**Conservation Assessment of *Persoonia glaucescens* Sieber ex Spreng. (Proteaceae)**

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***Persoonia glaucescens* Sieber ex Spreng. (Proteaceae)**

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

Proposed listing on NSW BC Act: List as Vulnerable

Reason for change: Non genuine change based on improved knowledge of the distribution and abundance of the species.

## Summary of Conservation Assessment

*Persoonia glaucescens* was found to be eligible for listing as Vulnerable under Criterion B1ab(i)(ii)(iii)(v) + B2ab(i)(ii)(iii)(v) + C2a(i)

The main reasons for this species being eligible are:

i) it has a highly restricted geographical range (EOO1,005 $km^2$),
ii) it exists at 7 threat-defined locations,
iii) it has a small population size (c. 2200), and
iv) there is an inferred continuing decline from vegetation clearing and degradation on private and roadside land and browsing of seedlings by deer and a projected continuing decline from high fire frequency, high fire severity and habitat loss from increased annual temperatures from climate change.

## Description and Taxonomy

*Persoonia glaucescens* Sieber ex Spreng. (Proteaceae), also known as Mittagong Geebung, is a medium to tall woody shrub (PlantNET 2022). It is described by PlantNET (2022) as an "erect shrub, young branchlets moderately hairy. Leaves oblanceolate or narrow-spathulate, 3-8 cm long, 4-18 mm wide, flat, sparsely hairy and strongly pruinose when young, glabrescent when mature, smooth. Inflorescences growing on into a leafy shoot, flowers mostly subtended by leaves, pedicels 1-3 mm long, erect, moderately hairy. Tepals 11-12 mm long, acuminate to caudate, sparsely to moderately hairy. Ovary glabrous. It is found in woodland to dry sclerophyll forest on sandstone; from Picton to Berrima".

*Persoonia glaucescens* was first described by Franz Sieber as *P. glaucescens* in 1827, before Stephan Endlicher reclassified it as a subspecies of *P. lanceolata* in 1848. Peter Weston observed that it grew together with *P. lanceolata* in the Balmoral-Hilltop area and did not appear to hybridise with it, and hence concluded it should be raised to species status again (Weston 1995). Since, possible hybrids have been observed in the Hilltop and UNSCA areas (BioNet SJJSI1021092, SDMP00012711).

*Persoonia lanceolata* is morphologically similar to *P. glaucescens* and occurs in the same area, however, the two species can be differentiated by their leaf coating. *Persoonia glaucescens* has leaves that are strongly pruinose (having a white powdery

covering), especially when juvenile, whereas the leaves of *P. lanceolata* are not pruinose. *Persoonia glaucescens* leaves are more elongated in shape than *P. lanceolata* and the leaf margins and young stems are red (NSW NPWS 2000a). *Persoonia lanceolata* has been recorded in the same areas as *P. glaucescens* near Hilltop, Buxton and on the western side of Upper Nepean State Conservation Area (UNSCA).

**Distribution and Abundance**

The NSW Scientific Committee (2002) state that "The species is a NSW endemic restricted to approximately 19 small and fragmented populations in the Southern Highlands of NSW roughly between Picton and Berrima." The historical distribution places the northern limit at Couridjah/Thirlmere Lakes National Park, the southern limit at Fitzroy Falls, the eastern limit in UNSCA and the western limit at the locality of High Range. The current distribution is smaller with the southern limit near Berrima as the species has not been found at Fitzroy Falls for over 100 years or at Kangaloon for over 20 years. The northern limit remains at Couridjah (Schlunke 2022) despite a past report that it had contracted a few kilometres south to Buxton (NSW NPWS 2000a).

Since the original Final Determination (NSW Scientific Committee 2002) there have been many targeted and non-targeted surveys that have recorded hundreds of new occurrences of *P. glaucescens* across its range (Figure 1 in Appendix II). In 2018 a long-term, plot-based monitoring program was established under the NSW Government Saving Our Species (SOS) program that consists of 24, 50 m x 50 m plots at five priority managements sites at Bargo SCA, Jellore (Joadja), Mt Alexandra (Nattai Creek and Braemar), Welby and UNSCA (Schlunke 2021).

The current distribution estimate is based on 4,331 unique records. Of these, 1,918 records were compiled from the Atlas of Living Australia, the NSW BioNet Atlas and herbarium specimens, 1,846 records from SOS monitoring plots (2018 to 2021) and 567 records from 2022 surveys (Schlunke 2022). The georeferences of 9 records were revised based on their descriptions. The current distribution does not include the 1901 record from Fitzroy Falls as *P. glaucescens* has not been recorded from that area since that time.

Area of Occurrence and Extent of Occurrence

The Area of Occurrence (AOO) is 284 $km^2$ based on 2 x 2 km grid cells, the scale recommended for assessing area of occupancy by IUCN (2022). The Extent of Occurrence (EOO) is 1,005 $km^2$ is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). The EOO and AOO were calculated using Kew Geospatial Conservation Assessment Tool (GeoCAT; Bachman *et al.* 2011) and encompass the entire known historical and extant distribution of the species, except the 1901 Fitzroy Falls record. The AOO is likely to be an underestimate as most survey effort in NPWS reserves and Crown Land has been restricted to fire trails and there is much potential habitat in between trails. However, large clusters of *P. glaucescens* plants are unlikely to be found in bushland areas as very few individuals are found away from tracks and trails (L. Hook pers. comm. February 2022). The distribution of *P. glaucescens* has both a linear extent and width of approximately 40 km.

Population Size

The total population size for *P. glaucescens* is uncertain but is estimated to be approximately 2,200. The estimated population size is more than double the estimate of "as low as 805" made in the 2002 Final Determination (NSW Scientific Committee 2002). This increase in estimated population size reflects new information from surveys and not an increasing trend over time. Similarly, in 2002 the population was considered "highly fragmented", however new information indicates the species has a more continuous distribution with the largest number of records found in bushland west of Bargo. The population size estimate of *P. glaucescens* can be broken down by geographical area (Table 1 in Appendix II):

1. Couridjah: estimated number of mature individuals is six (Schlunke 2022).

2. Greater Bargo to Wilson Drive: estimated number of mature individuals is approximately 500. *Persoonia glaucescens* has been recorded from approximately 19 km of fire trails traversing a mix of Crown and private land west of the township of Bargo and east of Bargo River, 5 km of Fire Road P1 in Bargo River SCA and an additional 21 historic record sites scattered on Crown and private land north, south and west of the township.

