus canobolensis* in MCSCA as potentially 60,000 including seedlings and juveniles, based on extrapolation from two plots placed to study the target taxon. This population count is highly speculative however, given two non-random plots chosen to specifically contain *E. canobolensis* were used and MCSCA contains significant areas of unsuitable habitat which were included in the extrapolation, such as valleys (Scott 2012). However, it is not unreasonable to assume the population is greater than 10,000 mature individuals given the dominance of the species across the reserve (Hunter 1998a, Scott 2012).

The EOO of *Eucalyptus canobolensis* is 171 km^2 based on a minimum convex polygon enclosing all accepted occurrences of the species, the method of assessment recommended by IUCN (2019). The AOO is 104 km^2 based on a 2 x 2 km grid, the scale recommended by IUCN (2019). Both EOO and AOO were calculated using GeoCAT software (Bachman *et al.* 2011) enclosing all accepted records where the species has been recorded. Based on these estimates, *E. canobolensis* has a highly restricted EOO and AOO.

Ecology

Habitat

Eucalyptus canobolensis occurs on basalt-derived soils predominantly above 1,100 m and is most common between 1,200 and 1,300 m altitude but can be found less abundantly down to 900 m (Hunter 1998a, Zimmer *et al.* 2021). Above 1,300 m, *E. pauciflora* becomes more prominent (Hunter 1998a*). Eucalyptus canobolensis* is rarely found in pure stands and often co-occurs with other eucalypts such as *E. pauciflora*, *E. dalrympleana*, *E. viminalis, E. macrorhyncha* and *E. dives* with *Exocarpos cupressiformis* and *Acacia melanoxylon* also in the canopy (Hunter 1998a; Scott 2012; R. Stapleton *in litt.* September 2022). The shrub layer under *E. canobolensis* often contains *Acacia dealbata, Cassinia longifolia, C. sifton* and *Pultenaea spinosa,* with the groundcover containing *Hibbertia obtusifolia, Cynoglossum australe, Acaena novae-zelandiae, Geranium solanderi* var. *solanderi, Bossiaea buxifolia, Viola betonicifolia, Hydrocotyle laxiflora, Stellaria pungens, Gonocarpus elatus, Glycine clandestina, Hardenbergia violacea, Senecio bathurstianus, S. quadridentatus, Poa labillardierei, P. sieberiana, Rytidosperma erianthum, R. racemosum* and *Urtica incisa* (R. Stapleton *in litt.* September 2022).

This is reiterated by Benson and McDougall (1998) who state that *Eucalyptus canobolensis* (recognised as a subspecies of *E. rubida* at that time) occurs in "Eucalypt woodland, co-dominant with *Eucalyptus pauciflora*" and that "subsp. *canobolensis* passes into subsp. *rubida* on lower slopes". The species is suggested to dominate much of the MCSCA, with other reports also implying that *E. canobolensis* is more common on ridges than in valleys (Scott 2012).

Eucalyptus canobolensis makes up a significant portion of the canopy layer in several plant communities on Mount Canobolas identified by Hunter (2002). Most of these communities are woodland formations with a grassy understorey, fitting most closely to the plant community types (PCT) of Broad-leaved Peppermint - Mountain Gum dry open forest of the Central Tablelands area of the South Eastern Highlands Bioregion (PCT 730) and Snow Gum – Mountain Gum tussock grass-herb forest of the South Eastern Highlands Bioregion (PCT 1197) (Hunter 2002; Medd and Bower 2019). These plant community types contain the Threatened Ecological Community Mount Canobolas *Xanthoparmelia* Lichen Community (Medd and Bower 2019).

The rainfall patterns of Mt Canobolas are strongly orographic with the mountain rising over 500 m above the surrounding plains (Hunter 2002). Mean annual rainfall is 950 mm which is 200–400 mm greater than the surrounding plains, and the summit region is prone to snowfalls in winter (Hunter 2002). Even during dry times, the summit may be clothed in cloud, which increases the effective rainfall by dew formation and reduces transpiration (Hunter 2002).

