

NSW Threatened Species Scientific Committee

Conservation Assessment of *Darwinia peduncularis* B.G.Briggs (Myrtaceae)

Vera Wong 17/08/2022

Science, Economics and Insight Division,
NSW Department of Planning and Environment

Darwinia peduncularis B.G.Briggs (Myrtaceae)

Distribution: Endemic to NSW

Current EPBC Act Status: Not listed

Current NSW BC Act Status: Vulnerable

Proposed listing on NSW BC Act: Vulnerable

Summary of Conservation Assessment

Darwinia peduncularis was found to be eligible for listing as Vulnerable under Criterion B2ab(i)(ii)(iii)(iv). The main reasons for this species being eligible are: (i) it has a highly restricted geographic range, (ii) it has less than 10 locations, and (iii) there is an estimated continuing decline from high frequency fire and disturbance from recreation and trail maintenance.

Description and Taxonomy

Darwinia peduncularis B.G.Briggs (Myrtaceae) is a medium sized shrub that grows in dry sclerophyll forest on sandstone hillsides and ridges in the Sydney and greater Blue Mountains regions. *Darwinia peduncularis* was named in 1962 and is described by PlantNET (2022) as a “Divaricate shrub to 1.5 m high. Leaves laterally compressed, spreading to c. 90 degrees, 7–12 mm long, glabrous. Flowers usually in pairs; peduncles (2-)4–7 mm long, often recurved; bracts leaf-like or triangular and scarious, 1–10 mm long; bracteoles oblong, 4–8 mm long, purplish red, caducous. Hypanthium 9–12 mm long, 1.5–2.5 mm diam. Sepals triangular, < 1 mm long, entire or toothed; about half as long as the petals. Style strongly curved, 6–10 mm long, white.”

Coastal subpopulations have slightly longer peduncles than inland populations, 3-4.5mm long compared to 2-4mm long (Williams pers. comm. in S. Douglas *in litt.* September 1998). Comparisons of herbarium specimens from the mountains and those closer to the coast confirm they are the same species (P. Wilson *in litt.* December 2022). The inland population grows at sites up to 800 m higher in elevation than the coastal populations, a climatic difference which can account for the difference in morphological size.

Distribution and Abundance

Darwinia peduncularis is endemic to NSW. *Darwinia peduncularis* occurs as local disjunct subpopulations in coastal New South Wales and in the greater Blue Mountains. It has been recorded from Brooklyn, Berowra, Galston Gorge, Hornsby, Bargo River, Glen Davis, Mount Boonbourwa, Hunter Main Rane, Mount Iris, Capertee Valley and Kings Tableland. Some populations are within the Murrumbidgee National Park, Wollemi National Park, Blue Mountains National Park and Berowra Valley Regional Park (NSW Scientific Committee 1999).

The species occurrences can be divided into four geographically distinct areas: the western side of Wollemi NP, Kings Tableland, Bargo River and Lower

NSW Threatened Species Scientific Committee

Hawkesbury/Berowra Valley. Since the 1999 Final Determination, the number of sites where *Darwinia peduncularis* is known to occur has increased from nine to 17. An additional six sites have been recorded from western Wollemi NP: Capertee Valley cliffs, Mount Iris, the ridge between Numietta and Coorongoba Creeks, Mount Coricudgy, Hunter Main Range Trail, Hunter Main Range Trail South. Two additional sites have been recorded in Murrumbidgee NP. Almost all records of *D. peduncularis* are in NPWS reserves, except for five records in the Berowra Valley (of which three are on council land, one is part on Crown Land and part on National Park and one is on Crown Land) and two records on Bargo River on unreserved Crown Land. The area of Crown Land surrounding the Bargo River record is in the area known as Mermaid Pool and Tahmoor Gorge, which 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).

There have been no comprehensive surveys for *Darwinia peduncularis* and there are many areas of potential habitat in the wide vicinity of existing records. The landscape surrounding the Wollemi and Blue Mountains NP occurrences is steep, remote untracked wilderness that is difficult to access. There is continuous bushland with large tracts of rocky habitat between the Lower Hawkesbury/Berowra sites.

The current distribution is based on a cleaned set of 452 unique records compiled from the Atlas of Living Australia, the NSW Bionet Atlas and herbarium specimens, and records from Mikaili 2022 and V. Wong (pers. obs. October 2022). Ninety-seven of the records were made prior to 2021. The remaining more recent records are from targeted surveys which have recorded GPS point locations of individual plants or clusters of plants at nine sites. The georeferenced co-ordinates of 18 records were revised based on their location descriptions.

Extent of Occurrence and Area of Occupancy

The Extent of Occurrence (EOO) of *D. peduncularis* is 8,189 km² and the Area of Occupancy (AOO) is 116 km². The AOO is 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 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 encompasses the entire known historical and extant distribution of the species. The AOO is likely to be a significant underestimate with vast areas of unsurveyed potential habitat in Wollemi and Blue Mountains NPs.

Population Size

The population size of *D. peduncularis* is uncertain but in the range of 3,000-4,600 based on a proportion of the current cohort of seedling surviving to maturity. Loss of mature individuals from fire together with mass recruitment is part of the normal population cycle for this species and, according to the IUCN Guidelines (2022), the downward phase of a fluctuation will not normally count as a reduction or continuing decline. At the 13 sites burnt in the 2019-20 fire season, there are zero or very few surviving mature individuals and in order to estimate population size some seedlings have been assumed to survive to maturity. The lower bound of the estimate assumes

NSW Threatened Species Scientific Committee

10% of seedlings will survive to maturity and the upper bound assumes that 30% of seedlings will survive to maturity.