3. Bargo SCA and Nattai NP (between Hilltop and Buxton, west of Wilson Drive): estimated number of mature individuals is approximately 280. *Persoonia glaucescens* has been recorded along 22 km of fire trails, including Little River, Moore Creek, Wattle Ridge, Seabrook and Bollins, W11 and Buxton West.

4. Joadja (along Wombeyan Caves Road): estimated number of mature individuals is approximately 400. The majority of *P. glaucescens* records are from Crown and private land adjacent to the Wombeyan Caves Road near Joadja and Borehole Creeks. There are additional records on the Joadja East, Joadja South and Barracks fire trails.

5. Mittagong and Braemar: estimated number of mature individuals is approximately 600. In Mittagong *P. glaucescens* has been recorded in the Box Vale Tramway Reserve near Nattai Creek and on Crown Land at Welby. A historic *P. glaucescens* record at Ironmines Oval could not be relocated in searches in 1999 and 2001 and is assumed extirpated. At Braemar *P. glaucescens* has been recorded at the sewage treatment plant and nearby Crown Land reserve.

6. Upper Nepean: estimated number of mature individuals is approximately 300. Most records are from the Sydney water catchment Special Areas land south of UNSCA between Fire Roads 1A, 2, 2A, 3 and the Tourist Road. There are six records from the southwest edge of UNSCA near Fire Roads 3 and 3E.

7. Hilltop, Colo Vale and Berrima: At Hilltop the estimated number of mature individuals is 35. At Colo Vale the estimated number of mature individuals is 14 at four sites. At Berrima the estimated number of mature individuals is approximately 60 individuals. *Persoonia glaucescens* only occurs in very small, isolated clusters around these townships.

The total population size estimate is a collation of the most recent count data from all records, including SOS monitoring plot data (Table 1; Figure 2 in Appendix II), an estimate of number of individuals at sites without count data and a proportion of the current crop of seedlings assumed to survive to maturity. In this conservation assessment a site is defined as a geographically distinct area that may contain one or more occurrences of *P. glaucescens* in close proximity. The methods used to estimate population size from records and monitoring data are as follows:

a. Records from sites with population and age class data – numbers included as stated. Where only seedlings were recorded it has been assumed that only one seedling at a GPS point record or nearby cluster of GPS point record <10 m apart will survive to maturity irrespective of whether one or more seedlings were recorded. This assumption has been used as no correlation was found in SOS monitoring plots between the total number of mature plants and the number of seedlings that emerged in the recruitment event of 2021 (Figure 3 in Appendix 2; Schlunke 2021). The approach aims to balance the likelihood that some isolated single seedlings will survive to maturity and many seedlings from a cluster of seedlings will not survive.

b. Data from SOS monitoring plots with recent (2019 and 2020) fires - population size count included as number of mature individuals prior to fire (Figure 2 in Appendix II). SOS monitoring plots were burnt or partially burnt in the Bargo area by the 2019-20 Green Wattle Fire and in Upper Nepean and Welby in 2019 or 2020 by hazard reduction burns. All burnt plots, except three in UNSCA, had seedling recruitment and are expected to recover to, or exceed, pre-fire population size.

c. Records prior to 2019-20 fires from sites with no population data – assigned as five mature individuals, which is the mean of all *P. glaucescens* record sites with recorded counts of up to 25 individuals. This assumption was used as most isolated record sites of *P. glaucescens* are of very small numbers or single plants.

d. Records prior to 2019-20 fires from sites with count data that does not distinguish between mature and immature plants - assumed to be mature plants. In the five years prior to 2020 very few seedlings were observed (L. Hook pers. comm. February 2022).

e. Records post 2019-20 fires in burnt areas (NPWS fire history spatial layer) - assumed to be seedlings unless stated as mature individuals, as fire kills mature adults.

Over one-third of the population of *Persoonia glaucescens* is known from conservation reserves or catchment Special Area land in planning to become a conservation reserve. This is a significant change in knowledge from the 2002 Final Determination (NSW Scientific Committee 2002), which stated that “Only two populations supporting a total of approximately 50 individuals occur within a conservation reserve (Nattai National Park).” It is now estimated that 14% of the population occurs within the conservation reserves Nattai NP, Bargo SCA, Bargo River SCA and UNSCA. *P. glaucescens* in Bargo SCA and Nattai NP and on the western side of UNSCA are included in Assets of Intergeneration Significance Declared Land areas. A further 8%

of the population is found in Mt Alexandra Crown Reserve on the western side of Mittagong, approximately 20 plants occur in a Crown Reserve at Berrima (1%), six plants occur in a Crown Reserve in Couridjah, 13% of the population is in the Sydney water catchment Special Area land south of UNSCA and 18% in the Sewage Treatment Plant near Braemar. The Upper Nepean catchment Special Area land is in planning to be made part of the SCA. 33% of the population occurs on unreserved Crown Land and 12% occurs on roadside, railway or private land. Large areas of Crown Land surrounding Bargo River, north of Bargo River SCA, has been nominated for National Parks conservation, however, is currently under an Aboriginal land claim, which pauses any land reservation (DPIE *in litt.* June 2021).

**Cultural significance**

The Mittagong Geebung occurs on the traditional lands of the Dharug, Gundungarra and Tharawal people. Geebung is an Aboriginal name for *Persoonia.* Geebungs hold cultural significance to Indigenous Australians for food and medicine. The chewy fruits of some species were a favoured food of Indigenous communities (Nash 2004; Packer *et al.* 2012). Indigenous Australians likely dispersed these plants long distances. Other NSW species of *Persoonia* have been used by Indigenous Australians as a treatment of skin infections and other skin disorders including psoriasis (Pengelly 2018). The anti-microbial properties of *Persoonia* have been demonstrated in laboratory trials (Atkinson 1949).

