Conservation Assessment of *Asterolasia rupestris* subsp. *recurva* B.J.Mole (Rutaceae)

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NSW Threatened Species Scientific Committee

Asterolasia rupestris subsp. *recurva* B.J.Mole (Rutaceae)

Distribution: Endemic to NSW
Current EPBC Act Status: Not listed
Current NSW BC Act Status: Not listed
Proposed listing on NSW BC Act: Critically Endangered

Summary of Conservation Assessment

Asterolasia rupestris subsp. *recurva* was found to be eligible for listing as Critically Endangered under B1ab(iii, v), B2ab(iii, v), and C2a(ii). The main reasons for this listing are: 1) it has an extremely restricted geographic range (AOO/EOO = 4 km^2); 2) the total number of mature individuals is extremely low (115); 3) it is found at only a single location, restricted to a single creek line in the Parlour Mountains northwest of Armidale on the New England Tableland, northern NSW; 4) there is inferred continuing decline in habitat quality as a consequence of increasingly frequent drought and adverse fire regimes; and 5) there is ongoing decline in the number of mature individuals increasingly frequent drought and adverse fire regimes.

Description and Taxonomy

Asterolasia rupestris was described by Mole *et al*. (2002) as:

"Upright shrub to 1.5 m tall. Stems with a stellate indumentum. Leaves shortly petiolate, or frequently sessile; lamina obcordate or obdeltate, 9–20 mm long, 6–15 mm wide, papery, apex emarginate, sometimes truncate, base attenuate, slightly conduplicate, margins recurved or flat; adaxial surface with a dense indumentum of hyaline multiangular stellate trichomes (15–31 trichomes per mm2); abaxial surface cobwebbed with stalked, multiangular stellate trichomes; petiole when present somewhat thickened and flat, often appressed to the stem. Inflorescence a terminal or axillary umbel of 3–5 flowers; peduncles 4–9 mm long; pedicels 6–15 mm long. Sepals inconspicuous, 0.5–1 mm long. Petals 5, elliptic, 5–9 mm long, yellow, abaxial surface with an indumentum of rust coloured stellate trichomes; adaxial surface glabrous. Stamens 10; filaments glabrous; anthers 1–2 mm long, each with a terminal gland. Carpels 5, stellate-tomentose; style glabrous; stigma hemispherical. Cocci beaked. Seed not seen."

Asterolasia rupestris subsp. *recurva* is distinguished from subsp. *rupestris* by the following: Leaf margins recurved (vs flat). Inflorescence an umbel of 3–6 flowers (vs 3–5 flowers); peduncles 4–8 mm (vs 4–6 mm) long; pedicels 8–15 mm (vs 7–10 mm) long. Petals 6–7 mm (vs 5–8 mm) long (Mole *et al*. 2002).

Distribution and Abundance

Asterolasia rupestris subsp. *recurva* is restricted to the Parlour Mountains northwest of Armidale on the New England Tableland, northern NSW. Only one population is known, with all individuals occurring along a single creekline on private freehold land (Mole *et al.* 2002; Copeland 2021). Further searches in potential habitat elsewhere,

including prior surveys of the New England Batholith reported on in Hunter and Clarke (1998) and Hunter (1999), have failed to locate additional populations. Additionally, general flora surveys by staff and students of the University of New England over many years have failed to locate further subpopulations of this taxon (P. Sheringham *in litt* July 2021; L. Copeland *in litt* June 2022).

Mole *et al.* (2002) refer to a record shown in the Australian Virtual Herbarium at a possible second location c. 7 km west of the known extant population. This collection (*NSW 374569, The Parlour, about 6 miles from Booralong, 28.10.1951, G.L.Davies s.n.*) has poor spatial precision (10000 m uncertainty), but 6 miles [9.6 km] from Booralong [likely Booralong Station in 1951] places it approximately in the same vicinity as the known population. This collection is therefore considered to have likely come from the same population as that described by Mole *et al.* (2002).

