Conservation Assessment of *Muehlenbeckia costata* K.L.Wilson & Makinson (Polygonaceae)

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***Muehlenbeckia costata* K.L.Wilson & Makinson (Polygonaceae)**
Distribution: NSW, Queensland
Current EPBC Act Status: Not listed
Current NSW BC Act Status: Vulnerable
Current Queensland NC Act Status: Not listed

Proposed listing on NSW BC Act: Delist.

Reason for change: Nongenuine change based on increased data on distribution, abundance and knowledge of threats acting on the species.

Summary of Conservation Assessment

Muehlenbeckia costata was found to be ineligible for listing as a threatened species as none of the Criteria were met.

This assessment details a nationwide assessment of the threatened status of *Muehlenbeckia costata*. The outcome of this assessment in NSW is the same as for the national assessment given: (1) the species' geographic distribution is not greatly different between NSW and Australia, with the NSW extent of occurrence estimated as 47,882 km^2 (*c.f.* 47,932 km^2) and the NSW area of occupancy estimated as 60 km^2 (*c.f.* 68 km^2); (2) the number of threat-defined locations is the same in NSW as in Australia; (3) the number of mature individuals is not greatly different between NSW and Australia, with NSW containing at least 87% of the total Australian population across 6 subpopulations; and (4) there is no evidence of continuing decline within either the NSW distribution or the Australian distribution. This means that *M. costata* is ineligible to be listed on the basis of the risk of extinction in both Australia and New South Wales.

Muehlenbeckia costata flowering in Bald Rock National Park in March 2020. Image: Gavin Phillips

Description and Taxonomy

Muehlenbeckia costata (scrambling lignum) is a conventionally accepted and recently described species (CHAH 2009, Wilson and Makinson 2024). It is described as a scrambling or decumbent subshrub or twiner to 4 m in height, dioecious. Stems slender, green to reddish, not glaucous, weakly striate, to 5 m long. Leaves solitary, persistent, not succulent, yellow-green, slightly paler abaxially, often reddish on margins and veins, not glaucous, simple, petiolate; petiole 10–20(–25) mm long, usually no more than 1/3 as long as blade; blade ovate to oblong-ovate, 25–75(–140) mm long, 10–50(–90) mm wide; distal third of blade with edges strongly convex; base truncate to more or less cordate or sagittate; margins strongly crisped, slightly wavy; apex obtuse, emarginate, or acute, occasionally short-apiculate (apiculum to 3 mm long); ocrea short-tubular, not ciliate on upper margin, soon disintegrating. Flowers 2–5 per cluster in usually axillary spikes 0.5–10 cm long, spikes not crowded at branch ends. Perianth 5-merous, sepaloid, divided for 2/3–3/4 of its length in female flowers, rather more in male flowers; perianth segments 1.5–2.0 mm long, persistent, greenish becoming orange and fleshy in fruiting stage, papery when dry. Stamens 8; anthers 0.7–0.9 mm long. Style 3-fid. Nut broad-elliptical in outline, subterete to broadly trigonous, 3–4 mm long, with 6 broad rounded longitudinal ridges, black, dull, tuberculate, partly enclosed by persistent perianth (Wilson and Makinson 2024).

There have been longstanding nomenclatural issues with *Muehlenbeckia costata*. The species was previously referred to in New South Wales (NSW) as *Muehlenbeckia costata* K.L.Wilson & Makinson ms. (Hunter 1995, 2005; Hunter *et al.* 1998) after it was included under this name in the Flora of New South Wales (Wilson 1990, 2000).

M. costata was subsequently listed on the *NSW Threatened Species Conservation Act 1995* in 2002 (NSW Scientific Committee 2002), with this name carrying over to the *Biodiversity Conservation Act 2016.* However, having not yet been formally described, the phrase name *Muehlenbeckia* sp. Mt Norman (J.T.Hunter 3847) Makinson was long considered the correct name (CHAH 2009). In early 2024, the species was formally described as *M. costata* K.L.Wilson & Makinson (Wilson and Makinson 2024), with this name now correctly applied.

In Queensland, *M. costata* is considered to be synonymous with *M.* sp. (Stanthorpe A.R.Bean 12466) (Pennay 2017), however recent investigations indicate that the specimen from Passchendaele State Forest underpinning the concept of *M.* sp. Stanthorpe does not match the recognised description for *M. costata*, and may be attributable to another taxon such as *M. rhyticarya* (T. Bean *in litt.* June 2023). This means that *M.* sp. Stanthorpe might be a *pro parte* synonym of *M. costata* in Queensland, with specimens from Girraween National Park currently referred to as *M.* sp. Stanthorpe clearly matching the concept of *M. costata* (RBGDT 2023a).

Muehlenbeckia costata is closest morphologically to the widespread species *M. rhyticarya* which has an overlapping distribution. *Muehlenbeckia costata* can be distinguished from *M. rhyticarya* by the non-glaucous stems and leaves (*c.f.* glaucous stems and leaves), the scrambling or twining habit (*c.f.* erect, low shrub habit) and crisped leaf margins (*c.f.* flat margins; Wilson 2000, 2012). *Muehlenbeckia adpressa* from southern Australia is also similar, though it can be differentiated by its smooth, ellipsoid to obovoid nut (*c.f.* tuberculate, trigonous nut) and semi-circular to oblong-ovate leaves (*c.f.* ovate to oblong-ovate leaves; Wilson 2000).