The use of 10-30% to estimate seedling survivorship is based on the proportions of adult plants pre-fire and seedlings post-fire at the two sites where that data exists, Kings Tableland and Capertee Valley cliffs. At Kings Tableland the ratio is 9:1 and at the Capertee Valley cliffs the ratio is 2:1. The pattern of seedling distribution recorded at Kings Tableland is widely spaced seedlings with some dense clumps and at the Capertee Valley cliffs the seedlings are mostly widely spaced. A site with densely packed seedlings competition will likely have a greater proportion of seedlings die from competition from other seedlings than at a site with sparse seedlings. The most recorded pattern of seedling distribution across *D. peduncularis* sites is of widely spaced seedlings with some dense clumps, like at Kings Tableland (V Wong pers. obs. February 2022) and therefore a seedling survivorship estimate of 10% has been used as the lower bound of survivorship for this assessment. The upper bound of survivorship of 30% is the average of the proportion of the adult to seedlings at both Kings Tableland and Capertee Valley Cliffs.

The population size estimate for the Lower Hawkesbury and Berowra Valley area is 1,200-1,300. This number is the sum of many records of local occurrences made in the late 1990s (usually with no distinction made between adults and seedlings) and 2022 estimates from three sites (V. Wong pers. obs. October 2022). Some 800 of the plants have been recorded from the Fishponds, Galston Gorge and Waddells Gully area of the Berowra Valley, 500-600 from the Gundar Ridge and Berowra area. 2022 surveys found seedlings at Gundah Ridge and Brooklyn, but not at Waddell's Gully where the largest-sized, and presumably the oldest, mature individuals were observed. At Brooklyn, there are only two mature plants and four seedlings and there are three record sites in Marramarra NP. Since the 1990s, there has been a mosaic of burns across different sites within the Lower Hawkesbury and Berowra Valley, which may have influenced local population sizes.

The population size estimate at Kings Tableland is 50 from the single known site. In 1998, 50 mature plants and no seedlings were recorded (S. Douglas *in litt.* August 1998). The site was burnt in 2012 and 2019-20 (NPWS Fire History spatial layer 2022). A 2022 survey found no mature plants and 456 seedlings (V. Wong pers. obs. February 2022).

The population size estimate for Wollemi NP is estimated to be 1,500-3,000. In 2019-20 all known *D. peduncularis* sites in Wollemi NP burnt at varying fire intensities in the Gospers Mountain summer fire killing most mature plants and triggering mass recruitment events (Mickail 2021, 2022; NPWS Fire History spatial layer 2022). In Wollemi NP 5,500 seedlings were estimated from six sites (Mikail 2021, 2022). No count data is available for two sites, near Mount Boonbourwa and near Mount Coricudgy, however at Mount Boonbourwa the species was noted as occasional, so an additional 30 individuals have been added to the population size estimate to at both sites, as the number equal to the smallest site estimate recorded in the area, Mt Iris.

At the Bargo River site, 83 mature individuals and 262 seedlings were recorded in 2022 (V. Wong pers. comm. September 2022) giving a population size estimate of 110-160, based on seedling survivorship of 10-30%.

Population Trends

NSW Threatened Species Scientific Committee

The current population size estimate of 3,000-4,600 is almost double the total population estimate made in the 1999 Final Determination which found “Local populations are small with a total population likely to be less than 2,500 and possibly less than 1,500 (The NSW Scientific Committee 1999).” This difference might suggest an increase in population size, however, the data quality from the 1999 estimate and unknown survivorship of the current cohort of seedlings is not sufficient to make any inference on population trends. Widespread seedling recruitment across almost all *D. peduncularis* sites, burnt and unburnt, infers that the total population may be increasing.

The recent mass recruitment event triggered by three years of above average rainfall across most large stands of *D. peduncularis*, burnt and unburnt, suggests an overall increasing population. In Wollemi NP, where all sites burnt in 2019-20, an estimated 5,500 seedlings were found at six sites (Mikaill 2021, 2022). At Kings Tableland 450 were counted (V. Wong pers. obs. February 2022). Seedlings were found at sites without recent fire at Bargo and Brooklyn (V Wong pers. obs. October 2022).

In recent times, three of the smallest known *D. peduncularis* sites have become locally extirpated or at the most very severely reduced since the Final Determination, Green Gully, Hunter Main Range Trail South and Brooklyn. In 2021 surveys, *D. peduncularis* was not found at the Hunter Main Range Trail South, where five mature plants had been found in 1998 (Mickaill 2021). At Green Gully in the Capertee Valley, none of the five plants recorded in 1998 (S. Douglas *in litt.* 1998) could be located (Hammill 2021). The records from Green Gully and Hunter Main Range locations were made in pre-GPS days, so may be incorrectly located and therefore may not have been found. However, both record sites have written description of their locations. Both sites have recent histories of very high frequency fires of two years and one-year respectively. *Darwinia peduncularis* is a fire-sensitive obligate seeder with a minimum of three years to maturity so any post-fire seedlings are killed by such short fire intervals.

At Brooklyn, a count of 20 plants on either side of the track between Parsley Bay and Dead Horse Bay was recorded in 1995. In 2004, only 2 adults (1 large and one recently mature) and 4 seedlings were recorded from one small patch on the edge of the track. The reason for decline is unknown but may be as a result of stochastic events on a small population.

Ecology

Darwinia peduncularis is a medium-sized shrub that flowers in winter to early spring (PlantNET 2021). *Darwinia peduncularis* commonly grows among rocky outcrops on exposed ridge lines, sandstone ledges, upper slopes and at the base of hillsides and escarpments. Stands of this species can be very small and often restricted to a small area of rocky habitat. *Darwinia peduncularis* grows on low nutrient, well drained, sandstone-derived soils.