Population Estimate

There is a minimum estimate of 115 mature individuals for *Asterolasia rupestris* subsp. *recurva,* drawn from the extensive survey conducted by Copeland (2021). The species is restricted entirely to a single extremely small site, the entirety of which was systematically surveyed by Copeland (2021), and so it is likely that the entire population has been surveyed. As a consequence, while 115 is a reliable minimum estimate of mature individuals for the species, it is very unlikely that there are a large number of additional mature individuals that were not surveyed, and this minimum estimate is likely to reflect the maximum estimate for the species. Copeland (2021) also reported juveniles in the population, but these were not thoroughly surveyed. This very small population makes the species particularly vulnerable to stochastic processes.

Area of Occupancy (AOO) and Extent of Occurrence (EOO)

Asterolasia rupestris subsp. *recurva* has an extremely restricted range, known only from a single small population along a short creek line. As a consequence, the Area of Occupancy (AOO) for the species is only 4 km^2.

The extremely restricted range for the species means that Extent of Occurrence (EOO) is also very small, 0.057 km^2, and less than the calculated AOO. Where EOO is less than or equal to AOO then IUCN guidelines recommend EOO estimates be changed to be equal to AOO to ensure consistency with the definition of AOO as an area that fits within EOO (IUCN Standards and Petitions Committee, 2019). As such, EOO used for this assessment is also 4 km^2.

EOO and AOO were estimated based on all records included in Copeland (2021). AOO was calculated by overlaying 2 km x 2 km grid cells over the known occurrence and is the spatial scale of assessment recommended by IUCN (2019). EOO was based on a minimum convex polygon enclosing all known occurrences of the species described by Copeland (2021), the method of assessment recommended by IUCN (2019)**.**

Ecology

Habitat

Mole *et al.* (2002) described habitat for this taxon as "low open forest on skeletal gravelly soils, along gullies". Copeland (2021) added further detail and included floristic co-associates in his description: "layered open forest dominated by Apple Box (*Eucalyptus bridgesiana*), Youman's Stringybark (*E. youmanii*), Silvertop Stringybark (*E. laevopinea*) and New England Blackbutt (*E. andrewsii*). Common shrubs included Grey Teatree (*Leptospermum brevipes*), Blunt Beard-heath (*Leucopogon muticus*) and Broad-leaf Geebung (*Persoonia cornifolia*), while the ground layer was dominated by Silvertop Wallaby Grass (*Rytidosperma pallidum*)". Copeland (2021) stresses that all *Asterolasia rupestris* subsp. *recurva* individuals were within 100 m of a small creek line, but in relatively dry areas and not associated with riparian habitat. Soils were described by him as loamy and derived from acid volcanics, and altitude ranged from 1120-1150 m above sea level. No plants were seen immediately to the west of this population where the geology changes to Parlour Mountains Leucoadamellite, a type of granite.

Notes associated with seven duplicated herbarium collections of this taxon describe habitat as:

- Gentle slope; NW aspect. *Eucalyptus andrewsii* shrubby woodland with *Asterolasia rupestris* and *Caustis flexuosa* [NE 86061, NSW810307; L.M. Copeland, 29 Oct 2005)
- Open forest. Stringybark & Box. Heathy understorey with *Calytrix tetragona*, *Leucopogon virgatus*, *Hakea dactyloides*, *Dodonaea boroniifolia*, *Grevillea ramosissima*, *Acacia buxifolia* (NE 80879, MEL 2068579A, MEL 2208066A, MEL 2208068A, MEL 2208069A; B.J. Mole, 20 Oct 1998)

Reproductive Ecology and Life History

There has been no targeted study of reproductive ecology in *Asterolasia rupestris* subsp. *recurva*; however, insights can be gained from studies in related *Asterolasia* species.

Pollination and seed dispersal

Armstrong (1979) indicated that *Asterolasia* flowers are generally insect-pollinated, with most visitors noted to be beetles and occasionally flies and bees, and this is likely to also be true of *Asterolasia rupestris* subsp. *recurva*. Seeds in *Asterolasia* are generally dispersed ballistically in combination with gravity or water, and species in the Sydney region are also known to be dispersed by ants, although distances are likely to be less than ten metres (Auld 2001).

There is no evidence for fragmentation in *Asterolasia rupestris* subsp. *recurva.* All known individuals occur in a single, extremely restricted subpopulation, and as a consequence all individuals are likely to be able to freely breed and disperse within this area.

Fire, germination, and seed dormancy

There has been no targeted study of reproductive ecology in *Asterolasia rupestris* subsp. *recurva*; however, field observations and studies in related *Asterolasia* species strongly indicate the species is likely a fire obligate seeder, with adult plants also able to resprout following low-severity fire.

