

**Conservation Assessment of *Eucalyptus approximans* Maiden
(Myrtaceae)**

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***Eucalyptus approximans* Maiden (Myrtaceae)**

Distribution: Endemic to NSW

Current EPBC Act Status: Not listed

Current NSW BC Act Status: Vulnerable

Proposed listing on NSW BC Act: Delist.

Reason for change: Non-genuine change based on increased data on distribution and population numbers and knowledge of threats to the species.

Summary of Conservation Assessment

Eucalyptus approximans was found to be ineligible for listing as a threatened species as none of the criteria were met.

Description and Taxonomy

Eucalyptus approximans (Barren Mountain Mallee) is a conventionally accepted species (CHAH 2006) that lies phylogenetically within the mallee ash clade of subgenus *Eucalyptus* section *Eucalyptus* series *Strictae* subseries *Regulares* (Nicolle 2021). It is described by Slee *et al.* (2020) (as *Eucalyptus approximans* subsp. *approximans*) as a “Slender mallee to 6 m tall. Forming a lignotuber. Bark smooth, white, grey, brown or pinkish, occasionally with ribbons of decorticated bark in the upper branches. Juvenile growth (coppice or field seedlings to 50 cm): stem rounded or square in cross-section, warty on lower internodes; juvenile leaves at first subsessile, opposite for 2 to 5 pairs then alternate, shortly petiolate, narrowly lanceolate to linear, 6.5–14 cm long, 1–2 cm wide, glossy, green. Adult leaves alternate, petiole 0.2–1.5 cm long; blade linear to lanceolate to falcate, 5.5–12 cm long, 0.5–1.6 cm wide, base tapering evenly to petiole, margin entire, concolorous, glossy, green, side-veins obscure or, if visible, acute, reticulation absent or sparse, intramarginal vein obscure or if present well removed from margin, oil glands numerous, island. Inflorescence axillary unbranched, peduncles 0.4–1.2 cm long, buds usually 7 (rarely 3) per umbel, pedicels 0.1–0.3 cm long. Mature buds clavate, 0.5 cm long, 0.3 cm wide, warty, scar absent, operculum rounded to flattened, stamens inflexed or irregularly flexed, anther reniform to cordate, versatile, dorsifixed, dehiscing by confluent slits, style short or long, ovary chambers 3 or 4 with 2 vertical ovule rows. Flowers white. Fruit on pedicels 0.1–0.3 cm long, cylindrical or cup-shaped, 0.6–0.8 cm long, 0.5–0.8 cm wide, disc slightly raised, level or descending, valves 3 or 4, near rim level or enclosed. Seeds pale to mid brown, 1–2 mm long, pyramidal or obliquely pyramidal, dorsal surface smooth, hilum terminal.”

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Eucalyptus approximans is distinguished from the closely related *E. codonocarpa* by the typically 7-flowered inflorescences (c.f. 3-flowered), the cupular to cylindrical fruit (c.f. campanulate fruit) and narrower mature foliage (Slee *et al.* 2020). Both of these species occur on the New South Wales (NSW) Northern Tablelands, but the ranges are not known to overlap. *E. approximans* is even closer morphologically to the geographically more distant *E. microcodon* from the McPherson Range of the NSW/Queensland border, though the former is distinguished from the latter by the narrower mature foliage as well as the more prominent oil glands in the leaves (Hill and Johnson 1991).

There remains some conjecture over the taxonomic rank of *Eucalyptus approximans*, however this assessment follows a narrow circumscription of *E. approximans* at the species level, distinct from *E. codonocarpa* and *E. microcodon* and in line with the taxonomy of the National Herbarium of NSW (NSW Flora Online 2022). *E. approximans* was originally described based only on specimens from Barren Mountain near Ebor (Maiden 1919) and several authorities still maintain this narrow circumscription at the species level (CHAH 2006; Nicolle 2021; NSW Flora Online 2022). However, *E. approximans* is sometimes treated in a broader taxonomic sense to include the more recently described *E. codonocarpa* and *E. microcodon* from northern NSW and Queensland as *E. approximans* subsp. *codonocarpa*, with the Barren Mountain plants being reduced to subspecies rank as *E. approximans* subsp. *approximans* (Brooker and Kleinig 2006; Slee *et al.* 2020). In both cases the Barren Mountain taxon remains distinct at either subspecies or species rank, and so the validity of the taxon as a separate, identifiable entity is not in dispute.