Lifespan and Generation Length

Eucalyptus canobolensis is a long-lived tree, with a mean diameter at breast height (DBH) of 37.2 cm recorded for large trees in unburnt forest (Zimmer *et al.* 2021). Trees this size, using growth rates of 1.5–2 mm per annum based on slower-growing

eucalypt species, are estimated conservatively to be 180–250 years old, with trees of 50 cm DBH predicted to be 250-330 years of age (Fensham *et al.* 2017, 2020).

Generation length in long-lived eucalypts such as *Eucalyptus canobolensis* has been calculated in the past utilizing data across a range of taxa, assuming a minimum age of first reproduction to be approximately 4 years and the minimum age of a large tree to be conservatively 200 years giving a conservative generation length of approximately 70 years (Fensham *et al.* 2020).

The primary juvenile period of *Eucalyptus canobolensis* is uncertain; however, unpublished data (Smith and Allen 2017) indicates the transition from juvenile to adult occurs when the trees are around 5-10 cm DBH.

Pollination and Seed Ecology

Pollination of *Eucalyptus canobolensis* is likely to be effected by a range of insects, small marsupials and birds in a mixed-mating system similar to other eucalypts (Field *et al.* 2011). Studies by Field *et al.* (2011) on the closely related species *E. rubida* and *E. aggregata* showed that trees flower synchronously in a season with a distinct peak at sites with ample mature plants. These related species also appear to favour local pollen sources, with studies showing upward of 82% of pure progeny fathered by local trees and dense clusters of plants producing pollen pools for individuals dominated by the nearest neighbours. It was also found that average pollen dispersal distances were greater in more continuous forest given the greater options for pollen foraging, showing the importance of continuous habitat for species like *E. canobolensis.* This means that fragmentation may reduce pollen dispersal and increase the extinction risk of small, isolated stands over time.

Eucalyptus canobolensis seed is dispersed locally by wind or gravity and has no known dormancy mechanism (Benson and McDougall 1998). Germination does appear to be stimulated by hot fire however, with highest seedling density apparent in areas severely burnt following fires, likely as a result of reduced competition in the ground layer (Zimmer *et al.* 2021).

Fire Response

Fire affected approximately 70% of Mount Canobolas State Conservation Area in February 2018, which has enabled study of *E. canobolensis* response to wildfire. Zimmer *et al.* (2021) found that the response of *E. canobolensis* varied in relation to fire severity and tree size. Smaller trees were more likely to resprout only from the base in higher severity fires as epicormic strands within the stem are as yet unprotected from fire impacts, resulting in 'top kill' of the stem. Larger trees were able to resprout both epicormically and basally (combination resprouting) following severe fire impacts, meaning an escape from the pressure of repeat, short-interval fires is reliant on the establishment of larger trees. Smaller age cohorts remain susceptible to the impacts of short-interval fires as their resprouting potential in response to repeated severe fires will be limited. These recent observations are supported by previous work: "A number of apparent juveniles of *Eucalyptus canobolensis* appear to have

regenerated more than once from previous fire events and have developed a small but noticeable lignotuber" (Hunter 1998b).

The influence of fire may also be important in *Eucalyptus canobolensis* seedling growth and survival. Hunter (pers. comm. in Smith and Allen 2017) suggests that *E. canobolensis* seedlings often do not emerge when there is a dense grass sward. Groups of similarly sized trees observed in survey plots (50 m x 20 m; Smith 2017) suggests that recruitment occurs predominantly in discrete events, with a smaller amount of recruitment outside these events. Observations by Zimmer *et al.* (2021) also support this, with *E. canobolensis* seedling density found to increase with fire severity, with highest densities being found in plots burnt at extreme severity, no seedlings being recorded in unburnt plots and seedling density decreasing with increased groundcover, including invasive weeds such as blackberry.