Population structure and site history for *Asterolasia rupestris* subsp. *recurva* suggest it is likely that the majority of the current cohort germinated in response to the last

known fire at the site in 1982, and are now over 40 years old (Benson and McDougall 2001; Copeland 2021). Similar *Asterolasia* species live from 20-40 years, which is likely also true for *Asterolasia rupestris* subsp. *recurva*, and so plants in the current cohort may be approaching natural senescence, while the population has lacked subsequent fires necessary to rejuvenate the population (Benson and McDougall 2001; Copeland 2021).

Germination in related *Asterolasia* species is promoted by fire, and this appears to also be true of *Asterolasia rupestris* subsp. *recurva*. Seed of the related *Asterolasia buxifolia* was found to be physiologically dormant, requiring smoke and winter temperatures for germination, and because ready access to light was also required, burial just below or at the soil surface was also necessary (Collete and Ooi 2017). Similarly, seed dormancy in *Asterolasia elegans* was found to be broken by seed heating (Auld et al. 2001). Scott (1994, cited in Auld 2001) found *Asterolasia elegans* populations to be structured based on a single post-fire recruitment event, with the species relying on post-fire seed germination to maintain populations, a pattern also seemingly apparent in *Asterolasia rupestris* subsp. *recurva*. As a consequence, while *A. elegans* is seemingly dependant on fire for germination, it also requires a sufficiently long fire-free interval for plants to mature and replenish its soil seedbank. Too frequent fire is then considered to be a threat to *A. elegans*, a pattern likely to also be seen in *Asterolasia rupestris* subsp. *recurva.*

Auld *et al.* (2000) found moderate levels of seed dormancy in the related *Asterolasia elegans* at seed release, with the non-dormant seed fraction decaying over time. Dormant seeds showed no evidence of decay over a two-year period, implying the establishment of a relatively long-lived persistent soil seedbank in this related species, which is likely also true for *Asterolasia rupestris* subsp. *recurva*.

Life History and Generation length

Generation length for *Asterolasia rupestris* subsp. *recurva* is unknown. IUCN (2022) offer 6 alternatives for estimation of generation length, with option 6 suitable for plants with seed banks. Under this option, generation length = “juvenile period + either the half-life of seeds in the seed bank or the median time to germination, whichever is known more precisely. Seed bank half-lives commonly range between <1 and 10 years.” Soil seedbank half-life, and median time to germination, are unknown in this taxon, but the common half-life range suggests a potential generation length of between 4 and 13 years. Other comparable *Asterolasia* species live between 20-40 years, and this is likely also true of *Asterolasia rupestris* subsp. *recurva.*

Threats

The main threats affecting *Asterolasia rupestris* subsp. *recurva* are; an increased likelihood and impact of drought as a consequence of anthropogenic climate change, adverse fire regimes, habitat degradation as a consequence of feral mammals, and root-rot, *Phytophthora cinnamomi.* Of these ‘*Anthropogenic Climate Change*’, ‘*Competition and habitat degradation by Feral Goats, Capra hircus Linnaeus 1758’*, and ‘*Infection of native plants by Phytophthora cinnamomi*’ are listed as Key Threatening Processes (KTPs) under the New South Wales Biodiversity Conservation Act (NSW BC Act).

The single, very small population, and extremely restricted distribution of *Asterolasia rupestris* subsp. *recurva* means that all threats are likely to threaten all individuals across the entire range of the species.

Increased likelihood and impact of drought as a consequence of anthropogenic climate change

Drought has been observed to severely impact *Asterolasia rupestris* subsp. *recurva* and is likely to pose an ongoing and increasingly severe threat for the species. Drought in the region in 2018-2019 severely affected the population, causing mortality in mature individuals, and reduction of general health, including death of limbs in the rest of the population (Copeland 2021). Observers did not record the number of mature individuals lost during this period, but reports were from reliable experts on the species (Copeland 2021). Some recovery via basal resprouting with the return to wetter conditions was observed during surveys in October 2021. However, high incidence of recurrent drought may pose a risk to the long-term stability of this taxon and population.