Distribution and Abundance

Eucalyptus approximans is a naturally rare species endemic to two mountain areas on the NSW Northern Tablelands near Ebor, approximately 70–80 km east of Armidale. This area lies within the New England Tablelands Bioregion (Department of Agriculture, Water and Environment 2012) on the traditional lands of the Gumbaynggir and Anaiwan First Nations people (Horton 1996; NSW NPWS 2002, 2021).

The NSW Scientific Committee (2008) state that “*Eucalyptus approximans* is endemic to New South Wales where it is known only from Barren Mountain, largely within New England National Park. Some plants also occur on the northern base of Barren Mountain, just outside the National Park boundary.” Since the 2008 determination, another extant site has been confirmed in Cathedral Rock National Park, which was first collected in 1972 but remained unrecognised until confirmation during surveys in 2003, 2017 and 2018 (M. Dwyer *in litt.* 2005; Copeland 2017; Phillips *et al.* 2018). All other records further north than these sites in databases such as the Atlas of Living Australia (2022) are considered erroneous, with these records attributable to *E. codonocarpa* and/or *E. microcodon* that have been recorded as *E. approximans* in the broader taxonomic sense.

Despite the known sites of *Eucalyptus approximans* being only approximately 25 km apart, the species’ population is considered to consist of two geographically distinct subpopulations given the very low likelihood of dispersal across this distance of both pollen and seed in eucalypts (Breed *et al.* 2015; Booth 2017).

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The Barren Mountain subpopulation is located mostly within New England National Park, with a small portion located on adjoining private property. The *Eucalyptus approximans* stands are confined to a large area of heathy shrubland on outcropping trachyte on the mountain's northern flank between 1250 and 1430 m elevation (Copeland 2008, 2017), with some larger plants also in the adjoining forest nearer the mountain summit (M. Dwyer pers. comm. August 2018). This subpopulation has been the most visited since 2003. The most recent observations are from 2018, when a 1 km traverse across the southern part of the subpopulation was undertaken. The subpopulation at this time was recorded as "many 1000's" in size (Phillips *et al.* 2018). No seedlings were observed, and most plants across the mountain were mature and occurred in dense stands (Phillips *et al.* 2018). Copeland (2008) recorded a "very conservative" estimate of 2,000 mature individuals. However, the extremely thick, almost impenetrable patches that are common across the large area of available habitat (G. Phillips pers. obs. August 2018) mean that the actual figure is likely to be much higher. A number of herbarium specimens held at the National Herbarium of NSW also note that *E. approximans* is abundant or frequent at various places across the site.

The second subpopulation of *Eucalyptus approximans*, in Cathedral Rock National Park, was originally known from two specimens collected in 1972, but the few subsequent records in following years from the park only note *E. codonocarpa* (ALA 2022). As a result, the record went long-unrecognised as *E. approximans*. After NPWS helicopter surveys in 2003 detected several discrete stands of fine-leaved mallees in the western section of the park, the possibility that genuine *E. approximans* may be present was once again considered (M. Dwyer pers. comm. August 2018). The sites went unsurveyed on the ground until 2017 when a targeted survey located a stand of *E. approximans* at one of the earlier helicopter survey waypoints, around an area of outcropping granite at c. 1520 m elevation (Copeland 2017). This site was then revisited in 2018, confirming the stand to be *E. approximans* and not *E. codonocarpa* (Phillips *et al.* 2018). Further targeted surveys in 2022 failed to locate any more stands across a greater area of the national park, though they were able to quantify the number of mature individuals at this site. The subpopulation size was estimated to be between 1,904 and 2,904 mature individuals, with an additional 150-350 seedlings (Mitchell-Williams 2022). Other remote locations identified in the 2003 helicopter surveys remain unverified and it remains possible that these additional stands in the Cathedral Rock National Park currently recorded as *E. codonocarpa* are also *E. approximans*.