Threats

Fire

There are indications that *Eucalyptus canobolensis* is adapted to some degree of burning and that fire plays an important part in the recruitment cycle of the species. Observations indicate that the majority of *E. canobolensis* burnt in the February 2018 fire have resprouted with smaller trees affected by severe fires being limited to basal coppicing and larger trees resprouting by both epicormic and basal shoots (Zimmer *et al.* 2021). There has also been significant seed germination, with the highest densities of seedlings recorded in areas of highest fire severity (Zimmer *et al.* 2021). However, some resprouts have died back since their initiation (H. Zimmer pers. obs., January 2019) and seedling density in post-fire plots has reduced in line with natural attrition (Zimmer *et al.* 2021).

Prior to the most recent fire in February 2018, Mount Canobolas had been affected by major wildfires in 1967, 1982 and 1985 in seasons of extreme weather conditions and below average rainfall (NSW NPWS 2003). These fires tend to start outside of MCSCA and enter the park and core habitat areas of *Eucalyptus canobolensis* from some distance away (NSW NPWS 2003).

Increased fire frequency, particularly in combination with high fire severity, would pose a potential direct threat to the survival of *Eucalyptus canobolensis* through a combination of three factors. Firstly, very intense or severe fires impact the capacity of young individuals to resprout. After the February 2018 fires, resprouting of smaller trees in areas of high intensity fire was observed to be restricted to basal resprouting only (Zimmer *et al.* 2021), with above-ground stems killed. Following from this, if two fires occur in quick succession, the second resprouting response may be less vigorous (as seen in other eucalypts e.g., Fairman *et al*. 2017, 2019). Finally, the current population is geographically concentrated and the potential for any particular fire to affect the whole population of the species is high. The fire regime applied to the species therefore should be actively managed to avoid high-intensity fires at short intervals (Scott 2012; Zimmer *et al.* 2021).

Very long inter-fire intervals could also represent a threat to the persistence of *Eucalyptus canobolensis*, if the species relies on intermittent hot fires for seedling regeneration and there is no recruitment during fire intervals (Zimmer *et al.* 2021). Species known to rely on fire for recruitment but restricted to fragmented landscapes have been shown to suffer population declines when wildfire is absent and only managed burning is undertaken (Tulloch *et al.* 2016).

Invasive species (blackberry)

Blackberry (*Rubus fruticosus* species complex) is a widespread weed of the Central Tablelands and is recognized as a priority weed in the region as well as one of the main weeds in the MCSCA (NSW OEH 2018). A prickly, tangled shrub, blackberry is able to rapidly spread and form extensive, dense thickets and adds to the fuel load available for fire when abundant (NSW DPI 2019). Blackberry has been found to be the species with the third highest cover/abundance of all flora recorded in MCSCA, being present in every vegetation community and forming impenetrable masses in some areas (Hunter 2000). Control programs within MCSCA have been ongoing since 1997 and are still being undertaken (Smith and Allen 2017; NSW OEH 2018) however blackberry invasion at high densities is continuing within many areas of the reserve and was noted to be more problematic after previous wildfires (Scott 2012).

Blackberry thickets suppress *E. canobolensis* recruitment from seed in the absence of fire and interact with fire to reduce seedling recruitment in post-fire landscapes where blackberry is abundant. Zimmer *et al.* (2021) found no *E. canobolensis* seedlings present in unburnt plots, while across all plots (burnt and unburnt) seedling density decreased with increasing cover of ground layer plants. Burning does not kill blackberry (NSW DPI 2019) and thickets can resprout rapidly from buried crowns and root suckering (Ainsworth and Mahr 2006). Fire intensity has no impact on the regenerative capacity of blackberry with infestations affected by high intensity fires still retaining enough live belowground material to re-establish pre-fire numbers by the end of the summer following fire, thus rapidly reforming thickets to compete with seedlings of native species (Ainsworth and Mahr 2006). The suppressive effect of dense blackberry infestations in both the pre- and post-fire landscape poses a significant threat to recruitment and population maintenance of *E. canobolensis.*