**Ecology**

*Persoonia glaucescens* is a woody shrub that grows on ridge-tops, plateaus and upper slopes in open woodland around Bargo and the Southern Highlands (NSW NPWS 2000a; Rymer and Ayre 2006). The distribution of *P. glaucescens* has been fragmented by past and ongoing vegetation clearing. Many of the recorded *P. glaucescens* sites are small with only a few individuals, which can be explained in part by land clearing but also by the long dispersal potential of seeds. Some occurrences of *P. glaucescens* appear to be clustered around past disturbances such as track and road margins and powerline easements (NSW NPWS 2000b; Schlunke 2018; Wasley 1997). Jellore is the exception to this pattern, with *P. glaucescens* occurring throughout the entire site (J. Schlunke pers. comm. May 2022).

*Persoonia glaucescens* is commonly associated with the canopy species *Corymbia gummifera*, *Eucalyptus sieberi*, *E. oblonga*, *E. piperita*, *E. radiata, E. racemosa* as well as *E. pauciflora* at higher altitudes west of Mittagong. Associated understorey species include *Acacia terminalis*, *A. brownii*, *A. ulicifolia*, *Banksia spinulosa*, *B. serrata*, *Bossiaea obcordata*, *Eriostemon australis*, *Hakea sericea*, *H. dactyloides*, *Isopogon anemonifolius*, *Lambertia formosa, Leptospermum trinervium*, *Petrophile pedunculata*, *P. sessilis* and *Pimelea linifolia* (Douglas, pers. obs. in NSW NPWS 2000a; J. Schlunke in litt. August 2022; Wasley 1997). The species has been found to occur on clayey and gravelly laterite soils associated with the Mittagong Formation (passage beds between Wianamatta Shale and Hawkesbury Sandstone) and represented by the Lucas Heights soil landscape (NSW NPWS 2000a). *Persoonia glaucescens* seems to prefer the interface between Lucas Heights and the Hawkesbury and Gymea soil landscapes (NSW NPWS 2000a).

*Persoonia glaucescens* is a long-lived shrub that is estimated to live for at least 20 years (NSW NPWS 2000b). It is likely to mature at the same age as the taxonomically similar *P. lanceolata*, which Auld *et al.* (2007) found to first mature at six years after a fire (13%) but took 12 years before 92% of plants matured. As such, the minimum generation length for *P. glaucescens* for this assessment is 13-16 years.

Fruit production in the related *Persoonia lanceolata* is very low in the first year of maturity but increases markedly in subsequent seasons (Auld *et al.* 2007), indicating that at least 13-15 years is needed for this species to start producing a substantial seedbank (McKenna 2007). This timeframe is consistent with the fire interval prescription for *P. glaucescens* of no fire more than once every 15 years (NSW RFS 2022).

Pollination, seed dispersal and gene flow.

*Persoonia glaucescens* flowers in late summer and autumn with tubular, yellow flowers that are distinctive to the genus. Peak flowering appears to occur in February, though this is likely to vary considerably with local climatic conditions (Wasley 1997). *Persoonia* flowers are primarily adapted to bee pollination (Armstrong 1979; Michener 1965) but are also pollinated by many other insect species (Bernhardt and Weston 1996). Native specialist bees in the genus *Cladocerapis* are considered the main pollinator of *Persoonia* spp., and forage exclusively for and pollinate flowers of *Persoonia* spp. (Michener 1965). Other native bee species that have been reported to collect nectar and/or pollen on *Persoonia* species are in the long-tongued families Anthophoridea, Apidae and Megachilidae, and in the short-tongued families Halictidae and Collietidae, (Michener 1965). Introduced honeybees *Apis mellifera* also pollinate *Persoonia* species (Bernhardt and Weston 1996). *Persoonia glaucescens* is an obligate outcrosser and therefore movement by pollinators between individuals is essential for successful pollination (Rymer *et al.* 2005). *Persoonia glaucescens* has low levels of pollination success, with one study finding less than one fifth of flowers maturing into fruit (Rymer *et al.* 2005).

*Persoonia glaucescens* produces a firm, elliptical, fleshy fruit (drupe) which is bright green and partially red in colour when they drop at maturation in late spring (Rymer 2006). *Persoonia* seeds which drop to the ground may end up in close vicinity to the adult plant, but some are moved away from an adult plant by animals (Rymer *et al.* 2005). *Persoonias* are one of the few species groups in southeast Australian forests that produce a large fleshy fruit, which is an attractive food source to a range of large native mammals and birds. The fruits are eaten by macropods, rats, possums, wombats and large birds such as currawongs and native parrots (Auld *et al.* 2007; Buchanan 1989; Rymer 2006). Swamp wallabies have been found to be an effective and common dispersal agent for *P. lanceolata* fruit, as seeds remained viable and dormant after they had passed through their gut (Auld *et al.* 2007). Swamp wallabies have the potential to disperse seeds many kilometres with home ranges up to 37 ha (Di Stefano *et al*. 2011) and genetic studies suggesting that they can disperse over 10 km (Paplinska *et al.* 2009). Deer species are known to include fruits in their diet (Gebert and Tixier 2008) and seeds generally survive ingestion (Mouissie *et al.* 2005) also making them a potential dispersal agent. *Persoonia* fruit are a food source for

Indigenous Australians (Packer *et al.* 2012), who historically would have played a role in seed dispersal.

*Persoonia* fruits ripen while on the ground, becoming initially softer and darker in colour, drying after four weeks. *Persoonia* seeds are held mechanically dormant by the woody endocarp and some species are also physiologically dormant. Dormancy in *Persoonia* spp. seeds is difficult to break artificially and not well understood (Myerscough *et al*. 2001). Mature fruit on the plant was found to have high levels of seed viability (86%) (Rymer *et al.* 2005).