A lack of comprehensive on-ground data complicates estimates of the total population of *Eucalyptus approximans*. No on-ground quantitative estimate of the extensive Barren Mountain subpopulation has been undertaken, aside from the "many 1000's" noted by Phillips *et al.* (2018) and the extremely conservative minimum of 2,000 mature individuals estimated by Copeland (2008). The Cathedral Rock subpopulation has an accurately estimated 1,904–2,904 mature plants within a GPS-mapped area of approximately 1 ha in one stand (Mitchell-Williams 2022), as well as a count of 344 at another stand (M. Dwyer *in litt.* 2005). Using the population density estimate from Cathedral Rock (Mitchell-Williams 2022), the number of mature individuals at Barren Mountain across the full area of available habitat of c. 84 ha (Appendix 2) may be as high as 160,000–244,000. However, the actual number of mature individuals is likely

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to be much lower than this, as *E. approximans* stands are not continuous across the full extent of habitat. Stands are interrupted by significant areas of wet heath and bare, outcropping rock (Copeland 2008; G. Phillips pers. obs. August 2018). Stand density is typically high where they do occur as indicated by high cover abundances of 50–75% (DPE 2022b). Based on plot data, it is likely that at least 29% of the available habitat at Barren Mountain is occupied by *E. approximans* at densities similar to the mapped stand at Cathedral Rock (DPE 2022b). Therefore, a plausible estimate for the minimum number of mature individuals at the site is 46,381. Therefore, the minimum global population of *E. approximans* is estimated to be 48,629 mature individuals, using the lowest bounds of the estimates at Barren Mountain and verified site counts at Cathedral Rock.

Extent of Occurrence and Area of Occupancy

The Extent of Occurrence (EOO) is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). EOO was measured at 16 km² when only considering verified locations, and 66 km² when including unverified sites identified by helicopter survey in Cathedral Rock NP. Area of Occupancy (AOO) was calculated using 2 x 2 km grid cells, the scale recommended by IUCN (2022), and was calculated to be 20 km² when considering only verified locations and 28 km² when including unverified sites identified by helicopter survey in Cathedral Rock NP. Both EOO and AOO were calculated using ArcGIS (Esri 2015), enclosing all confirmed survey records and cleaned spatial datasets. Based on these estimates, *Eucalyptus approximans* has a very highly restricted EOO and a highly restricted AOO.

Number of Locations

Currently, no evidence of continuing decline is apparent in the population of *Eucalyptus approximans* as recognised threats are only regarded as plausible future threats (IUCN 2022). In this case, the most likely threat that may affect the currently unaffected areas in the future can be used to define locations (IUCN 2022). Thus, if the most serious likely future threat of increased frequency and duration of drought due to climate change is considered, both subpopulations of *E. approximans* can be treated as separate threat-defined locations. The two subpopulations are approximately 25 km apart and in different landscape positions at different elevations (Copeland 2017), so the threat response, if it were to occur, is likely to differ between them.

Ecology

Habitat

Eucalyptus approximans grows in heathy shrublands around rocky outcrops in shallow, nutrient poor soils above 1250 m elevation (Copeland 2008; Phillips *et al.* 2018). However, soil profiles differ between the two sites where the species occurs. Barren Mountain has deeper, fine-textured soils derived from trachyte, whereas Cathedral Rock has shallow, coarse-textured sandy soils derived from granite (Copeland 2017, Phillips *et al.* 2018). *E. approximans* often forms dense stands with a high number of shrubs, ferns and sedges underneath and rarely co-occurs with other

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species of eucalypts, likely due to the limitations of the preferred shallow soils (Copeland 2008). Co-occurring species at Barren Mountain include *Melaleuca tortifolia*, *Gahnia* sp., *Allocasuarina rigida* and *Gleichenia dicarpa* (Phillips *et al.* 2018). At Cathedral Rock the species occurs with *Eucalyptus acaciiformis*, *Leucopogon neoanglicus*, *Leucopogon affinis*, *Leptospermum novae-angliae* and *Lomandra longifolia* (Phillips *et al.* 2018).