The habitat of *D. peduncularis* in Wollemi NP has been described by Bell (2008) as on exposed ridgelines above Wollemi Creek in the centre of the park, in an open woodland/ heath of *Eucalyptus rossii*, *E. bensonii* and *E. multicaulis*, with a variety of shrubs including *Leptospermum parvifolium*, *Leucopogon muticus*, *Leptospermum trinervium*, *Calytrix tetragona*, *Baeckea densifolia*, *Leptospermum sphaerocarpum*, *Leptospermum arachnoides*, *Caustis flexuosa*, *Acacia linifolia*, *Bossiaea heterophylla* and *Dillwynia retorta*. Other occurrences are in sheltered localities in an open forest of

NSW Threatened Species Scientific Committee

Eucalyptus consideriana and *E. piperita*, with *Hakea dactyloides*, *Leptospermum trinervium*, *Dillwynia retorta*, *Gompholobium virgatum*, *Persoonia oblongata*, *Styphelia tubiflora*, *Isopogon anemonifolius*, *Lomatia silaifolia*, *Monotoca scoparia*, *Lomandra obliqua*, *Stylidium productum* and *Caustis flexuosa*. MicKaill (2021) describes occurrences in shrubland with *Hakea propinqua*, *Platysace lanceolata*, *Leucopogon muticus*, *Actinotus helianthi*, *Goodenia decurrens*, *Chloanthes stoechadis* and *Dampiera* spp.

At the Kings Tableland site, it grows in thin, rocky soil on two rocky hills with *Eucalyptus sieberi*, *Angophora costata* with a variety of shrubs including *Banksia serrata*, *Dillwynia retorta*, *D. elegans*, *Persoonia levis*, *Boronia floribunda*, *Allocasuarina distyla*, *Viminaria juncea*, *Woolisia pungens* and *Leptospermum trinervium*.

In the Berowra Valley it has been recorded growing with *A. costata*, *Corymbia gummiferum*, *Ceratopetalum apelatum*, *Eucalyptus piperita*, *Eucalyptus eximia* with *Backhousia myrtifolia*, *Banksia spinulosa*, *Ceratopetalum gummiferum*, *C. apelatum*, *Elaeocarpus reticulatus*, *Grevillea linearifolia*, *Leptospermum trinervium*, *Logania albiflora*, *Melaleuca deanii*, *Monotoca elliptica*, *Phebalium dentatum* and *Smilax glycyphyla*.

At Brooklyn it grows in a Banksia/teatree woodland with *Angophora costata*, *Banksia serrata*, *Ceratopetalum gummiferum*, *Xanthorrhoea arborea* and *Leptospermum* sp.

The life span of *D. peduncularis* is unknown but estimated to be in the range of 20-30 years, based on estimates for *Darwinia glaucophylla* (Booyens *et al.* 2020). The life span estimate of Booyens *et al.* (2020) is derived from mortality data observations from Auld and Scott (1997). If *D. peduncularis* seedlings mature at 3-4 years, then the generation length for the species can be inferred to be 12-17 years.

Pollination, gene flow and seed dispersal

Darwinia peduncularis has small, tubular flowers which are typically pollinated by small, long-beaked honeyeaters such as the New Holland Honeyeater *Phylidonyris novaehollandiae* and Eastern Spinebill *Acanthorhynchus tenuirostris* (Armstrong 1979; Ford and Paton 1977) and bees (V. Wong pers. obs. October 2022). Other *Darwinia* species have been known to be pollinated by native Thynnid, or flower, wasps and native Anthophoridae, or long-tongued bees (Armstrong 1979). *Darwinia peduncularis* is unlikely to self-pollinate, unlike many *Darwinia* species, as it has a long style which collects the apical pollen from the anthers inside the flower and requires a vector to transfer the pollen onto the stigma of the flower (Briggs 1964, Robinson *et al.* 2003).

With honeyeaters and bees as the main pollinators of *D. peduncularis*, gene exchange in would usually occur over short distances, but can potentially occur occasionally over long distances. The small, long-beaked honeyeaters most likely to pollinate *D. peduncularis* are territorial with home ranges typically <3 ha, however, are known to sometimes travel >5 km (Krauss *et al.* 2017). In the Western Australian bird pollinated shrub, of the Myrtaceae family, *Calothamnus quadifidus*, long-distance pollen dispersal was found up to 5km, with some pollen suspected to be dispersed much further (Byrne *et al.* 2007). Small nomadic honeyeater species, which can travel much greater distances (Byrne *et al.* 2007), also have the potential to pollinate and move between *D. peduncularis* sites. Honeybees can forage up to 12 km from a hive, but they mostly forage closer to a hive (Beekman and Ratrieks 2001). Native bees forage

NSW Threatened Species Scientific Committee

over much shorter distances than honeybees, 700 m to over 1000 m (Greenleaf *et al.* 2007; Smith *et al.* 2016). Based on pollinator behaviour, the effective pollination distance between large stands of *D. peduncularis* sites over 5km, but very unlikely more than a kilometre between small stands.

The seeds of shrubby Sydney *Darwinia* species are described as dry, indehiscent (non-splitting) nuts (Auld and Ooi 2009). This type of seed is usually dispersed by physical forces: wind, water or attached to the coat of an animal (Dardick and Callahan 2014). There are no studies on seed dispersal in *D. peduncularis*, however, in three other *Darwinia* species endemic to the Sydney basin, ants have been found to play an important role in seed dispersal (Auld 2009). Ant body size is positively correlated with dispersal distance and larger ants are likely to carry larger seeds (Giladi 2006). In sclerophyll vegetation near Sydney, ants have been found to disperse seeds between mostly less than 2m and rarely over 4 m (Westoby 1991). If ants and physical forces are the dispersal agents for this species, then it is highly unlikely that seeds are transported far from any subpopulation.

Population dynamics in relation to fire

Darwinia peduncularis is a fire sensitive obligate seeder, with adults killed by fire followed by mass recruitment of seedlings (Mickaill 2021). Seedlings begin to reach maturity after three years (Mickaill 2022). For all *Darwinia* species, few seeds are produced in the first year of flowering and fecundity increases as the plants grow and soil seedbanks should increase rapidly five to 10 years after a fire (Auld and Scott 1997). Most of the annually produced seed-crop is released in a viable, dormant state and is incorporated into the seedbank, although there is some yearly variation in the proportion of non-dormant seeds produced. The recommended fire prescription for this species is <7 years (Rural Fire Service 2017).