Subpopulations

The total current known population of *P. glaucescens* can be divided into 5-8 subpopulations based on geographic separation of clusters of occurrences that restricts gene flow from either pollination or seed dispersal. Gene exchange in *P. glaucescens* can potentially occur over long distances, with honeybees having the potential to pollinate up to 12 km from a hive (although they mostly forage closer to a hive) (Beekman and Ratnieks 2001) and wallabies having the potential to disperse seed 10km (Paplinska *et al.* 2009). Based on these distances all *P. glaucescens* occurrences would be a single subpopulation. However, the geographic pattern of *P. glaucescens* occurrences consists of clusters of sites located within 2 km of each other and separated from other clusters of sites by many kilometres of cleared and developed land. Cleared and developed land is likely to act as an effective barrier to all but extremely rare episodes of genetic exchange, which defines a subpopulation in the IUCN Guidelines (2022). This division of subpopulations fits with the suggestion by Beekman and Ratnieks (2001) that honeybees are a poor pollinator *of P. glaucescens* compared to native bees. Native bees forage over much shorter distances than honeybees, 700 m to over 1000 m (Greenleaf *et al.* 2007; Smith *et al.* 2016), which is likely to make effective pollination distance within a couple of kilometres rather than in the order of up to 10 km.

Based on this information, the *P. glaucescens* subpopulations are:

- Greater Bargo – all occurrences from Couridjah to Hill Top, including Bargo SCA and Nattai NP are a subpopulation of approximately 800 individuals. A single record at Point Hill in Nattai NP may be a separate subpopulation as it appears to be isolated from other known sites but is linked to other occurrences by continuous bushland that has restricted access as Sydney water catchment Special Area land.
- Greater Mittagong – all occurrences from Colo Vale to Mittagong are a subpopulation of approximately 625 individuals with larger clusters of *P. glaucescens* at Nattai Creek, Welby and Braemar. There is an 8 km separation between the large cluster at Braemar and the sites in Bargo River SCA. There is continuous bushland in the Crown Land reserve around Mt Alexandra that may contain unrecorded occurrences of *P. glaucescens*.
- Joada – the *P. glaucescens* sites near Joadja to the north and south of Wombeyan Caves Road represent a subpopulation of approximately 400 individuals. The subpopulation is separated by 7 km of cleared land from Mittagong. The records further west of the Jellore cluster are likely to be a separate subpopulation unless unknown plants occur between the sites.

- Berrima - the scattered sites around Berrima are a subpopulation of 60 individuals.
- Upper Nepean - the sites in the southern end of UNSCA and the Special Area land south of the reserve are a subpopulation of approximately 400 individuals. The records on the western border of UNSCA are separated by 5 km from the other records in this reserve and could be a separate subpopulation (22 individuals). There is continuous undisturbed bushland between the two sites, with potential for undiscovered *P. glaucescens* individuals to exist there which would make the Upper Nepean area one subpopulation. The occurrences in the Upper Nepean subpopulation are separated by 5-10 km of cleared land, and the effective macropod dispersal barrier of the Hume Highway, from the Greater Mittagong subpopulation.

Fire ecology and seedling germination

*Persoonia glaucescens* is a fire sensitive obligate seeder, with adults killed by fire and regeneration solely from seed (Schlunke 2018, 2019, 2021, 2022). Recruitment appears to be influenced by multiple interacting factors, including fire, burn temperature, rainfall, disturbance and season (Haynes and Gregory 2021; Schlunke 2021). Fire plays an important, but not essential, role in stimulating the germination of *P. glaucescens* seeds. Post-fire germination levels are variable, sometimes low and not related to the number of mature individuals before a fire (Figures 4 and 5 in Appendix II; Schlunke 2021; Wasley 1997). Mechanical disturbance of the seedbank and/or the reduced competition and increased light associated with such disturbance appears to promote seedling germination, as is found with many *Persoonia* species, (NSW NPWS 2000a; Schlunke 2018; Wasley 1997).

A widespread recruitment event in 2021 suggests that an extended period of above average rainfall is an important trigger for germination. Seedlings were detected whether a site had been recently burnt or not. In fact, far more seedlings were counted on average in long unburnt SOS monitoring plots than those recently burnt (in 2019 or 2020) (Figure 6 in Appendix II). A similar pattern was found in a study of another Sydney Basin *Persoonia, P. hirsuta* where heat-shock had no significant effect on germination (Emergy and Offord 2019). In the drought years prior to 2020, very few seedlings were observed at any *P. glaucescens* site (L. Hook pers. comm. February 2022), including after a 2019 hazard reduction burn in UNSCA (Schlunke 2021).

It is possible that past high frequency fire may limit recruitment. All SOS plots have a fire interval prior to 2019-20 fires that is longer than the length of time considered necessary for the seedbank to develop (13-15 years) (McKenna 2007; Wasley 1997). However, sites at Bargo and Upper Nepean have had a high fire frequency and had the lowest numbers of seedlings emerge. Upper Nepean sites have a history of repeated fires at intervals of 1-8 years from the late 1960s to the mid-1990s (NPWS Fire History spatial layer).

High fire severity is thought to cause seed mortality in *P. glaucescens* as the seed is mainly stored in the litter layer (Schlunke 2021; Wasley 1997). Seed is also stored in the soil, which can survive high temperatures associated with fire (Wasley 1997). In *P. hirsuta* seedling recruitment and growth after the 2019-20 bushfires fires showed no relationship to fire severity, but seedling mortality was significantly higher in

monitoring plots recently exposed to high fire severity. (Andres *et al*. 2022). High fire severity does not explain poor recruitment in the Upper Nepean subpopulation as the fires of 2019 and 2020 were hazard reduction burns of cool to medium intensity that only partially burnt all but one of the plots (Schlunke 2021).