At Barren Mountain, *Eucalyptus approximans* is found within the Plant Community Types (PCT) of Bellinger Escarpment Rockplate Mallee Heath (PCT 3819), Ebor Basalt Wet Heath (PCT 3936) and Northern Escarpment Messmate Cool Wet Forest (PCT 3287) (DPE 2022a). *Eucalyptus approximans* makes up a significant component of the Bellinger Escarpment Rockplate Mallee Heath, having a high median cover score within the shrub layer for that PCT (DPE 2022b). In Cathedral Rock NP the species is found in Warra Rockplate Shrubland (PCT 4130), Northern Escarpment Messmate Moist Grassy Forest (PCT 3288) and Cathedral Rock Granite Peppermint-Gum Forest (PCT 3500) (DPE 2022a).

Life History

Like many other mallee eucalypts, *Eucalyptus approximans* is known to readily reshoot from a basal lignotuber as the primary regenerative strategy following disturbance such as fire (Clarke *et al.* 2000; Nicolle 2006). In many eucalypts, lignotuber development is most substantial in fire- and drought-prone landscapes, with larger, more tolerant lignotubers developing in habitats where species are at their physiological limits or site abiotic qualities are most marginal (Noble and Diggle 2013). This is the situation for *E. approximans*. Recent surveys showed 100% of individuals in the Cathedral Rock subpopulation were reshooting from lignotubers following extreme fire conditions in December 2019 (Mitchell-Williams 2022), with a similar response recorded post-fire in 2004 (M. Dwyer *in litt.* 2005). Only 30 months post-fire, reshooting stems had attained 35–50% of the height of dead standing mature stems (Mitchell-Williams 2022), despite the stand showing significant signs of drought stress prior to burning (Phillips *et al.* 2018). Growing trials on *E. approximans* have shown the lignotuber is developed enough to provide sufficient regenerative capacity to produce multiple secondary stems following mechanical removal of the main stem only 24 months after germination (G. Phillips pers. obs. June 2021). However, removal of stems through burning is known to limit stem regeneration faster than mechanical removal in other mallees (Noble and Diggle 2013). Other related lignotuberous mallee species from temperate habitats, such as *E. obstans*, have been predicted to take 7–10 years to establish lignotuber fire tolerance with 100% seedling mortality resulting from burning only four years post-fire (Auld *et al.* 1993). Fire tolerance development in temperate mallees also appears to be dependent on the prevailing conditions in which plants germinate, with fire tolerance developing more rapidly in seedlings which germinate in burnt conditions compared to those that germinate in unburnt conditions (Tozer and Bradstock 1997).

Seedling recruitment is relatively rare in mallee eucalypts (Wellington and Noble 1985b) and a lack of seedlings and/or juvenile plants has been noted in long unburnt stands of *Eucalyptus approximans* (Phillips *et al.* 2018). Even post-fire, seedling recruitment in mallees can be low despite the release of large volumes of seed from the canopy stored seed bank (Tozer and Bradstock 1997) and this appears true for *E.*

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approximans. Only 150–350 seedlings were observed amongst a count of 1904–2904 resprouting individuals in Cathedral Rock NP 30 months after the 2019 wildfires (Mitchell-Williams 2022). Seedling survival in mallees appears to be largely dependent on moisture availability and competition for resources in the nutrient poor soils they often grow in (Wellington and Noble 1985b; Auld *et al* 1993; Tozer and Bradstock 1997). Drought severely limits recruitment (Wellington and Noble 1985b; Auld *et al*. 1993) though only minimal recruitment is needed to maintain a population due to the high survivorship of the lignotuberous mature plants (Tozer and Bradstock 1997). Seedlings of the temperate mallee *E. luehmanniana* that establish in unburnt habitats have been found to have higher rates of mortality over time than those that establish in burnt habitats, showing that post-fire increased availability of resources and release from litter-dwelling herbivores is key to seedling survival and long-term stand maintenance in mallees (Tozer and Bradstock 1997).