A second fire before the current cohort of seedlings has matured may result in population reductions. Plants that have seeds stored in the soil usually have some residual seedbank following post-fire germination, giving a site some resilience to two fires close together. A population may be severely reduced but may not necessarily be eliminated locally. However, in some places, after some fires, the entire soil seedbank may be exhausted, and local extinction could occur. The depletion of the seedbank will depend on the level of soil heating during the passage of fire (Bradstock and Auld 1995).

In other *Darwinia* species, heat is the fire-related cue that breaks seed dormancy, with the seed germination of several species increasing within a limited range of heating temperatures (80-100° C), while excessive heat damages seeds (Auld and Ooi 2009). This observation is consistent with seedling recruitment of *D. peduncularis* recorded at two sites in Wollemi NP after the Gaspers Mountain fire in 2019-20 (Mickaill 2021). At the Capertee Cliff site, fire intensity was much greater than at the Hunter Main Range site. The number of seedlings at the Hunter Main Range site, with the less intense burn, was more than 200 times greater than at Capertee Cliffs, however this may also be a consequence of the size of the stand before fire and/or seeds and seedlings being washed away from rocky soil in the heavy rains that followed the fires.

Seasonal timing and intensity of hazard reduction burns will influence recruitment success and timing (Mackenzie *et al.* 2021). Studies of fire and seasonal temperature influence on germination in another native shrub, *Boronia* spp., found that different

NSW Threatened Species Scientific Committee

species had highly variable responses, despite being closely related (Mackenzie *et al.* 2016). Seasonal temperature (summer/winter), heat shock (related to soil heating from fire intensity) and smoke, were important cues that were dissimilar for the different species studied and should be considered for any hazard reduction burns of *D. peduncularis* sites.

Slashing along a utility easement has been shown to have a positive effect on the abundance of *Darwinia glaucophylla* by creating an environment with more light and less competition (Booyens *et al.* 2014). This is probably also the case for *D. peduncularis* which is known to include plants growing along a gas easement in Marramarra NP and under electricity cable poles in the Berowra Valley. However, any positive effect will depend on how often slashing occurs as repeated slashing may disrupt flowering and fruiting and lead to a reduction in the potential seedbank.

Subpopulations

There are 14 subpopulations based on gene exchange from pollination by small honeyeaters and bees up to and over around 5km between large stands and not more than 1km between small stands. In the Lower Hawkesbury and Berowra Valley area, there are seven geographically distinct clusters of occurrences separated by 4-7km. Berowra NP is one subpopulation with 7km separating large occurrences along the river valley, a natural animal movement corridor. The occurrences in Ku-ring-gai Chase NP at Brooklyn and Campbells Crater are very small and are both subpopulations. The records in Marramarra NP are three subpopulations. In Wollemi NP, there are eight geographically distinct clusters of records separated by up to 4-10 km. There are seven subpopulations: Hunter Main Range Trail, Mount Coricudgy, Mount Boonbourwa, the ridge between Numietta and Cooroongooba Creeks, Mount Iris, Green Gully and Capertee Cliffs. Kings Tableland and Bargo are isolated subpopulations with over 40 to over 70km separating the from other subpopulations. If undiscovered record exists between known sites, then the number of subpopulations may be fewer.

Darwinia peduncularis is not considered severely fragmented, even though the known occurrences of this species are isolated by many kilometres from each other across the landscape. According to the IUCN Criteria (2022) a species is considered severely fragmented if most (>50%) of its areas of total occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) is separated from other habitat patched by a large distance relative to dispersal kernel of the species (IUCN 2022). While most known patches are beyond the dispersal distance of kernel, currently, only three patches of this species would be considered non-viable.

Threats

Darwinia peduncularis is threatened by high frequency fire, small population sizes, track and trail use and maintenance (NSW Scientific Committee 1999). The species is also potentially threatened by increased severity of drought from climate change, weed invasion, disease and feral pests (DPE 2022a).

High frequency fire

Frequent recurrent fire in *D. peduncularis* populations is a serious, ongoing threat. Short time intervals between fires in obligate seeders can disrupt the replenishment of seed banks, which are essential to post-fire recruitment and population persistence

NSW Threatened Species Scientific Committee

(Enright *et al.* 2015; Gallagher *et al.* 2020; Zimmer *et al.* 2021). A narrowing of the favourable interval between fires is known as “interval squeeze” (Enright *et al.* 2015). Estimates of the minimum fire interval to maintain *Darwinia* spp. is five to 10 years (Auld and Scott 1997). *Darwinia peduncularis* stands that are small or very restricted in area are particularly vulnerable to the threat of high frequency fire, however sometimes the rocky habitat of this species can offer some refuge from fire. ‘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 Act.

All known sites of *D. peduncularis* in Wollemi NP and Kings Tablelands burnt in the widespread 2019-20 fires, many at high and extreme fire intensity (Mikaili 2021; V. Wong pers. obs. November 2021). A second fire at any of these sites within the next few years before seedlings mature and produce substantial amounts of seed will put these stands at increased risk of local extinction. Also at risk from any fire in the next few years is part of the Berowra NP Fishponds population, which burnt in 2020 and two sites in Marramarra NP which burnt in 2018 (NPWS Fire History spatial layer 2022).