There may be considerable variation in seedbank viability and recruitment between *Persoonia glaucescens* sites and/or seasons. *P. glaucescens* soil seedbank viability was reported to be very low by Wasley (1997) and mature fruit on the plant was found to have high levels of seed viability (86%) by Rymer *et al.* (2005). Similarly, in *P. hirsuta* a soil seedbank of empty seeds, despite canopy seeds largely full, was found at one site (Haynes and Gregory 2021). Other species of Sydney Basin *Persoonia* species have been found to have large and persistent soil seedbanks capable of withstanding multiple fires (Auld *et al*. 2007; Ayre *et al*. 2009; Emery & Offord 2018). Seed availability can be limited by seed predation by the Bush Rat *Rattus fuscipes* and the Black Rat *Rattus rattus* (Rymer *et al.* 2005; Rymer 2006). Recruitment success is limited by seedling browsing by both native and non-native herbivores.

**Threats**

The NSW Scientific Committee (2002a) state that "The existing populations are highly fragmented due to the clearing of habitat for agriculture and are threatened by further clearing, frequent fire and habitat degradation. Various activities are contributing to habitat degradation including land clearing, recreational vehicle use, weed invasion, and adverse fire reqimes. *P. glaucescens* is also potentially threatened by its very low seed viability, herbivory on seedlings, and pollination disruption by the European honeybee *Apis mellifera*."

Vegetation clearing and degradation

Vegetation clearing is an observed, ongoing threat to *P. glaucescens*. Approximately 12% of the currently known total adult population occurs on private, roadside or railway lands and 33% occurs on unreserved Crown Land. Schlunke (2022) noted from a post-fire survey of historic records near Wilson Drive between Couridjah and Buxton that the background loss of habitat due to development for housing and other infrastructure was significant as many of the past *P. glaucescens* records were likely the result of impact assessment surveys prior to urban development. Recently, 47 plants were cleared for development on private land near Balmoral, with only one regenerating seedling found (Schlunke 2022). Eight roadside sites with records of the species along Wilson Drive between Balmoral and Buxton are suspected to have been cleared in the last five years as a result of road maintenance, however, all have recent seedling recruitment (Schlunke 2022). Most of the *P. glaucescens* records on private land are of very small numbers of plants (except at the Tahmoor mine where over 150 seedlings were recorded in 2020 and 2022) and represent much of the north-eastern andsouthern extent of this species. "Clearing of Native Vegetation" is listed as a key threatening process under the BC Act.

As a regional area close to Sydney, the pressures on the habitat of *P. glaucescens* from urban, rural and semi-rural development are increasing with a rapidly growing regional population. The human population of the Wollondilly LGA has increased over 20% in the ten years 2011-21 with population growth in Bargo and the Southern Highlands accelerating in recent years, including from COVID related migration

(Australian Bureau Statistics 2022; Wingecarribee Shire Council 2020). The number of people living in the Bargo and Southern Highlands area is projected to increase a further 20% in the next 20 years (Wingecarribee Shire Council 2022).

Many records of *P. glaucescens* on conservation reserves are close to access trails and are at minor risk from inappropriate use of these trails. While this species can benefit from disturbance, too frequent trail and road maintenance activities may kill plants before they mature and set seed.

High frequency fire and high severity fire

*Persoonia glaucescens* can persist in a landscape without fire for many decades, however, is well adapted to surviving fire in the environment. Recent SOS monitoring data suggests that *P. glaucescens* grows in large healthy populations for many decades without fire (Schlunke 2021). The species has more successful seedling recruitment at long unburnt sites than at recently burnt sites or at burnt or unburnt sites with a history of high fire frequency (Figure 5 in Appendix II; Schlunke 2021).

*Persoonia glaucescens* is an obligate seeder, mature plants are killed by fire and short time intervals between fires can disrupt the replenishment of seed banks, which are essential to post-fire recruitment and population persistence (Auld *et al.* 2007; Enright *et al*. 2015; Gallagher *et al*. 2021). A narrowing of the favourable interval between fires is known as “interval squeeze” and may cause population decline or local extinction by depleting or exhausting seedbanks (Enright *et al*. 2015). The minimum fire interval to maintain *P. glaucescens* is estimated to be 13-15 years (McKenna 2007).

Many of the current known *Persoonia glaucescens* subpopulations were burnt in the 2019/20 fire season. A second fire in the decade before the current cohort of *P. glaucescens* seedlings mature and set seed may threaten local occurrences of the species. While fire ecology studies of other Sydney Basin *Persoonia* spp. have found large and persistent soil seedbanks capable of withstanding multiple fires (Auld *et al*. 2007; Ayre *et al*. 2009; Emery & Offord 2018), this may not be the case for all *P. glaucescens* sites. Bargo SCA and Upper Nepean have histories of high frequency fire followed by a long period without fire and have lower levels of seedling germination compared to sites very long unburnt. *Persoonia glaucescens* sites with a seedbank depleted by multiple fires may need a greater interval between fires than the recommended 13-15 years for the seedbank to recover. ‘High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition’ is listed as a Key Threatening Process under the BC Act.

High fire severity is likely to increase seed and seedling mortality in *Persoonia glaucescens*, reducing recruitment success. *P. glaucescens* seed is mainly stored in the litter layer, where it may be at risk of high mortality during fire (Wasley 1997). High fire severity has been observed to kill all seeds near the soil surface in the mid-north coast species *P. katerae* (G. Phillips pers. comm. July 2022), where viable seeds were only found on the cooler fire edge and nearby non-burnt area. Seed which becomes more deeply buried in the soil is more likely to survive high temperatures associated with fire (Wasley 1997). In *P. hirsuta,* seedling dieback and mortality were significantly higher in monitoring plots exposed to high fire severity (Andres *et al*. 2022). “Fire regimes that cause declines in biodiversity” is listed as a Key Threatening Process under the EPBC Act.