Land clearing

Extensive clearing of plants and habitat of *Eucalyptus canobolensis* has almost certainly occurred in the past. Much of the suitable habitat for *E. canobolensis* down to 900 m altitude both on the mountain and the slopes surrounding Mount Canobolas has been heavily cleared for agriculture and forestry use (Fig. 1) and it is highly likely that the species was more widely distributed in this area, based on the current spread of isolated individuals away from the core population in MCSCA (Hunter 1998b; Scott 2012). Mapping of forestry areas alone shows that softwood *Pinus radiata* plantations have reduced the area of native vegetation from a pre-clearing estimate of *c.* 24,000 ha to *c.* 13,800 ha or approximately 42%. The additional areas cleared for agriculture far exceed this amount, and so the Area of Occupancy and habitat available for *E. canobolensis* has reduced by at least 50% with a proportionate reduction in mature

individuals also suspected, even accounting for a lower relative abundance on the lower slopes of the mountain.

A small amount of clearing for infrastructure is also likely to have contributed to past declines, even within the MCSCA. Mining also represents at least a minor threat to the species: records of *Eucalyptus canobolensis* exist on and around the Cadia Valley mining lease on the mountain's southern slopes, and minor population loss is likely to have occurred in these areas, although the bulk of the mining operations are at lower altitudes (Resource Strategies Pty. Ltd. 2012). A mineral exploration licence also currently covers MCSCA, so the prospect of future clearing for this purpose cannot be dismissed in the core area of extant *E. canobolensis* habitat (NSW DPIE 2019).

In the core extant habitat within the MCSCA, development of visitor facilities to cater for the high visitation to the mountain could also contribute to small scale loss of individuals or habitat. Development of access roads, parking facilities, amenities and walking tracks, in addition to pre-existing camping and day use area maintenance, may impact on the *Eucalyptus canobolensis* population. A recent proposal for an extensive network of mountain bike tracks traversing significant portions of the park has potential to have additional impacts on the species by degrading its habitat (NSW DPIE 2019).

Climate change

Increases in temperature due to climate change predicted for the central west of NSW (NSW OEH 2014a) may cause reductions in habitat quality for *Eucalyptus canobolensis* in future. The species is currently restricted to higher elevations on and around Mount Canobolas with core populations occupying the 1200–1300 m zone, becoming rarer above that where *E. pauciflora* is predominant (Hunter 1998a, 1998b). Mount Canobolas itself reaches 1397 m altitude and exists as an isolated volcanic remnant separated from other mountains of similar elevation to the north, east and south (NSW DPIE 2019). This means that a narrow zone of retreat exists for the species to move upward into as climate warms, which is problematic for endemic montane plants, pushing them towards extinction as the zone of required habitat contracts even in the face of modest warming. Dispersal-limited plants (such as *E. canobolensis*) are at heightened risk (Engler *et al.* 2009; Dirnbock *et al.* 2011).

Assessment against IUCN Red List criteria

For this assessment it is considered that the survey of *Eucalyptus canobolensis* has been adequate and there is sufficient scientific evidence to support the listing outcome.

Criterion A Population size reduction

Assessment Outcome: Endangered under Criterion A2(c)

Justification: *Eucalyptus canobolensis* has suffered considerable range contraction as a result of past clearing of habitat for agricultural development, softwood *Pinus radiata* plantations and native production forestry operations. Although the core of the extant population is predominantly within the Mount Canobolas State Conservation Area, it