Lignotuberous mallees are typically extremely long-lived as their ability to regenerate vegetatively appears to be unlimited (Nicolle 2006). While the aboveground stems may be young, the overall age of the plant may be considerably older (Nicolle 2006). Previous radiocarbon studies on mallees have shown that lignotubers can be thousands of years old (Nicolle 2006), though many are often up to 200 years old (Wellington and Noble 1985a) with the aboveground stems usually no more than 20 years old (Nicolle 2006). Many lignotuber sprouting mallees produce reproductively fertile stems 4–7 years after germination (Nicolle 2006), indicating a primary juvenile period of this length.

The generation length of *Eucalyptus approximans*, which relies more on resprouting from long-lived lignotubers over seedling regeneration, can be estimated using the age of first reproduction + z * length of reproductive period (IUCN 2022), where z is a constant between 0 and 1 calculated using survivorship and the relationship between fecundity and age (Fensham *et al*. 2020). Using a lifespan of 200 years, a primary juvenile period of seven years comparable to other mallees and a value for z of 0.33 as calculated for other long-lived tree species (Fung and Waples 2017), the generation length of *E. approximans* is estimated at approximately 70 years, in line with that calculated for other eucalypt species (Fensham *et al*. 2020).

Reproductive and Seed Ecology

Eucalyptus approximans flowers primarily in autumn (Brooker and Kleinig 2006; Slee *et al*. 2020) though has the potential to flower sporadically at other times through the year (G. Phillips pers. obs. August 2018). The flowers are protandrous, and a mixed mating system that favours outcrossing is likely, as found in most other eucalypts (Breed *et al*. 2015). Pollinators are likely to be various insects, small mammals and birds, similar to many other eucalypts (Field *et al*. 2011). Birds are known to enable long-distance pollen dispersal and gene flow in other small-flowered mallee species however pollen dispersal is often limited to less than 1 km in stands in intact (uncleared) vegetation (Breed *et al*. 2015) and so any long-range dispersal is likely to be highly infrequent between the subpopulations of *E. approximans*.

Seed dispersal in eucalypts is very restricted and dependent on plant height, canopy width, seed weight and wind strength (Booth 2017). Given the low mallee habit, seed dispersal in *Eucalyptus approximans* is likely to be highly localised around parent plants, however the relatively high average winds of the region (BOM 2022) may aid

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further movement. Predation of seed by ants is also known to be high in eucalypt species (Wellington and Noble 1985b; Booth 2017) and soil seed banks are likely to be relatively short-lived. Seeds of the semi-arid mallee *E. incrassata* were found to maintain viability after 300 days of burial, however, seed dropped on the soil surface appeared to be almost completely exhausted through germination, viability loss or predation in only 60-150 days (Wellington and Noble 1985b). Seed supply for regeneration is thus maintained by holding seeds in the canopy, potentially for several years, and the slow release of seeds to the soil over time from this aerial seed bank (Tozer and Bradstock 1997).

Threats

The NSW Scientific Committee (2008) stated that “At present there is no evidence that the population of *Eucalyptus approximans* is undergoing a continuing decline, although inappropriate fire regimes and long-term climate change may threaten the species in the future. The very highly restricted geographic distribution means that the species may be prone to the effects of human activities or stochastic events within a very short time period.”

There remains no evidence of continuing decline in the population of *Eucalyptus approximans*. Recent surveys show no decrease in mature populations or extent or quality of habitat, even after extreme fire conditions following severe, long-term drought (Copeland 2017; Phillips *et al.* 2018; Mitchell-Williams 2022). No other threats to recruitment have been observed pre- or post-fire, such as weed encroachment or herbivory (Copeland 2017; Phillips *et al.* 2018; Mitchell-Williams 2022). Given the Cathedral Rock NP subpopulation is completely reserved, and the Barren Mountain subpopulation is mostly within New England NP and the rest on land with low suitability for clearing (Copeland 2008), direct human impacts on the species are also likely to be negligible. Longer term threats such as changes in fire regimes and increased frequency and duration of drought due to climate change may still adversely affect the population in time.