Projected long-term changes to fire conditions under ongoing climate change, of larger, more frequent, more severe fires (Abatzoglou *et al*. 2019; Bowman *et al*. 2020; Jones *et al.* 2022) have the potential to deplete *P. glaucescens* seedbanks through multiple episodes of high frequency fire and seed mortality during episodes of high severity fire. Changes to severe fire weather are not predicted to occur across the distribution of *P. glaucescens* until after 2050-60, after which significant increases to fire magnitude and length of fire season are predicted (AdaptNSW 2022; Clarke and Evans 2019; Clarke *et al.* 2011). High fire frequency is not typical of most *P. glaucescens* sites; therefore, it is likely that it will be many decades before possible climate induced changes to fire extent and severity reduces subpopulation size. Occurrences around the urban fringe or isolated in farmland are unlikely to experience high frequency fire. 'Anthropogenic climate change' is listed as a Key Threatening Process under the BC Act.

Seasonal timing and intensity of hazard reduction burns influences recruitment success and timing of Australian shrubs (Mackenzie *et al.* 2021). Studies of fire and seasonal temperature influence on germination in *Boronia* spp., found that different species had highly variable responses, despite being closely related (Mackenzie *et al.* 2016). The germination cues of seasonal temperature (summer/winter), heat shock (related to soil heating from fire intensity) and smoke were important cues that were different for the different *Boronia* species studied and this is probably also true for different species of *Persoonia*. Germination cues should be considered for burns of *P. glaucescens* habitat to maximise seedling recruitment after fire.

Decline in habitat suitability from increased annual temperatures and decreasing precipitation from climate change

*Persoonia glaucescens* is speculated to be a species highly sensitive to climate change as it has a high degree of habitat specialisation, a limited range size and limited capacity to move (Andres *et al.* 2021). For the current distribution of *P. glaucescens*, ongoing climate change is predicted to increase average mean temperatures by 1.5-1.8$^{o}$C and decrease average dry month precipitation by 13-15%. Andres *et al.* (2021) project that the extent of suitable habitat of *P. glaucescens* will decline by 31-56% by 2060 under a medium emissions scenario of a sustainable approach to emissions reductions and a high emission scenario of little substantial future deviation to historical trajectory, respectively. Under warmer, drier conditions, *P. glaucescens* is inferred to experience increased mortality, decreased recruitment and may be a less competitive understory species. An intolerance of drier conditions is supported by a drought related mature plant mortality of 30% recorded in the unburnt SOS monitoring plots at Mt Alexandra (Figure 2, Appendix II). However, given that *P. glaucescens* had good recruitment at these sites post drought and that there is no information on the thermal tolerance of the species, this modelling should be considered speculative and not predictive. Any climate-related decline in population size is unlikely to follow a linear trajectory. 'Anthropogenic climate change' is listed as a Key Threatening Process under the BC Act.

Seedling browsing by deer

Seedling browsing by deer is an inferred, ongoing threat to *P. glaucescens* in the Upper Nepean subpopulation, where seedling recruitment is very poor. Fallow Deer are resident in the south Upper Nepean SCA and nearby parts of the Metropolitan

Special Area land (J. Banks pers. comm. July 2022; Wong 2021). NPWS aerial and ground-based deer control efforts of the last few years have had little success (J. Bros pers. comm. June 2022). An increase in the primary herbivore, combined with low viable seed supply has been suggested as the likely cause of regeneration failure in a West Australian *Persoonia*, *P. elliptica* (Nield *et al.* 2014).

Pollination disruption by honeybees

Honeybees may disrupt pollination of *P. glaucescens.* Bernhardt and Weston (1996) and Rymer *et al*. (2005) observed that honeybees are a frequent forager but a poor pollinator because they have a higher proportion of movements within a plant, rather than between plants, and they store pollen in their hind legs that makes it unviable and inaccessible for pollination. Rymer *et al.* (2005) considered the most effective pollinator of *P. glaucescens* to be specialist native bees, which carry pollen in a way that makes it readily available for pollination and move between individual plants more than between flowers on the same plant. Bernhart and Weston (1996) noted that honeybees can cross-pollinate *P. glaucescens* as some pollen remains available for pollination on their head and thorax. A recent conservation genetics study of *P. hirsuta* suggests that honeybees are effective pollinators of *Persoonia* spp. (Haynes and Gregory 2021).

Disease

*Phytophthora cinnamomi* is an inferred, ongoing threat to *Persoonia glaucescens*, because it affects other *Persoonia* species (Department of the Environment and Energy 2018). Schlunke (2018) noted potential signs of disease on three individuals, manifested as blackening of stems and leaves, but did not find *Phytophthora* in or around *P. glaucescens* populations. 'Infection of native plants by *Phytophthora cinnamomi*' is listed as a Key Threatening Process on the BC Act.

Weed invasion

The tendency of *Persoonia glaucescens* to occur on disturbance margins makes it particularly susceptible to peripheral weed invasion and competition. Weeds have the potential to compete with *P. glaucescens* plants of any age for space and light. Weed competition has occasionally been recorded on database records, has not been reported from *P. glaucescens* monitoring sites (Schlunke 2018, 2019, 2021) but is an inferred ongoing potential threat in urban interface and farmland areas.

Hybridisation

*Persoonia glaucescens* is suspected to hybridise with the common *P. lanceolata*, and thus genetic dilution of remaining populations may occur (NSW NPWS 2000a). Hybridisation is a natural process and possible hybrids are only recorded from two sites, at Hilltop and UNSCA, so hybridisation is currently not considered a threat.

**Assessment against IUCN Red List criteria**

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

*Criterion A* *Population Size reduction*

Assessment Outcome: Data Deficient

Justification: *Persoonia glaucescens* has an estimated population size of around 2,200 individuals, which includes known mature individuals and a proportion of the current crop of seedlings assumed to survive to maturity. Many mature individuals were killed by fire in 2019-20 and a mass germination event occurred in both burnt and unburnt areas in 2021. Overall population trends are unknown.

The generation time of *P. glaucescens* is at least 13-16 years, or minimum three generations of 39-48 years. This calculation is based on a minimum longevity of 20 years (NSW NPWS 2000b) and an inferred age of maturity of 6-12 years from the taxonomically similar *P. lanceolata*.