is highly likely that the species was more widespread in the general area in the past (Hunter 1998b, Scott 2012) with scattered remnant trees across adjacent forestry managed and agricultural areas providing evidence that suitable habitat formerly extended down to 900 m altitude on the surrounding slopes. Based on tenure and elevation mapping of the area (NSW Department of Finance, Service and Innovation 2017), there is a maximum of *c.* 24,000 ha of available area above 900 m elevation surrounding Mount Canobolas, of which *c.* 10,200 ha (approximately 42%) is now softwood plantations and a larger amount than this has been converted to agricultural and other cleared land uses. Even allowing for lower relative abundance of *E. canobolensis* at altitudes below 1000 m, a past population size reduction of at least 50% is strongly inferred, based on a decline in the EOO, AOO and habitat quality for the species of at least this magnitude, with the actual percentage likely to be substantially higher. This effectively irreversible decline has occurred within 3 generations, or 210 years, during the era of European colonisation in the region, meeting the threshold for Endangered (Fensham *et al.* 2020).

Criterion B Geographic range

Assessment Outcome: Endangered under Criterion B1ab(iii) +B2ab(iii)

Justification: *Eucalyptus canobolensis* has a highly restricted geographic distribution. The EOO of *E. canobolensis* is 171 km^2, which meets the threshold for listing as Endangered. The Area of Occupancy (AOO) has been calculated as 104 km^2, also meeting the threshold for listing as Endangered.

In addition to these thresholds, at least two of three other conditions must be met. These conditions are:

a) The population or habitat is observed or inferred to be severely fragmented or number of locations equals 1(CR), ≤5(EN), ≤10(VU).

Assessment Outcome: Subcriterion met for Critically Endangered.

Justification: *Eucalyptus canobolensis* is found at one threat-defined location. This assessment of number of locations is based on the potential interacting impacts of fire and weeds (specifically *Rubus fruticosus* species complex), the most serious plausible threats.

Eucalyptus canobolensis is not considered to be severely fragmented because the majority of individuals are found in one subpopulation around Mount Canobolas.

b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

Assessment Outcome: Subcriterion met for continuing decline inferred and projected for (iii) area, extent and/or quality of habitat.

Justification: Continuing decline is inferred in the quality of habitat as a result of large infestations of blackberry (*Rubus fruticosus* species complex) and increasing density in areas of unmanaged habitat around Mount Canobolas

(Hunter 2000. The development of blackberry thickets prevents seedling recruitment by *Eucalyptus canobolensis* and contributes to flammability of its habitat; it also suppresses seedling recruitment in post-fire landscapes with the ability to rapidly re-establish pre-fire groundcover even after high fire intensities which would otherwise promote *E. canobolensis* germination (Ainsworth and Mahr 2006; NSW DPI 2019; Zimmer *et al.* 2021). Through these interactions with fire, the continued spread of blackberry is inferred to contribute to ongoing reduction in habitat quality for *E. canobolensis* as it reduces the recruitment potential of the eucalypt when fires do occur, as well as increasing the chance of fires killing young trees that are not yet able to reshoot epicormically, affecting the long-term viability of stands (Zimmer *et al.* 2021). Blackberry control is ongoing in key areas in the core habitat of *E. canobolensis* within MCSCA, however total elimination is unlikely due to the density of infestations away from areas of current control and without continued intensive management, this threat will likely continue to increase given the current levels of infestation (Hunter 1998b, 2000, 2002; Smith and Allen 2017; NSW DPIE 2019).

c) Extreme fluctuations.

Assessment Outcome: Subcriterion not met.

Justification: *Eucalyptus canobolensis* is a long-lived tree unlikely to undergo extreme fluctuations.

Criterion C Small population size and decline

Assessment Outcome: Criterion not met.

Justification: Hunter (1998a) estimated the total population of *Eucalyptus canobolensis* as 60,000 including seedlings and juveniles. This estimate was based on extrapolation from two 25 m x 25 m quadrats, so is not likely to be reliable (Scott 2012). However, the total number of mature individuals of *E. canobolensis* is still considered to be >10,000 (Scott 2012). To be listed as threatened under Criterion C, a species must have <10,000 mature individuals, therefore *E. canobolensis* does not meet the threshold for listing under Criterion C.

At least one of two additional conditions must be met. These are:

C1. An observed, estimated or projected continuing decline of at least 10% in 10 years (up to a max. of 100 years in future).