Changes in fire regimes due to climate change

Changes in fire regimes may affect *Eucalyptus approximans* in the long-term as it is possible that frequent out-of-season fire may reduce the ability of plants to regenerate from the lignotuber over time. Increased mortality in semi-arid mallee species with increased autumn burning can be significant, with stand half-life (time to 50% mortality) reducing by approximately 40–62% with every yearly reduction in fire interval from four-yearly to annual burning (Clarke and Diggle 2013). Annual spring burning, when mallees are naturally in a stronger vegetative growth phase, is noted to have a much lower impact, with mortality reduced by 80% compared to annual autumn burning (Clarke and Diggle 2013). Thus, regular out-of-season fires when mallees are in a reduced growth phase (autumn and winter) may generate greater decline than those in the phases of active growth (spring and summer). However, current predicted changes in the mean monthly forest fire danger index for the New England region resulting from climate change indicate that severe fire weather is predicted to increase in spring and summer and stabilize or decrease in autumn and winter, with the fire season shifting earlier by the year 2100 (Clarke *et al.* 2011; AdaptNSW 2022). Therefore, the risk of future out-of-season autumn and winter fires diminishing the

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recruitment potential of *E. approximans* appears to be currently low, though may become more apparent in future.

Detailed fire history for Barren Mountain is lacking. While there is information indicating three wildfire events impacted the site in the 40 years prior to 2000 (Copeland 2008), no recent fires are recorded in fire history databases (NSW NPWS 2022) resulting in the site being currently mapped as long unburnt (NSW NPWS 2014). At Cathedral Rock, extensive wildfires impacted the known stand in 1988/89 (month unknown), January 1995, October to December 2004 and November to December 2019 (NSW NPWS 2022), giving a mean fire interval of approximately 10 years. This is currently equivalent to the recommended minimum fire return interval for the species of 10 years (NSW DPE 2022c). No out-of-season fires have been recorded and neither subpopulation of *Eucalyptus approximans* appears to have declined due to these fire regimes given the positive post-fire responses recorded, even after extreme fires (M. Dwyer *in litt.* 2005; Copeland 2008; Mitchell-Williams 2022).

Due to the combination of a predicted lessened risk of fire in seasons of reduced growth potential in the future, no recorded out-of-season fires in either subpopulation of *Eucalyptus approximans* to date, and no detectable decline from current fire intervals or severities, fire regime change is not considered a plausible threat in isolation that will rapidly drive *E. approximans* to extinction. Indeed, the ecological requirement of fire to enable stand regeneration in mallees may mean that the current long-unburnt status of the Barren Mountain subpopulation may be more of a concern than more regular fire at that site, and so the current recommendation to consider wildfire or prescribed burns to be allowed to enter that area (NSW NPWS 2014) may be appropriate.

Increased frequency and duration of drought due to climate change

No continuing decline from drought or the additive effects of drought and fire is apparent in *Eucalyptus approximans*. At Cathedral Rock, substantial drought-induced dieback was observed in 2018 (Phillips *et al.* 2018) before extreme fire consumed the stand in 2019 (NSW NPWS 2022). In 2022, 30 months post-fire, all mature plants at this site were seen to be resprouting strongly and 150-350 seedlings were also recorded (Mitchell-Williams 2022). It is noted that conditions have been wet since the 2019 fire (BOM 2022) and conducive to growth and recovery. Adverse effects from increased drought, especially after fire, is therefore a plausible future threat to *E. approximans* if fire was more regularly followed by drought as this is known to negatively impact other temperate mallee species (Auld *et al.* 1993; Tozer and Bradstock 1997). However, this scenario is yet to come to pass and the predicted lower risk of out-of-season fires in the future (Clarke *et al.* 2011; AdaptNSW 2022) would seem to make these cumulative impacts less likely and slow acting if they did occur.