Approximately 12% of the *P. glaucescens* population occurs on private, roadside or railway land which is subject to ongoing clearing and degradation. Recently, 47 plants were cleared on private land near Balmoral, with only one regenerating seedling found (Schlunke 2022). Eight other record sites along the roadside of Wilson Drive between Balmoral and Buxton are suspected to have been cleared in the last five years (L. Hook pers. comm. February 2022), however these sites have recent seedling recruitment (Schlunke 2022). Many previous records of the species were likely the result of impact assessment surveys prior to residential or rural residential development (Schlunke 2022). Rapid human population growth in the regional centres of Bargo and Southern Highland townships (Australian Bureau Statistics 2022; Wingecarribee Shire Council 2020, 2022) is likely to increase pressures on *P. glaucescens* from urban, rural and semi-rural development.

Background loss of habitat and individuals from land clearing on private land is likely to account for considerable, but unknown, past losses to *P. glaucescens*. Information on the area of woody vegetation cleared in the region where *P. glaucescens* grows, from the timeframe of the last three generations of *P. glaucescens* (39-49 years), is available from satellite derived spatial layers between 1988 and 2014 (DPE 2022a, DPE 2022b). This amounts to 1 $km^2$ or 0.3% of the total historic area of woody vegetation cleared, well below any thresholds for Criterion A assessment. However, continuing loss of individuals from land clearing on private land is a significant threat to the species. For example, if the loss of all current known private land, railway and roadside sites were to occur, this would reduce the AOO of *P. glaucescens* by around 15%, mostly in the northeast and southern parts of its distribution.

Andres *et al.* (2021) suggest that projected increases in average mean temperatures due to anthropogenic climate change may reduce the extent of habitat suitable for *P. glaucescens* by 31-56% by 2060, or 38 years. An intolerance of drier conditions is suggested by a drought related mature plant mortality of 30% recorded in unburnt SOS monitoring plots at Mt Alexandra (Figure 2, Appendix II). However, the suspected reduction in suitable habitat from increased temperatures is unlikely to cause a linear proportional reduction in the number of mature individuals; although the species may be susceptible to drought losses, it also has the potential to recover from seedbank. Therefore, this modelling is not considered suitable to assess Criterion A.

*Criterion B Geographic range*

Assessment Outcome: Vulnerable B1ab(i)(ii)(iii)(v) + B2ab(i)(ii)(iii)(v)

Justification: *Persoonia glaucescens* has a highly restricted geographic distribution. The EOO is 1,005 $km^2$ and the AOO is 284 $km^2$. The AOO is based on 2 x 2 km grid cells, the scale recommended for assessing area of occupancy by IUCN (2022). The

EOO is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). *Persoonia glaucescens* meets the Endangered threshold for AOO (<500 $km^2$) and Endangered threshold for EOO (<5, 000 $km^2$).

In addition to these thresholds, at least two of three other conditions must be met (and if the species only meets a lower threat category in these sub-criteria than for the EOO and/or AOO threshold, its overall threat category for Criterion B is that lower category). 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: Subcriterion met for Vulnerable

Justification: There are seven threat-defined locations for *Persoonia glaucescens*. The most serious plausible threat to *P. glaucescens* is vegetation clearing and degradation. The IUCN Guidelines (2022) state that "Where the most serious plausible threat is habitat loss that occurs gradually and cumulatively via many small-scale events, such as clearance of small areas for small-holder grazing, a location can be defined by the area over which the population will be eliminated or severely reduced within a single generation or three years, whichever is longer." There are over 30 recorded sites of *P. glaucescens* on private lots and over 20 roadside record sites that are at potential risk of clearing or significant habitat damage over a single generation. These sites represent approximately 12% of the current known population, located in many disjunct sites across a 40km linear extent from Couridjah to Berrima. In accordance with the IUCN guidelines (2022) all of these record sites can be considered one multi-polygon tenure-based location.

The threat of land clearing does not apply to *P. glaucescens* occurrences in conservation reserves or Crown Land reserves and is unlikely in the near future on unreserved Crown Land. The most serious plausible threat of high fire frequency and high fire severity has been used to define another five locations for *P. glaucescens* on these land tenures. The record sites in Bargo SCA, Bargo River SCA, the large area of Crown Land north of Bargo SCA and Nattai NP and Crown Land Reserves in Couridjah and Hilltop are connected by continuous or near continuous bushland and all burnt in the 2019-20 Green Wattle fire and are a second location. The Upper Nepean sites are separated from other sites by a large extent of cleared farmland, are subject to infrequent hazard reduction burns and occasional wildfire and are a third location. The Mt Alexander Crown Reserve is an area of urban fringe bushland that stretches from Mittagong to Braemar and is a fourth location. This reserve has a fire management regime of small, infrequent hazard reduction burns. The small area of reserved Crown Land on the Wingecarribee River near Berrima is the fifth location. The sixth and seventh locations comprise the Joadja subpopulations on either side of Wombeyan Caves Road.

*Persoonia glaucescens* is not severely fragmented. Many of the isolated occurrences of this species are less than five individuals and could be

considered smaller than is required to support a viable population or are located on private land and at risk of clearing. Very small, geographically isolated occurrences are unlikely to be recolonised from seed dispersal. However, these non-viable sites do not add up to >50% of the total AOO of *P. glaucescens*, the definition required by the IUCN Guidelines (2022) for a species to be severely fragmented.

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 (i), (ii), (iii), (v)

Justification: *Persoonia glaucescens* has an estimated, inferred and projected continuing decline in EOO, AOO, habitat quality and mature individuals from vegetation clearing and degradation on unreserved lands, high frequency fire and high severity fire, seedling browsing by deer and habitat loss from increased annual temperatures from climate change.

*Persoonia glaucescens* has an estimated and inferred decline from a much larger historic population because of widespread land clearing for farming and urban development. Vegetation clearing and local extirpation continues across the species range. Recently, 47 plants were cleared on private land near Balmoral, with only one regenerating seedling subsequently found (Schlunke 2022). Eight other recorded sites along Wilson Drive between Balmoral and Buxton are suspected to have been cleared in the last five years but do have recent seedling recruitment (Schlunke 2022). 12% of the population is located on private, roadside and railway land.