Assessment Outcome: Subcriterion not met.

Justification: There is little evidence to suggest continuing decline in mature individuals is currently occurring or predicted to do so in the future, despite observed declines in habitat quality. The population is currently regarded as stable (Scott 2012).

C2. An observed, estimated, projected or inferred continuing decline.

Assessment outcome: Subcriterion not met.

Justification: There is little evidence to suggest continuing decline in mature individuals is currently occurring, despite observed declines in habitat quality. The population is currently regarded as stable (Scott 2012).

In addition, at least 1 of the following 3 conditions:

a (i). Number of mature individuals in each subpopulation < 50 (CR); < 250 (EN) or < 1000 (VU).

Assessment Outcome: Subcriterion not met.

Justification: The total population of *Eucalyptus canobolensis* is estimated to be >10,000, consisting of a single subpopulation.

a (ii). % of mature individuals in one subpopulation 100% (VU), 95-100% (EN), 90-100% (CR).

Assessment Outcome: Subcriterion met at Vulnerable level.

Justification: 100% of mature individuals *of Eucalyptus canobolensis* occur within one subpopulation in the area around Mount Canobolas.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Subcriterion not met.

Justification: *Eucalyptus canobolensis* is a long-lived tree unlikely to undergo extreme fluctuations.

Criterion D Very small or restricted population

Assessment Outcome: Criterion not met.

Justification: *Eucalyptus canobolensis* has more than 10,000 mature individuals in the population, occurs at only one location and has an AOO of 104 km^2.

To be listed as Vulnerable, a species must meet at least one of the two following conditions:

D1. Population size estimated to number ≤50 (CR), ≤ 250 (EN), or ≤1,000 (VU) mature individuals.

Assessment Outcome: Criterion not met.

Justification: *Eucalyptus canobolensis* has more than >10,000 mature individuals.

D2. Restricted area of occupancy (typically <20 km^2) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment outcome: Criterion not met.

Justification: Although *Eucalyptus canobolensis* only occurs in one location, its current known threats do not fit this criterion.

Criterion E Quantitative Analysis

Assessment outcome: Data Deficient.

Justification: Currently there is insufficient data to undertake a quantitative analysis to determine the extinction probability of *Eucalyptus canobolensis.*

Conservation and Management Actions

Eucalyptus canobolensis is currently listed on the NSW *Biodiversity Conservation Act 2016* and a conservation project has been developed by the NSW Department of Planning and Environment under the Saving our Species program. The conservation project identifies priority locations, critical threats and required management actions to ensure the species is extant in the wild in 100 years. *E. canobolensis* sits within the site-managed management stream of the SoS program.

Activities to assist this species currently recommended by the SoS program (NSW OEH 2014b; NSW DPE 2022) and Mount Canobolas State Conservation Area Plan of Management (NSW DPIE 2019) include:

Habitat loss, disturbance and modification

- Control blackberry infestations where required including within MCSCA as per the appropriate plan of management (NSW DPIE 2019).
- Ensure fire management is sympathetic to the required fire regime of the species to ensure adequate recruitment and regeneration.
- Maintain current abundance levels of *Eucalyptus canobolensis* within the MCSCA.
- Negotiate with Forests NSW to create buffer zones around the MCSCA to reduce impacts from plantation harvesting operations.
- Ensure any new facilities, operations or other works have an appropriate environmental impact assessment within MCSCA and only allow if they are consistent with the purposes of reservation of the park and reduce impact on the population of *Eucalyptus canobolensis*.

Ex situ conservation

- Undertake appropriate seed collection and storage with the aim of storing 20,000 seeds from across the breadth of the known populations.
- Implement national translocation protocols (Commander *et al.* 2018) if population augmentation or translocation is required in future.

Survey and Monitoring

- Design and implement a monitoring program of population demographics.
- Monitor the population response to fire, including mortality, resprouting and seedling recruitment.
- Monitor the extent and severity of blackberry infestations within the population to prioritise areas of control.