While there is broad uncertainty around specific values, climate projections consistently predict drought to become more severe, and likely more frequent across NSW, including across the range of *Asterolasia rupestris* subsp. *recurva* (Herold et al., 2021; Kirono et al., 2020; NESP Earth Systems and Climate Change Hub, 2020; Shi et al., 2020).

While NARCLIM projections predict that while there is likely to be a 0.63 – 3.07% increase in rainfall across the range of *Asterolasia rupestris* subsp. *recurva* between 2020-2069, this is likely to also be accompanied by a rise in average temperature of 0.79 - 2.24^{o}c, and an increase in 0.62-3.81 days of extreme heat (>35^{o}c) over the same period; predictions closely resembling those provided for the region by CSIRO, who also predict drought for the area as being increasingly likely over this period (CSIRO and the Bureau of Meteorology 2022; CSIRO 2023; Nishant et al. 2022).

Mortality and decline in health of plants associated with drought is also likely to interact with fire events, making the population more susceptible to fire, and less likely to recover than during non-drought periods.

Adverse fire regimes

There has been no targeted study of appropriate fire regimes for *Asterolasia rupestris* subsp. *recurva*. However, observations of the known population, and studies in other *Asterolasia* species provide evidence that while fire is likely necessary for germination, adverse fire regimes pose an ongoing threat to *Asterolasia rupestris* subsp. *recurva*, with too infrequent, too frequent, and high severity fire all likely to negatively affect mortality and recruitment.

Future fire regimes for the range of *Asterolasia rupestris* subsp. *recurva* are difficult to determine, however fire in Australia is generally predicted be more frequent and more severe in the future as a consequence of rising average temperatures (Canadell et al., 2021; Department of Agriculture, Water, and the Environment 2022). Increased frequency of drought is also likely to contribute to an increase in the frequency and severity of fire across the range of *Asterolasia rupestris* subsp. *recurva*.

Conversely, *Asterolasia rupestris* subsp. *recurva* is confined to private land generally managed to reduce the frequency of fire, which also poses a severe threat for the species, which requires fire to prompt germination and remove older plants as they reach senescence.

Long fire intervals
In closely related *Asterolasia* species fire is necessary for seed germination and population transition as individuals age, with very little germination outside of fire events, and this is likely also true of *Asterolasia rupestris* subsp. *recurva* (Auld et al. 2001; Benson and McDougall 2001; Copeland 2021). Without sufficiently frequent fire there will be no germination, while the existing population will senesce, restricting reproduction and resulting in ongoing population decline.
Asterolasia rupestris subsp. *recurva* is confined to private land where fire is restricted. The last significant fire occurred in the area in 1982 (P. Sheringham *in litt*), and it is likely that this event triggered germination of the current cohort of plants. As a consequence these plants are around 40 years old, and may soon start to naturally senesce, with fire required to rejuvenate the population.

Short fire intervals
As with other *Asterolasia*, it is suspected that fire is needed to break dormancy in the soil seed bank for *Asterolasia rupestris* subsp. *recurva.* However, too frequent fire events are likely to kill offspring and deplete the seedbank, preventing successful reproduction. Seedlings are likely to be fire sensitive, killed by repeat fire events prior to reaching a sufficient size to survive or resprout. Similarly, while fire is likely required for germination, the population requires a sufficiently long fire-free interval for individuals to mature and replenish its soil seedbank; too frequent fire will cause seeds to germinate, but kill the new cohort before it has the opportunity to reach maturity and produce seed.

High severity fire
While fire is likely necessary for germination and population rejuvenation in *Asterolasia rupestris* subsp. *recurva,* high severity fire may have the opposite effect, killing both mature plants and seeds and preventing recovery through either resprouting or seed germination (Le Breton et al., 2023). While seeds of obligate seeders like *Asterolasia rupestris* subsp. *recurva* are likely to be able to withstand high temperatures consistent with fire events (Collete and Ooi 2017), sufficiently severe fire may kill seeds in the soil rather than prompt germination (Le Breton et al., 2023). There is currently no research into fire severity and seed mortality in *Asterolasia rupestris* subsp. *recurva*. Similarly, resprouting from the base of adult plants has been observed following drought (Copeland 2021), and it is likely that a similar response would occur after low and moderate intensity fire. However, if fire is too severe it is likely to kill plants outright, and prevent resprouting.