A continuing decline in habitat quality is inferred from high fire frequency and high fire severity. *Persoonia glaucescens* is a fire-sensitive, obligate seeder. Mature plants are killed by fire and short time intervals between fires can disrupt the replenishment of seed banks, which are essential to post-fire recruitment and population persistence (Auld *et al.* 2007; Enright *et al*. 2015; Gallagher *et al*. 2021). A second fire in the next decade before the current crop of *P. glaucescens* seedlings mature and set seed may threaten local occurrences of the species. At Upper Nepean and Bargo SCA, low seedling numbers may have been caused by a recent history of high frequency fire depleting of soil seedbanks. In Bargo SCA pockets of extreme fire-severity from the 2019-2020 bushfires may limit seedling survival (Andres *et al*. 2022).

A continuing decline is also projected in the extent of suitable habitat of *Persoonia glaucescens* of 31-56% by 2060 from ongoing climate change causing increasing average annual temperatures (Andres *at al*. 2021). *P. glaucescens* is thought to be susceptible to increasing annual temperature as it has a high degree of habitat specialisation, a limited range size and capacity to move (Andres *at al*. 2021) and is known to be impacted by drought (Figure 2, Appendix II). A continuing decline in *P. glaucescens* habitat quality is inferred after 2050-60, based on projected increases in fire magnitude and length of fire season resulting from anthropogenic climate change (AdaptNSW 2022; Clarke and Evans 2019; Clarke *et al.* 2011).

At Upper Nepean a continuing decline in number of mature individuals is inferred from seedling browsing by deer (Wong 2021).

c) Extreme fluctuations

Assessment Outcome: Data deficient

Justification: There are insufficient data to assess against this Subcriterion.

*Criterion C Small population size and decline*

Assessment Outcome: Vulnerable for C2a(i)

Justification: The estimate for the number of mature individuals is approximately 2,200 which meets the threshold for Endangered. This estimate includes known mature individuals and a proportion of the current crop of seedlings assumed to survive to maturity. Many mature individuals were killed by fire in 2019-20 and a mass germination event occurred in both burnt and unburnt areas in 2021. The population size is likely an underestimate, but unlikely to exceed the Vulnerable threshold of 10,000. The number of mature individuals in four subpopulations exceeds the Endangered threshold of >250 but meets the Vulnerable threshold of ≤1000.

At least one of two additional conditions must be met (and if the species only meets a lower threat category in these sub-criteria, its overall threat category for Criterion C is that lower category). 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 no data available on population size change over one or more generations. *Persoonia glaucescens* has a generation time of at least 13-16 years, as described in Criterion A. Data on population size change at SOS monitoring plots is available for the four years 2018-2021 (Figure 2 and Figure 7 Appendix II) which shows that despite loss of mature individuals from drought and fire, healthy seedling recruitment suggests numbers of mature individuals will recover or increase, except in the Upper Nepean subpopulation which had poor seedling recruitment in all but one plot.

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

Assessment Outcome: Subcriterion met for Vulnerable

Justification: *Persoonia glaucescens* is inferred to be continuing to decline from vegetation clearing and degradation and seedling browsing by deer, and continuing decline is projected based on high fire frequency, high fire severity and habitat loss from increased annual temperatures from climate change (AdaptNSW 2022; Clarke and Evans 2019; Clarke *et al.* 2011). *Persoonia glaucescens* then meets Criterion a(i) below for Vulnerable, with the number of individuals in each subpopulation being ≤1000 but greater than 250. No subpopulation contains 90-100% of mature individuals and there is no evidence for extreme fluctuations.

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 Vulnerable

Justification: There is an estimated 5-8 subpopulations of *P. glaucescens* based on the assumption that gene exchange between stands has the potential to occur via pollination or seed dispersal over around 2 km. There are 800 individuals in the greater Bargo subpopulation, 650 in the greater Mittagong subpopulation, 400 in the Joadja subpopulation, 60 in the Berrima subpopulation and approximately 300 in the Upper Nepean subpopulation. Isolated records west of Joadja and at Point Hill in Nattai NP and the records on the western side of UNSCA are likely to be very small subpopulations.

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

Assessment Outcome: Not met

Justification: The mature individuals are spread between 5-8 subpopulations, with the largest approximately 35% of the total population in the greater Bargo area and next largest approximately 30% of the total population in the greater Mittagong area.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Data Deficient

Justification: There is insufficient data to assess against this Subcriterion.

*Criterion D Very small or restricted population*

Assessment Outcome: Criterion not met.

Justification: The population size of *Persoonia glaucescens* is approximately 2,200, which falls above the threshold for this category. *P. glaucescens* does not have an AOO or number of locations close to thresholds for D2 and there is no plausible future threat that could drive this taxon to extinction in a very short time.

To be listed as Vulnerable under Criterion 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

Assessment Outcome: Subcriterion not met

Justification: The estimate of population size for *P. glaucescens* is approximately 2,200, which is above the threshold of ≤1,000 for this category.

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: Subcriterion not met.

Justification: The AOO of *P. glaucescens* is 284 km$^2$ which exceeds the suggested threshold of <20 km$^2$ and the number of locations is seven which is above the suggested threshold of ≤5 for this category. There is no plausible future threat that could drive this taxon to extinction in a very short time.

*Criterion E Quantitative Analysis*

Assessment Outcome: Data deficient

Justification: No quantitative analysis has been carried out to assess the probability of extinction in this taxon.

**Conservation and Management Actions**

*Persoonia glaucescens* is currently listed on the NSW BC Act 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. *Persoonia glaucescens* sits within the Site-managed species stream of the SoS program and the conservation project can be viewed here: https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10593.

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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:**
*Persoonia glaucescens* was found to be Vulnerable under Clauses 4.3(c)(d)(e)(ii)(iii) + 4.4(c)(e)(i)(ii)(A)(III)

**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**: Vulnerable under Clause 4.3(c)(d)(e)(ii)(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: Vulnerable under Clause 4.4(c)(e)(i)(ii)(A)(III)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **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: 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: 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. |