The landscapes of *D. peduncularis* do not have a history of many high frequency fires, but that is expected to change with ongoing climate change, increasing the threat of high frequency fire to the species. An episode of multiple fires at intervals of less than 7 years that would only allow for no or only minimal replenishment of the seedbank has occurred at nine of the 14 *D. peduncularis* sites (NPWS Fire History spatial layer 2022). Fires one and three years apart may explain the disappearance of the very small stands (both of five plants) at Hunter Main Range South and Green Gully, respectively. Projected changes to fire conditions under ongoing climate change of larger, more frequent, more severe fires (Abatzoglou *et al.* 2019; AdaptNSW 2022; Bowman *et al.* 2020) may expose *D. peduncularis* sites to more episodes of ‘interval squeeze’. ‘Anthropogenic climate change’ is listed as a Key Threatening Process under the Act.

The NSW Bush Fire Coordinating Committee has approved a new category of bushfire management zoning, Ignition Management Zone (IMZ), to minimise fire spread in parts of the environment that are difficult to access (NSW BFCC *in litt.* March 2022, Jon Gaibor pers. comm, *in litt.* October 2022). Ignition Management Zones threaten *D. peduncularis* stands as they are planned to be burnt every time fuel loads reach 14-15 tonnes per hectare, which may occur in in as little as four years (J. Gaibor pers. comm. October 2022), less than the minimum interval needed to restore seedbanks for population persistence in *D. peduncularis*.

Many of the *D. peduncularis* sites are in very thin, rocky soils that may wash away with seeds and seedlings if heavy rain follows intense fire. This effect has been observed in another fire sensitive, obligate seeder, *Leionema lachnaeoides*, that grows in thin, rocky soils in the Blue Mountains (V. Wong pers. obs. November 2021). The combination of fire followed by intense rain can result in an increased risk of damage or loss of a small stand of the species.

Disturbance from recreational use or trail maintenance

Disturbance by walkers, bike riders and trail maintenance are inferred to be a minor ongoing threat to *D. peduncularis* populations in urban interface areas and on tracks,

NSW Threatened Species Scientific Committee

roads and fire trails. There are several *D. peduncularis* sites in the Berowra Valley on popular walking tracks including Fishpond site which is subject to substantial recreational pressures, with a track through the middle and a popular swimming area. The sites at Bargo and Brooklyn are also on popular walking tracks. In some cases, disturbance is inferred to have a positive influence on populations.

Increased severity of drought from ongoing climate change

Increased frequency and severity of drought associated with ongoing climate change may threaten the long-term survival of *D. peduncularis* (Abram *et al.* 2021; Dai 2021). Severe drought has been observed to impact *D. peduncularis* stands by hastening plant death as the thin, rocky soils in which it often grows easily dry out. The Berowra Valley population was observed to have suffered during the drought of 1997/98 (S. Douglas *in litt.* June 1998). The most recent drought was in 2018 and 2019, but it is unknown how the conditions affected *D. peduncularis*. Heavy rain after drought can wash away plants and its seedbank from the thin, rocky soils.

Weed invasion

Weeds have not been reported from *D. peduncularis* sites but are inferred to be an ongoing threat in all urban interface areas of the Berowra Valley. Weeds have the potential to compete with *D. peduncularis* plants of any age for space and light. No weeds were found at the sites surveyed in Wollemi NP (MicKaill 2021, 2022), Blue Mountains NP (V. Wong pers. obs. February 2022), Brooklyn or at two Berowra Valley sites (V. Wong pers. obs. October 2022)

Disease

Darwinia peduncularis has the potential to be susceptible to the exotic pathogens, *Phytophthora cinnamomi* and *Austropuccinia psidii* (Myrtle Rust), especially stands in areas close to high levels of foot and bike traffic. *Phytophthora cinnamomi* is an introduced pathogen that has had a devastating effect on plant communities worldwide, causing catastrophic dieback in many species. Myrtle rust is an exotic fungus that affects Myrtaceae, destroying tissue, limiting reproductive success, and ultimately leading to plant death (Makinson 2018). There is no information available on the presence of *P. cinnamomi* or *A. psidii* in *D. peduncularis* subpopulations, but the species is identified by NSW Scientific Committee (2003) as a species that may be adversely affected by *P. cinnamomi*. 'Infection of native plants by *Phytophthora cinnamomi*' is listed as a Key Threatening Process on the BC Act.

In 2022, at the Kings Tableland *D. peduncularis* site, some juvenile plants were observed to have dead and deformed leaves, with up to 80% defoliation. The cause of this dieback is unknown but is likely to have been caused by disease or insects (V. Wong pers. obs. February 2022).

Feral Pests

Honeybees have been thought to harvest nectar from *D. peduncularis* flowers without pollinating the plant, reducing reproductive success (DPE 2022a). Irwin *et al.* (2010) found that honeybees that harvest nectar from tubular flowers, like those of *D. peduncularis*, do not pollinate the plant, which reduces the species reproductive success by removing the attractant to pollinating species like honeyeaters. However, field observations of bees foraging on the flowers of *Darwinia peduncularis* suggests

NSW Threatened Species Scientific Committee

otherwise, with the body of honeybees sometimes contacting the style and stigma (V. Wong pers. obs. October 2022).

Assessment against IUCN Red List criteria

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

Criterion A Population Size reduction

Assessment Outcome: Data deficient

Justification: The current population size estimate is uncertain but in the range of 3,000-4,600 based on a proportion of the current cohort of seedlings surviving to maturity. The current estimate is almost double the total population estimate made in the 1999 Final Determination for this species, which found “Local populations are small with a total population likely to be less than 2,500 and possibly less than 1,500” (NSW Scientific Committee 1999). This difference might suggest an increase in population size, however, data quality from the 1999 estimate and unknown survivorship of the current cohort of seedlings is not sufficient to make any inference on population trends. Widespread seedling recruitment across almost all *D. peduncularis* sites, burnt and unburnt, suggests that the total population may be increasing. There is no other quantitative data available on population size change over time.