While loss of mature plants to fire is a normal part of life history and population dynamics for obligate seeders, the loss of a high percentage of mature individuals during severe fires, combined with death of seeds in the seed bank, means that germination following these fire events may not be sufficient to replace those mature individuals that have been lost, and the population will continue to decline with each successive fire event.

Fire is likely to become more severe across the range of *Asterolasia rupestris* subsp. *recurva,* regardless of whether fire becomes more frequent as a consequence of increased temperatures and drought, or remains infrequent as a result of private land management. Increased temperature and drought cause fires to become generally more severe, while infrequent fire may increase fuel loads, meaning that when fires do finally occur, they will have more fuel to burn, and will be more severe as a result.

Habitat degradation as a consequence of feral mammals – pigs (*Sus scrofa*) and goats *(Capra hircus*)

While pigs and goats do not currently appear to directly impact *Asterolasia rupestris* subsp. *recurva,* they have been observed near the population, and pose an ongoing threat. Copeland (2021) noted evidence of feral pig foraging near the western extent of the population, while goat populations are known throughout the wider area and have been reported grazing on other threatened plant species (Copeland 2021).

Feral pigs and goats are broadly distributed across Australia, including throughout NSW, and pose a severe ongoing threat to a wide variety plant species and ecosystems, including *Asterolasia rupestris* subsp. *recurva* (Copeland 2021; Department of Sustainability, Environment, Water, 2005). Both pigs and goats degrade habitat, with pigs wallowing and damaging watercourses and riparian habitat, and goats directly grazing on and trampling native plants (Department of Sustainability, Environment, Water, 2005). The impact of these species both contribute to ongoing erosion and degradation of surrounding habitat, as well as spreading weed species on their fur and in dung, and potentially serving as a vector for disease like *Phytophthora cinnamomi* (Department of Sustainability, Environment, Water, 2005; Government of South Australia Phytophthora Technical Group, 2006).

Root-rot, *Phytophthora cinnamomi*

Phytophthora cinnamomi is an introduced water mould (oomycete) pathogen that has had a devastating effect on plant communities worldwide, causing catastrophic dieback in many species, and is listed as the Key Threatening Process 'Dieback caused by the root-rot fungus *Phytophthora cinnamomi*' on the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and 'Infection of native plants by *Phytophthora cinnamomi*' on the NSW BC Act. *Phytophthora cinnamomic* dispersed through flowing water or runoff from infected soil, or soil clinging to cars, people, or animals (Commonwealth of Australia, 2014).*Phytophthora cinnamomi* is thought to be widely spread across NSW, particularly on the east coast, but the total extent of its spread is unknown.

Phytophthora cinnamomi affects a huge variety of plants across families, including severely affecting the closely related *Asterolasia phebalioides,* and moderately affecting *A. buxofolia*, and so is likely to also pose a considerable threat to *Asterolasia rupestris* subsp. *recurva* (Government of South Australia Phytophthora Technical Group, 2006; NSW Department of Environment and Climate Change, 2008; Reiter et al., 2004; Wan et al., 2019).

Assessment against IUCN Red List criteria

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

Criterion A *Population Size reduction*

Assessment Outcome: Data Deficient

Justification: There is insufficient population data to determine potential rate of future decline in *Asterolasia rupestris* subsp. *recurva*. There have only been two surveys of the species, one in 2002, and the second in 2021. Although initial assessments estimating 30-40 individuals (Mole *et al*. 2002) differed from the recent count of 115 individuals by Copeland (2021), this apparent increase in number is affected by different count methods and search areas, and cannot be used to determine population dynamics or patterns of decline in the species.

Criterion B *Geographic range*

Assessment Outcome: Critically Endangered under B1ab(iii, v), B2ab(iii, v)

Justification: *Asterolasia rupestris* subsp. *recurva* is completely restricted to a single, tiny population on a creek line in the Parlour Mountains, northern NSW. As a consequence, both EOO and AOO for *Asterolasia rupestris* subsp. *recurva* are 4 km^2, below the threshold for Critically Endangered for Criterion B1 (EOO <100 km2) and for B2 (AOO < 10 km2).