With its ecological tolerance to fire and drought conferred by the lignotuber, low requirement for seedling recruitment to maintain stand viability and a current distribution determined by the exclusion of competitors through preferences for shallow, infertile soils and fire-prone habitats as opposed to climate tolerances alone (Copeland 2008), it is probable that *Eucalyptus approximans* can tolerate a wider

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climate envelope than it currently occupies. With increased mean temperatures and impacts of drought, it has been predicted through bioclimatic modelling that eucalypts in temperate areas will suffer range contractions and a shift in climatic envelope generally to the south by the year 2085 (Butt *et al.* 2013; Gonzalez-Orozco *et al.* 2016). The magnitude of these contractions is difficult to gauge for some range-restricted eucalypt species such as *E. approximans* though, as the environmental tolerance of many is likely wider than the space they currently occupy as other factors such as competition, disturbance frequency and soil profile define current distributions as opposed to climatic limitations (Hughes *et al.* 1996; Butt *et al.* 2013). Thus, reductions in range and number of mature individuals if they occur by this mechanism are likely to be gradual and based more on dispersal and recruitment limitations, especially with the seasonal climate scenarios predicted for the local region in which *E. approximans* occurs (AdaptNSW 2022). Given this, increased frequency and duration of drought due to climate change remains a plausible future threat but is not considered one that will rapidly drive the species to extinction in a short amount of time.

Assessment against IUCN Red List criteria

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

Criterion A *Population Size reduction*

Assessment Outcome: Criterion not met.

Justification: There is no evidence of a current or historical population reduction for *Eucalyptus approximans*. Given a maximum three generation timespan of c. 210 years, a population size reduction of at least 50% for reversible and ceased causes (A1) or 30% for irreversible or continuing causes (A2, A3 and A4) has not been observed, nor is it predicted with confidence to occur up to 100 years into the future.

Criterion B *Geographic range*

Assessment Outcome: Criterion not met.

Justification: *Eucalyptus approximans* is endemic to two mountain areas near Ebor on the NSW Northern Tablelands and has a very highly restricted geographic distribution. The Extent of Occurrence (EOO) of *E. approximans* has been calculated as 16–66 km², which meets the threshold for listing as Critically Endangered. The Area of Occupancy has been calculated as 20–28 km², meeting the threshold for Endangered. In addition to these thresholds, at least two of three other conditions must be met to qualify for listing under Criterion B. These conditions are:

- The population or habitat is observed or inferred to be severely fragmented or there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

Assessment Outcome: Subcriterion met for Endangered due to having two threat-defined locations.

Justification: *Eucalyptus approximans* is found at two threat-defined locations when considering the most likely threat that may affect currently unaffected

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subpopulations, with this threat being increased frequency and duration of drought due to climate change.

Eucalyptus approximans is not considered severely fragmented as all individuals are found in large, non-isolated subpopulations and all subpopulations are considered viable.

- 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 not met.

Justification: Continuing decline is not evident in the known subpopulations of *Eucalyptus approximans*. The Barren Mountain subpopulation is currently long unburnt (NSW NPWS 2014) and despite dieback being apparent in the midst of extreme drought, reshooting has been noted after rainfall (Phillips *et al.* 2018). Additionally, at Cathedral Rock vigorous resprouting of 100% of mature individuals and presence of relatively substantial number of seedlings has been noted following extreme fire conditions on the back of prolonged drought (Phillips *et al.* 2018; Mitchell-Williams 2022). No clearing of stands is known or predicted as almost all plants are in conservation reserves and the few unreserved plants are in land not conducive to clearing (Copeland 2008). Therefore, no observed, estimated, inferred or projected decline in Extent of Occurrence, Area of Occupancy, extent and/or quality of habitat, number of locations or number of individuals is yet evident. Future declines resulting from the identified threats of changes in fire regime and increased frequency and duration of drought due to climate change are only regarded as plausible future threats as there is not a high degree of certainty that they will take place, not satisfying the definition for continuing decline (IUCN 2022).