Generation length is inferred to be 12-17 years based on the mid-point of observations of time to maturity of *D. peduncularis* seedlings after the 2019-20 fire season of more than two years, mostly likely 3-4 years (Mickaill 2021; V. Wong pers. obs. January 2022) and the life span estimate of *D. glaucophylla* of 20-30 years (Booyens *et al.* 2020).

Criterion B Geographic range

Assessment Outcome: Vulnerable under Criterion B2ab(i)(ii)(iii)(iv)

Justification: *Darwinia peduncularis* has a highly restricted geographic distribution. The extent of occurrence (EOO) is 8,189 km² and the area of occurrence (AOO) is 116 km². The AOO is 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 based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). *Darwinia peduncularis* meets the Endangered threshold for AOO (<500 km²) and Vulnerable threshold for EOO (<20, 000 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: There are 4-7 locations defined by the threat of fire which fits the category of either Endangered or Vulnerable. Four or five locations are based on the subpopulations north of Sydney burning in a single or two wildfires which would represent the worse-case scenarios, which is not recommended to be used by the IUCN guidelines (2022). As a consequence, the subpopulations north of Sydney have been divided into 3-4 locations which

NSW Threatened Species Scientific Committee

fits the threshold for Vulnerable. *Darwinia peduncularis* is not considered severely fragmented.

Justification: The most serious plausible threat for defining the number of locations is high frequency fire. *Darwinia peduncularis* is a fire-sensitive obligate seeder and a second fire at any recently burnt stand before the current cohort of seedling mature will put that stand at risk of local extinction.

There are 4-7 threat-defined locations (1) Wollemi NP, (2) Kings Tablelands, (3) Bargo River, (4) Marramarra NP, (5) Brooklyn and Ku-Ring-Gai Chase NP, (6) Berowra and Gundah Ridge, and (7) Fishponds and Waddells Gully. The Kings Tablelands and Bargo River sites are vastly geographically separated from other sites and are two separate locations. The occurrences in Wollemi NP are connected by continuous bushland which was all burnt by the Gospers Mountains fire in 2019-20 and are a third location. The occurrences in the Lower Hawkesbury and Berowra Valley are linked by continuous bushland and could be considered one location. A 2002 wildfire burnt all Lower Hawkesbury sites but stopped short of the Berowra Valley sites. However, the close proximity of these sites to large residential areas would result in a high level of fire-fighting resourcing against any approaching wildfire and the area is unlikely to burn in a single fire. Defining the north Sydney sites as one location is a “worse-case scenario” which is not the recommended approach in the IUCN Guidelines (2022). The threat of high frequency fire is greater from repeated small hazard reduction burns than multiple large wildfires and as such the areas can be divided into two to four locations: (1a) Brooklyn and Ku-Ring-Gai Chase NP, (1b) Marramarra NP, (2a) Berowra and Gundah Ridge and (2b) Fishponds and Waddells Gully.

- 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) and (iv)

Justification: Three years of above average rainfall, 2020 to 2022, and fire in the greater Blue Mountains subpopulations, has triggered a mass recruitment event in most large stands of *D. peduncularis*, suggesting an overall increasing population. However, despite this projected increase as seedlings mature, small, isolated subpopulations of *D. peduncularis* have become locally extinct or at most very severely reduced at Hunter Main Range south, Green Gully and Brooklyn and as such continuing decline is estimated, inferred and projected in AOO, quality of habitat and number of locations from high frequency fire, disturbance from recreational and trail maintenance and increasing severity of drought from climate change.

Continuing decline is estimated, inferred and projected from high frequency fire from ongoing climate change and from intensive bushfire management practices. High frequency fire depletes seed banks in fire sensitive obligate seeders and reduces population size over repeated fires (Enright *et al.* 2015). High frequency fire is likely to be responsible for the losses of the Hunter Main Range South and Green Gully subpopulations, resulting in a reduction of the

NSW Threatened Species Scientific Committee

AOO of the species as these sites are separated by over 4 km from the nearest *D. peduncularis* sites. Projected changes to fire conditions under ongoing climate change of larger, more frequent, more severe fires (Abatzoglou *et al.* 2019; AdaptNSW 2022; Bowman *et al.* 2020) may expose *D. peduncularis* sites to more episodes of high frequency fire. A second fire at any of the recently burnt subpopulations before seedlings mature and produce substantial amounts of seed will result in declines in the number of individuals and put these subpopulations at increased risk of local extinction. Loss of isolated subpopulations in the greater Blue Mountains may result in a reduction of the AOO, EOO and number of locations of the species. Ongoing decline in habitat extent and quality and number of mature individuals in western Wollemi NP sites is projected from a proposed new high fire frequency bushfire management regime, Ignition Management Zones (IMZ), which are planned to be burnt in as little as four years since previous fire (J. Gaibor pers. comm. October 2022).

Continuing decline is inferred in *D. peduncularis* subpopulations adjacent to popular walking tracks, bike tracks, vehicle tracks and urban interface areas from recreational pressures by walkers and bike riders and from track and trail maintenance. There are several *D. peduncularis* sites on popular walking tracks in the Berowra Valley, at Brooklyn and Bargo. The Brooklyn site is particularly at risk from this threat as the remaining six plants are located directly on the edge of the walking track.

c) Extreme fluctuations.

Assessment Outcome: Data deficient

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

Criterion C Small population size and decline

Assessment Outcome: Criterion not met.

Justification: The population size of *D. peduncularis* is uncertain but in the range of 3,000-4,600, based on a proportion of the current cohort of seedling surviving to maturity, which is well with the threshold for Vulnerable. However, the additional Subcriteria are either data deficient or not met.

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 not data sufficient available to assess population size change over time. Generation length is estimated to be 12-17 years.

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

Assessment Outcome: Subcriterion not met.

NSW Threatened Species Scientific Committee

Justification: Three years of above average rainfall, 2019-2022, and fire in the greater Blue Mountains subpopulations, has triggered a mass recruitment event in most large stands of *D. peduncularis*, suggesting an overall increasing population despite the loss or severe reduction of three very small subpopulations of *D. peduncularis*. Continuing decline is projected from high frequency fire and disturbance from recreational and trail maintenance.