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 there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

   Assessment Outcome: Condition Met for Critically Endangered – 1 threat location

   Justification: The single, very small mature population (115), and extremely restricted distribution (AOO/EOO = 4 km2) of *Asterolasia rupestris* subsp. *recurva* means that all active and plausible threats describe a single threat location for the species. The active threats of mortality and habitat degradation as a result of drought, and adverse fire regimes, and the serious plausible threats of habitat degradation by feral mammals and infection with *Phytophthora cinnamomi* are likely to threaten all individuals across the entire species range.

   The *Asterolasia rupestris* subsp. *recurva* population is not considered to be severely fragmented, as all known plants occur within a highly restricted area along a 600 m stretch of creek vegetation within a larger area of contiguous vegetation.

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: Condition met - continuing decline is inferred in (iii) area, extent and/or quality of habitat, and (v) number of mature individuals.

   Justification: There is inferred decline in both the quality of habitat available to *Asterolasia rupestris* subsp. *recurva*, and the number of mature individuals as a consequence of drought and adverse fire regimes. Drought in the region in 2018-2019 severely affected the population, causing mortality in mature

individuals, and reduction of general health, including death of limbs, in the rest of the population (Copeland 2021). While there is broad uncertainty around specific values, climate projections consistently predict drought to become more severe, and likely more frequent across NSW, including across the range of *Asterolasia rupestris* subsp. *recurva*, likely leading to ongoing mortality of mature individuals as seen in the 2018-2019 drought, and a decline in the quality of available habitat as it becomes increasingly arid during these periods (CSIRO and the Bureau of Meteorology 2022; CSIRO 2023; Herold et al., 2021; Kirono et al., 2020; NESP Earth Systems and Climate Change Hub, 2020; Shi et al., 2020). Mortality and decline in health of plants associated with drought is also likely to interact with fire events, making the population more susceptible to fire, and less likely to recover than during non-drought periods.
Adverse fire regimes are also inferred to cause a decline in both the quality of habitat available to *Asterolasia rupestris* subsp. *recurva*, and the number of mature individuals. While fire is likely necessary for germination, adverse fire regimes pose an ongoing threat, with too infrequent, too frequent, and high severity fire all likely to severely affect mortality and recruitment. Future fire regimes for the range of *Asterolasia rupestris* subsp. *recurva* are difficult to determine, however fire in Australia is generally predicted be more frequent and more severe as a consequence of rising average temperatures, while simultaneously being restricted by land management at the site at which *Asterolasia rupestris* subsp. *recurva* occurs (Canadell et al., 2021; Department of Agriculture, Water, and the Environment 2022).

Without sufficiently frequent fire there will be no germination, while the existing population will senesce, restricting reproduction and resulting in ongoing population decline. Conversely, while fire is likely required for germination, the population requires a sufficiently long fire-free interval for individuals to mature and replenish its soil seedbank; too frequent fire will cause seeds to germinate, but kill the new cohort before it has the opportunity to reach maturity and produce seed.

While loss of mature plants to fire is a normal part of life history and population dynamics for obligate seeders, the loss of a high percentage of mature individuals during severe fires, combined with death of seeds in the seed bank, means that germination following these fire events may not be sufficient to replace those mature individuals that have been lost, and the population will continue to decline with each successive fire event.

The species is completely restricted to a single, tiny population on a creek line in the Parlour Mountains, northern NSW, and as a result these threats are both likely to affect the entire population and all occupied habitat (Copeland 2021).

c) Extreme fluctuations.
Assessment Outcome: Not Met

Justification: There is no evidence for extreme fluctuations *Asterolasia rupestris* subsp. *recurva*. The species is likely long-lived, with the current

cohort having germinated following the last fire in 1982. Recruitment is thought to be tied to fire events, with no fluctuations in population size other than cyclic germination events following fire.

Criterion C Small population size and decline

Assessment Outcome: Critically Endangered under C2 a (ii) and endangered under C2 a (i)

Justification: There is a minimum estimate of 115 mature individuals for *Asterolasia rupestris* subsp. *recurva,* below the threshold for listing as Critically Endangered (<250) under C. The thoroughness of the population survey means that it is very unlikely that there are a large number of additional mature individuals in the population, and so this minimum estimate is likely to also very closely reflect the maximum population estimate for the species.