- Confirm and database lower altitude occurrences of *Eucalyptus canobolensis* in order to determine full extent of the species potential range.

Information and research

- Raise awareness of *Eucalyptus canobolensis* within the local community, particularly targeting the isolated individuals outside the MCSCA.
- Undertake genetic work to investigate *Eucalyptus canobolensis* status as a species/subspecies and its relationship with *Eucalyptus rubida* to properly assess the impact of hybridisation on the population.
- More precisely assess population size, distribution, ecological requirements and the relative impacts of threatening processes.

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APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria
The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome:
Eucalyptus canobolensis was found to be Endangered under Clause 4.2 (1) (b) (2) (c) and 4.3 (b) (d) (e) (iii)

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Endangered under Clause 4.2 (1)(b)(2)(c)

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	for critically endangered species	a very large reduction in population size, or
	(b)	for endangered species	a large reduction in population size, or
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	(a)	direct observation,	
	(b)	an index of abundance appropriate to the taxon,	
	(c)	a decline in the geographic distribution or habitat quality,	
	(d)	the actual or potential levels of exploitation of the species,	
	(e)	the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	

Clause 4.3 - Restricted geographic distribution of species and other conditions
(Equivalent to IUCN criterion B)
Assessment Outcome: Endangered under Clause 4.4 (b) (d) (e) (iii)

The geographic distribution of the species is:			
	(a)	for critically endangered species	very highly restricted, or
	(b)	for endangered species	highly restricted, or
	(c)	for vulnerable species	moderately restricted,
and at least 2 of the following 3 conditions apply:			
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,	
	(e)	there is a projected or continuing decline in any of the following:	
		(i)	an index of abundance appropriate to the taxon,

		(ii)	the geographic distribution of the species,
		(iii)	habitat area, extent or quality,
		(iv)	the number of locations in which the species occurs or of populations of the species,
	(f)	extreme fluctuations occur in any of the following:	
		(i)	an index of abundance appropriate to the taxon,
		(ii)	the geographic distribution of the species,
		(iii)	the number of locations in which the species occur or of populations of the species.

Clause 4.4 - Low numbers of mature individuals of species and other conditions (Equivalent to IUCN criterion C)
Assessment Outcome: Clause not met

The estimated total number of mature individuals of the species is:						
	(a)	for critically endangered species			very low, or	
	(b)	for endangered species			low, or	
	(c)	for vulnerable species			moderately low,	
and either of the following 2 conditions apply:						
	(d)	a continuing decline in the number of mature individuals that is (according to an index of abundance appropriate to the species):				
		(i)	for critically endangered species		very large, or	
		(ii)	for endangered species		large, or	
		(iii)	for vulnerable species		moderate,	
	(e)	both of the following apply:				
		(i)	a continuing decline in the number of mature individuals (according to an index of abundance appropriate to the species), and			
		(ii)	at least one of the following applies:			
			(A)	the number of individuals in each population of the species is:		
				(I)	for critically endangered species	extremely low, or
				(II)	for endangered species	very low, or
				(III)	for vulnerable species	low,
			(B)	all or nearly all mature individuals of the species occur within one population,		
			(C)	extreme fluctuations occur in an index of abundance appropriate to the species.		

Clause 4.5 - Low total numbers of mature individuals of species (Equivalent to IUCN criterion D)
Assessment Outcome: Clause not met

The total number of mature individuals of the species is:			
	(a)	for critically endangered species	extremely low, or
	(b)	for endangered species	very low, or
	(c)	for vulnerable species	low.

Clause 4.6 - Quantitative analysis of extinction probability (Equivalent to IUCN criterion E)
Assessment Outcome: Data deficient

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

Clause 4.7 - Very highly restricted geographic distribution of species– vulnerable species (Equivalent to IUCN criterion D2)
Assessment Outcome: Clause not met

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.