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: Not met.

Justification: The largest subpopulation is on the ridge between Numietta and Coorongooba Creek with an estimated 1,500-3,000 individuals which is above the threshold (≤ 1000) to meet Vulnerable for this species.

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

Assessment Outcome: Subcriterion not met

Justification: The population of *D. peduncularis* is divided between 14 subpopulations. The largest subpopulation is on the the ridge between Numietta and Coorongooba Creek containing an estimated 50-67% of the total population.

- 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 *D. peduncularis* is 3,000-4,600 which exceeds the thresholds for this criterion. *Darwinia peduncularis* does not have an AOO restricted to $< 20\text{km}^2$. The number of locations is 4-7 which could meet the Subcriterion however there is no currently known plausible future threat that could drive the taxon to CR or EX in a very short time.

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

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

Assessment Outcome: Subcriterion not met.

Justification: The population size of *D. peduncularis* is uncertain but in the range of 3,000-4,600 based on a proportion of the current cohort of seedling surviving to maturity which exceeds the thresholds for this Criterion.

NSW Threatened Species Scientific Committee

D2. Restricted area of occupancy (typically <20 km²) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment Outcome: The number of locations is 4-7 based on the threat of high frequency fire, which could meet the Subcriterion however there is currently no known plausible future threat that could drive the taxon to CR or EX 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

This species 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. *Darwinia peduncularis* 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=10205>.

References

Abram NJ, Henley BJ, Gupta A. sen, Lippmann TJR, Clarke H, Dowdy AJ, Sharples

JJ, Nolan RH, Zhang T, Wooster MJ, Wurtzel JB, Meissner KJ, Pitman AJ, Ukkola AM, Murphy BP, Tapper NJ, Boer MM (2021) Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Communications Earth and Environment*, **2**, 1–17

Abatzoglou JT, Williams AP, Barbero R (2019) Global emergence of anthropogenic climate change in fire weather indices. *Geophysical Research Letters* **46**, 326–336.

AdaptNSW (2022) Interactive climate change projections map. Available at: <https://www.climatechange.environment.nsw.gov.au/projections-map?region=south-east-and-tablelands&climateprojection=tasmean&range=0> (accessed on 25 July 2022)

NSW Threatened Species Scientific Committee

- Armstrong JA (1979) Biotic pollination mechanisms in the Australian flora — a review. *New Zealand Journal of Botany* **17**(4), 467–508.
- Auld TD (2009). Petals may act as a reward: myrmecochory in shrubby *Darwinia* species of south-eastern Australia. *Austral Ecology* **34**(3), 351–356.
- Auld TD, Ooi MK (2009) Heat increases germination of water-permeable seeds of obligate-seeding *Darwinia* species (Myrtaceae). *Plant Ecology* **200**(1), 117–127.
- Auld TD, Scott J (1997) Conservation of endangered plants in urban fire-prone habitats. In 'Proceedings: Fire Effects on Rare and Endangered Species and Habitats Conference, Coeur D'Alene, Idaho' pp. 163–71.
- Bachman S, Moat J, Hill AW, de la Torre J, Scott B (2011) Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool, in Smith V & Penev L (eds) e-Infrastructures for data publishing in biodiversity science. *ZooKeys* **150**, 117–126. (Version BETA)
- Bell SA (2008) Rare or threatened vascular plant species of Wollemi National Park, central eastern New South Wales. *Cunninghamia* **10**, 331–371.
- Booyens (2010) 'The effect of disturbance regimes (fire and slashing) on populations of *Darwinia glaucophylla* on the Central Coast of NSW, Australia.' Thesis Submitted in partial fulfilment of the requirements for the degree of Master of Philosophy, University of Newcastle, Australia.
- Booyens C, Chalmers A, Beckers D (2014) The effect of disturbance regime on *Darwinia glaucophylla* (Myrtaceae) and its habitat. *Proceedings of the Linnean Society* **136**, 231–244.
- Bowman DM, Kolden CA, Abatzoglou JT, Johnston FH, van der Werf GR, Flannigan M (2020) Vegetation fires in the Anthropocene. *Nature Reviews Earth & Environment* **1**(10), 500–515.
- Bradstock RA, Auld TD (1995) Soil temperatures during experimental bushfires in relation to fire intensity: consequences for legume germination and fire management in south-eastern Australia. *Journal of Applied Ecology* **32**, 76–84.
- Briggs BG (1964) The control of interspecific hybridization in *Darwinia*. *Evolution* **1**, 292–303.
- Byrne M, Elliott CP, Yates C, Coates DJ (2007) Extensive pollen dispersal in a bird-pollinated shrub, *Calothamnus quadrifidus*, in a fragmented landscape. *Molecular Ecology*, **16**(6), 1303–1314.
- Dai AG (2012) Increasing drought under global warming in observations and models. *Nature Climate Change* **3**, 52–58.
- Dardick C, Callahan AM (2014) Evolution of the fruit endocarp: molecular mechanisms underlying adaptations in seed protection and dispersal strategies. *Frontiers in plant science* **5**, 284.
- Department of Planning and Environment (2022a) *Darwinia peduncularis* – profile. Available at:
<https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10205> (accessed 17 October 2022)

NSW Threatened Species Scientific Committee

Department of Planning and Environment (2022b) NSW BioNet Resources. Available at:

<https://www.environment.nsw.gov.au/topics/animals-and-plants/biodiversity/nsw-bionet/resources> (accessed 8 July 2022).

Department of Planning and Environment (2022c) NSW State Vegetation Type Map C1.1M1. DPE Spatial Layer, 20 June 2022.