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: Data Deficient

Justification: There is insufficient population data to determine potential rate of future decline in *Asterolasia rupestris* subsp. *recurva*. There have only been two surveys of the species, one in 2002, and the second in 2021. Although initial assessments estimating 30-40 individuals (Mole *et al*. 2002) differed from the recent count of 115 individuals by Copeland (2021), this apparent increase in number is affected by different count methods and search areas, and cannot be used to determine population dynamics or patterns of decline in the species.

Copeland (2021) noted the death of some mature individuals and clear decline in the health of the remaining population as a consequence of drought, a threat likely to increase in the future, and also noted that senescence was likely across the population in the absence of fire. While these threats are predicted to continue and likely worsen in the future, this study did not record the number of individuals lost, in decline, or senescing, and as such no specific numeric estimates can be made for these trends in the future.

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

Assessment Outcome: Met

Justification: Observed and predicted drought is inferred to cause ongoing decline in the number of mature individuals for *Asterolasia rupestris* subsp. *recurva*. Drought in the region in 2018-2019 severely affected the population, causing mortality in mature individuals, and reduction of general health, including death of limbs, in the rest of the population (Copeland 2021). While there is broad uncertainty around specific values, climate projections consistently predict drought to become more severe, and likely more frequent

across NSW, including across the range of *Asterolasia rupestris* subsp. *recurva*, likely leading to ongoing mortality of mature individuals as seen in the 2018-2019 drought (CSIRO and the Bureau of Meteorology 2022; CSIRO 2023; Herold et al., 2021; Kirono et al., 2020; NESP Earth Systems and Climate Change Hub, 2020; Shi et al., 2020). Mortality and decline in health of plants associated with drought is also likely to interact with fire events, making the population more susceptible to fire, and less likely to recover than during non-drought periods.

Adverse fire regimes are also inferred to cause a decline the number of mature *Asterolasia rupestris* subsp. *recurva*. While fire is likely necessary for germination, adverse fire regimes pose an ongoing threat, with too infrequent, too frequent, and high severity fire all likely to severely impact mortality and recruitment. Future fire regimes for the range of *Asterolasia rupestris* subsp. *recurva* are difficult to determine, however fire in Australia is generally predicted be more frequent and more severe as a consequence of rising average temperatures, while simultaneously being restricted by land management at the site at which *Asterolasia rupestris* subsp. *recurva* occurs (Canadell et al., 2021; Department of Agriculture, Water, and the Environment 2022).

Without sufficiently frequent fire there will be no germination, while the existing population will senesce, restricting reproduction and resulting in ongoing population decline. Conversely, while fire is likely required for germination, the population requires a sufficiently long fire-free interval for individuals to mature and replenish its soil seedbank; too frequent fire will cause seeds to germinate, but kill the new cohort before it has the opportunity to reach maturity and produce seed.

While loss of mature plants to fire is a normal part of life history and population dynamics for obligate seeders, the loss of a high percentage of mature individuals during severe fires, combined with death of seeds in the seed bank, means that germination following these fire events may not be sufficient to replace those mature individuals that have been lost, and the population will continue to decline with each successive fire event.

The species is completely restricted to a single, tiny population on a creek line in the Parlour Mountains, northern NSW, and as a result these threats are both likely to affect the entire population and all occupied habitat (Copeland 2021).

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: Met for Endangered (≤250 individuals)

Justification: There is a minimum estimate of 115 mature individuals for *Asterolasia rupestris* subsp. *recurva*, below the threshold for listing as Endangered (≤250) under C2 a(i).

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

Assessment Outcome: Critically Endangered (90-100%)

Justification: There is only one known population of this taxon occurring within a 600m stretch of creekline. All mature individuals consequently occur in a single sub-population.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Data Deficient

Justification: There is no evidence for extreme fluctuations *Asterolasia rupestris* subsp. *recurva*. The species is likely long-lived, with the current cohort having germinated following the last fire in 1982. Recruitment is thought to be tied to fire events, with no fluctuations in population size other than cyclic germination events following fire.

Criterion D Very small or restricted population

Assessment Outcome: Met for Endangered D and Vulnerable D2

Justification: There is a minimum estimate of 115 mature individuals for *Asterolasia rupestris* subsp. *recurva,* below the threshold for listing as Endangered (<250) under D. The thoroughness of the population survey means that it is very unlikely that there are a large number of additional mature individuals in the population, and so this minimum estimate is likely to also very closely reflect the maximum population estimate for the species.