- c) Extreme fluctuations.

Assessment Outcome: Subcriterion not met.

Justification: *Eucalyptus approximans* is a long-lived mallee eucalypt and is unlikely to undergo extreme fluctuations.

Criterion C Small population size and decline

Assessment Outcome: Criterion not met.

Justification: The current estimated population for *Eucalyptus approximans* is a minimum of 48,629 mature individuals, exceeding the threshold for Vulnerable.

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

- C1. An observed, estimated or projected continuing decline of at least: 25% in 3 years or 1 generation (whichever is longer) (CR); 20% in 5 years or 2 generations (whichever is longer) (EN); or 10% in 10 years or 3 generations (whichever is longer) (VU).

Assessment Outcome: Subcriterion not met.

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Justification: There is no evidence of continuing decline in mature individuals of *Eucalyptus approximans*, with all subpopulations currently regarded as stable and/or secure (Copeland 2008, 2017; Mitchell-Williams 2022).

C2. An observed, estimated, projected or inferred continuing decline in number of mature individuals.

Assessment Outcome: Subcriterion not met.

Justification: There is no evidence of continuing decline in mature individuals of *Eucalyptus approximans*, with all subpopulations currently regarded as stable and/or secure (Copeland 2008, 2017; Mitchell-Williams 2022).

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: Both subpopulations of *Eucalyptus approximans* have >1000 mature individuals. Barren Mountain has an estimated minimum of 46,381 individuals and Cathedral Rock an estimated minimum of 2,248 individuals.

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

Assessment Outcome: Subcriterion met for Critically Endangered.

Justification: Current knowledge suggests the vast bulk of mature individuals of *Eucalyptus approximans* reside within the Barren Mountain subpopulation, which contains an estimated 93–95% of the total population, meeting the threshold for Critically Endangered.

- b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Subcriterion not met.

Justification: *Eucalyptus approximans* is a long-lived mallee eucalypt and is unlikely to undergo extreme fluctuations.

Criterion D Very small or restricted population

Assessment Outcome: Criterion not met.

Justification: *Eucalyptus approximans* is currently estimated to have a minimum population of at least 48,629 mature individuals.

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

D1. Population size estimated to number fewer than 1,000 mature individuals

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Assessment Outcome: Criterion not met

Justification: *Eucalyptus approximans* is currently estimated to have a minimum population of at least 48,629 mature individuals.

- D2. Restricted area of occupancy (typically <20 km²) 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: *Eucalyptus approximans* occurs at only two threat-defined locations, however it also has an estimated AOO of 20–28 km². Identified plausible future threats of changes in fire regime and increased frequency and duration of drought due to climate change may adversely affect the species sometime in the future, but these effects are likely to be gradual and slow acting if or when they commence. Given the fire and drought tolerance conferred by the lignotuberous habit (Nicolle 2006) and a very high observed survivability rate even after extreme fires following prolonged drought to date (Mitchell-Williams 2022), these threats are considered unlikely to rapidly drive the species to either extinction or a critically endangered status in a very short time after the threats become apparent, which is here considered the maximum allowable timeframe of 100 years into the future given the 70-year generation length of *E. approximans*.

Criterion E Quantitative Analysis

Assessment Outcome: Data deficient.

Justification: Currently there is not enough data to undertake a quantitative analysis to determine the extinction probability of *Eucalyptus approximans*.

Conservation and Management Actions

Eucalyptus approximans 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. *Eucalyptus approximans* currently sits within the Keep-watch management stream of the SoS program.

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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 approximans was found to be Least Concern and thus ineligible for listing as a threatened species as none of the Clauses were met.

Clause 4.2 – Reduction in population size of species (Equivalent to IUCN criterion A)

Assessment Outcome: Clause not met

(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: Clause not met

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,	

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	(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.

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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.
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