Enright NJ, Fontaine JB, Bowman DMJS, Bradstock RA, Williams RJ (2015) Interval squeeze: Altered fire regimes and demographic responses interact to threaten woody species persistence as climate changes. *Frontiers in Ecology and the Environment* **13(5)**, 265–272.

Ford, HA, Paton DC (1977). The comparative ecology of ten species of honeyeaters in South Australia. *Australian Journal of Ecology* **2(4)**, 399–407.

Gallagher RV, Allen S, Mackenzie BD, Yates CJ, Gosper CR, Keith DA, Auld TD (2021) High fire frequency and the impact of the 2019–2020 megafires on Australian plant diversity. *Diversity and Distributions* **27(7)**, 1166–1179.

Giladi I (2006) Choosing benefits or partners: a review of the evidence for the evolution of myrmecochory. *Oikos* **112(3)**, 481–492.

Hammill K (2021) *Darwinia peduncularis* – Survey and habitat notes for post-fire surveys, Capertee sites Wollemi NP, June to September 2020. KHS Ecology and Bushfire.

Irwin RE, Bronstein JL, Manson JS & Richardson L (2010) Nectar robbing: ecological and evolutionary perspectives. *Annual review of ecology, evolution, and systematics* **41**, 271–292.

IUCN Standards and Petitions Subcommittee (2022) Guidelines for Using the IUCN Red List Categories and Criteria. Version 15.

https://nc.iucnredlist.org/redlist/content/attachment_files/RedListGuidelines.pdf.

Krauss SL, Phillips RD, Karron JD, Johnson SD, Roberts, DG, Hopper SD (2017) Novel consequences of bird pollination for plant mating. *Trends in Plant Science* **22(5)**, 395–410.

Mackenzie BD, Auld TD, Keith DA, Ooi MK (2016) How fire and seasonal temperatures influence the germination of many plant species: Insights from 'Boronia' (Rutaceae). *Australasian Plant Conservation: Journal of the Australian Network for Plant Conservation* **25(2)**, 5–7.

Mackenzie BD, Auld TD, Keith, DA, Ooi, MK (2021) Fire seasonality, seasonal temperature cues, dormancy cycling, and moisture availability mediate post-fire germination of species with physiological dormancy. *Frontiers in Plant Science* **12**, 795711.

Makinson RO (2018) Myrtle Rust in Australia – a draft Action Plan, presented at the Plant Biosecurity Cooperative Research Centre's National Science Exchange, Melbourne.

Mickaill NNL (2021) Targeted Surveys and Post-fire site assessment of the vulnerable *Darwinia peduncularis* (Myrtaceae) at Priority Sites within Wollemi National Park,

NSW Threatened Species Scientific Committee

Saving our Species (SoS) Program. Unpublished Report to NSW Department of Planning, Industry and Environment.

NSW Government (2021) Project Summary *Darwinia peduncularis* (*Darwinia peduncularis*). Available at:

<https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/saving-our-species-program/saving-our-species-database> (accessed 20 December 2021)

NSW Scientific Committee NSW (1999) Final determination to list the shrub *Darwinia peduncularis* B. Briggs as a Vulnerable species [WWW Document]. Available at:

<https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/nsw-threatened-species-scientific-committee/determinations/final-determinations/1996-1999/darwinia-peduncularis-a-shrub-vulnerable-species-listing> (accessed 24 November 2021)

NSW Scientific Committee NSW (2003) Infection of native plants by *Phytophthora cinnamomi* – key threatening process listing. Available at:

<https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/nsw-threatened-species-scientific-committee/determinations/final-determinations/2000-2003/infection-of-native-plants-by-phytophthora-cinnamomi-key-threatening-process-listing> (accessed 29 April 2022).

PlantNET (The NSW Plant Information Network System) Royal Botanic Gardens and Domain Trust. Available at:

<https://plantnet.rbgsyd.nsw.gov.au/cgi-bin/NSWfl.pl?page=nswfl&lvl=sp&name=Darwinia~peduncularis> (accessed 17 November 2022)

Robinson L (2003) Field Guide to the Native Plants of Sydney.

Rural Fire Service (2017) Threatened Species Hazard Reduction List – Part 1 – Plants. Available at: https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0017/24335/Web-Version-ThreatenedSpeciesHazardReductionList-Part1-Plants-06-04-2017.pdf

Westoby M, French K, Hughes L, Rice B, Rodgerson L (1991) Why do more plant species use ants for dispersal on infertile compared with fertile soils? *Australian Journal of Ecology*, **16(4)**, 445-455.

Zimmer H, Allen J, Smith R, Gibson R, Auld T (2021) Post-fire recruitment and resprouting of a threatened montane eucalypt. *Australian Journal of Botany* **69**, 21-29.

Expert Communications

Lily MicKaill, Botanist.

Meagan Hinds, Project Officer Conservation Assessment, Biodiversity and Conservation.

Peter Wilson, Principal Research Scientist, National Herbarium of New South Wales, Steve Douglas, Botanist, Ecological Surveys.

NSW Threatened Species Scientific Committee

APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria

The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome:

Darwinia peduncularis was found to be eligible for listing as Vulnerable under Clause 4.3(c)(e)(ii)(iii)(iv)

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)(iv)

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,

NSW Threatened Species Scientific Committee

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

Clause 4.4 - Low numbers of mature individuals of species and other conditions (Equivalent to IUCN criterion C)

Assessment Outcome: Clause not met

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

Clause 4.5 - Low total numbers of mature individuals of species (Equivalent to IUCN criterion D)

Assessment Outcome: Clause not met

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

NSW Threatened Species Scientific Committee

Clause 4.6 - Quantitative analysis of extinction probability (Equivalent to IUCN criterion E)

Assessment Outcome: Data deficient

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

Clause 4.7 - Very highly restricted geographic distribution of species–vulnerable species

(Equivalent to IUCN criterion D2)

Assessment Outcome: Clause not met

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