Even though Criterion D is met for EN, Criterion D2 needs to be additionally and independently assessed, as it is relevant to Clause 4.7 of the NSW Biodiversity Conservation Regulation 2017. The highest threat category for Criterion D2 is Vulnerable.

To be listed as Vulnerable under D2, a species must meet at least one of the two following conditions:

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: Met for Vulnerable D2

Justification: *Asterolasia rupestris* subsp. *recurva* is only known from a single, tiny population (AOO/EOO 4 km^2), restricted to a 600 m length of creek line in the Parlour Mountains, northern NSW, and a result a single threat could potentially easily affect the entire population. In particular, a severe and ongoing drought, or a single severe fire could plausibly drive the species to extinction in a single generation.

Criterion E Quantitative Analysis

Assessment Outcome: Data Deficient

Justification: No population viability analysis has been conducted for *Asterolasia rupestris* subsp. *recurva*.

Conservation and Management Actions

This species is currently not listed on the NSW *Biodiversity Conservation Act 2016.* Following publication of a Final Determination by the NSW Threatened Species Scientific Committee, a conservation project will be developed by the NSW Department of Planning and Environment under the Saving our Species (SoS) program. The conservation project will identify priority locations, critical threats and required management actions to secure the species in the wild for the next 100 years.

Some suggested actions are provided here.

Population monitoring

- Increased and ongoing population monitoring is required to determine population dynamics in the species and provide clear data around loss of mature individuals

Habitat loss, disturbance and modification

- ensure that the locations of all individuals are recorded on relevant state databases, including those used by land management and fire response agencies
- protect individuals near tracks (current or future) from trampling and accidental damage using signage, track markers or fencing

Invasive species

- monitor feral goat populations in the area, and install fencing if shown to be negatively impacting on individuals of their habitat
- monitor feral pig populations in the area, and install fencing if shown to be negatively impacting on individuals of their habitat

Ex situ conservation

- develop a targeted seed collection program for ex situ seed banking
- explore the feasibility of establishing an ex situ translocation population in accordance with the Guidelines for the Translocation of Threatened Plants in Australia (Commander et al. 2018). Monitor all translocated individuals to maturity, seed set and recruitment to ensure they are viable and are contributing to a reduction in the extinction risk of the species

Fire impacts

- undertake research to enable development of an appropriate fire regime for the taxon, focusing particularly on the impacts of frequent recurrent fire and the resilience of the soil seed bank

Disease impacts

- undertake research to determine the susceptibility of *Asterolasia rupestris* subsp. recurva and its habitat to Phytophthora

- monitor for presence of Phytophthora within the population, and introduce sanitary controls if necessary

Stakeholders

- inform landowners and managers of sites where there are known populations and consult with these groups regarding options for conservation management and protection of the species
- where research identifies potential habitat for the species in areas that are privately owned, liaise with landholders to provide information on the species and its habitat requirements, and encourage reporting of any sightings

Survey and Monitoring priorities

- monitoring for increased habitat degradation
- undertake regular surveys to determine whether there is a decline in the population
- monitoring for recruitment/herbivory/illegal collections

Information and Research priorities

- identify an optimal fire regime for the taxon by assessing population-level responses to a range of fire regimes and modelling population viability across all fire scenarios
- investigate the presence of feral goat and determine if they are likely to pose a direct threat to the taxon in riparian habitat
- investigate the ecological requirements of *Asterolasia rupestris* subsp. recurva that are relevant to persistence and recruitment, including
  - reproductive status, longevity, fecundity, and frequency and size of recruitment events.
  - soil seed bank dynamics, particularly the longevity of seed in the soil seed bank.
  - the effect of drought on mortality rates of the species.
  - pollinator identity, biology and requirements.
  - population genetic structure, levels of genetic diversity and minimum viable population size.

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Expert Communications

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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: Critically Endangered under Clause 4.3 (a)(d)(e, i, iii) and 4.4 (a)(d, i),(e, i, ii (A, I)(B))

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Data Deficient

(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: Critically Endangered 4.3 (a)(d)(e, i, 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: Critically Endangered under 4.4 (a)(d, i),(e, i, ii (A, I)(B))

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: Endangered under 4.5 (b)

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: Met for Vulnerable under D2

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.