Distribution and Abundance

Muehlenbeckia costata is locally restricted to a number of rocky outcrops scattered widely across the New England Tableland of northern NSW and southeast Queensland, with two outlying sites in the Pilliga and the NSW Central Tablelands near Lithgow. This range lies across the New England Tablelands, Nandewar, Brigalow Belt South and South Eastern Highlands Bioregions (DAWE 2012) and the traditional lands of the Ngarabul, Bundjalung, Kamilaroi, Gumbaynggir and Wiradjuri First Nations people (Horton 1996; NSW NPWS 2002, 2007, 2013a, 2016, 2021).

Prior to 1994, *Muehlenbeckia costata* was known only from four collections: one from near Stanthorpe in southeast Queensland, one from the NSW Central Tablelands at Wallerawang near Lithgow, and two from the NSW Northern Tablelands, being at Mount Kaputar, and a freshly burnt area within what is now Warra National Park (Binns 1992; Richards and Hunter 1997). Following severe fire in Girraween and Bald Rock National Parks in October 1994, the species was then found to be common on rock outcrops in new sites in both national parks (Hunter 1995) and was also recorded post-fire in what is now Butterleaf National Park in 1996 (Richards and Hunter 1997). A further occurrence was discovered in the Willala Aboriginal Area on the eastern edge of the Pilliga to the west of the then-known range in 2010 (Hunter 2011a). This means that the species is currently known from six sites across its range (Table 1).

Each site typically consists of localised clusters of records on and between rocky outcrops in an area of continuous habitat that may be affected by a single fire event. These areas are likely to have local gene flow within them via seed dispersal by birds and reptiles following mass fruit production in the post-fire landscape (Hunter *et al.* 1998). However, the six known sites are separated from one another by distances of more than 50 km. There are also considerable areas of cleared land and unsuitable habitat in between most sites, which is likely to pose a significant barrier to gene flow through either pollen or seed dispersal. Thus, the six known sites can all be considered distinct subpopulations as defined by IUCN (2022).

The northernmost subpopulation straddles the border between Queensland and NSW and occurs within Girraween and Bald Rock National Parks southeast of Stanthorpe. This subpopulation has been recorded across six of the largest outcrops in the area from Mount Norman in the west to Bald Rock in the east covering an area of approximately 20 km^2, with outcrops under 10 ha in size only supporting the species when they are satellites of the larger outcrops (Hunter 1995; Hunter *et al.* 1998). The species can form extensive mats on the outcrops where it is found here, covering areas where soil accumulates in cracks and on flatter areas of the outcrops (G. Phillips pers. obs. March 2020). It has been estimated that up to 1,200 plants inferred to be mature, were present following the 1994 fire across the parks (Hunter *et al.* 1998), however this estimate may be conservative given the large numbers seen on Bald Rock alone (likely in the 1000's of plants) following intense fire in 2019 (G. Phillips pers. obs. March 2020). Further searches following the 1994 fires failed to find *Muehlenbeckia costata* on any other burnt outcrops in the area, so it appears restricted to these large outcrops above 1,100 m elevation in this subpopulation (Hunter *et al.* 1998).

Table 1 - Abundance of *Muehlenbeckia costata* across all known subpopulations as of June 2023.

Site/Subpopulation	**Tenure**	**Estimate of Mature Individuals**	**Site Notes**	**References**
Girraween/Bald Rock	QPWS/NPWS	1,200+	Spans approx. six large outcrops over 20 km^2	Hunter *et al.* 1998
Butterleaf	NPWS/Private Conservation	3,000+	Numerous large outcrops and forest habitat across 22 km^2	Hunter *et al.* 1998; Hunter 2020; P. Sheringham *in litt.* June 2023
Warra	NPWS	2,000	Two mountain summits approx. 1.5 km apart	Hunter *et al.* 1998
Mount Kaputar	NPWS	2,000+	Common across high summit region of approx. 1.5 km^2	G. Phillips pers. obs. April 2020, September 2020.
Willala	NPWS	50	Small patch on sandstone	Hunter 2011a

Wallerawang	Uncertain, possibly NPWS	Unknown	Single specimen from 1901*	BioNet 2023
ESTIMATED MINIMUM INDIVIDUALS		**8,250**		

* The Wallerawang subpopulation is here regarded as potentially extant despite not being recorded since 1901. This is due to the potential for the species to remain undetected for extremely long periods in the soil seedbank, the requirement for surveys in a window following suitable fire to record standing plants, and the large areas of suitable habitat that remain in the general area.

Two further subpopulations of *Muehlenbeckia costata* lie along the eastern edge of the New England Tableland in NSW. Butterleaf is the northernmost of these and the largest known subpopulation. It spans Butterleaf National Park and the adjoining Bezzants Lease private conservation reserve northeast of Glen Innes. Here, plants have been found across several large outcrops and within the forest matrix between them (Hunter 2020), spanning an area of approximately 22 km^2. Around Mount Scott within Butterleaf National Park, there was initially estimated to be up to 300 plants across an area of 1,500 x 500 m following fire in 1996 (Richards and Hunter 1997; Hunter *et al.* 1998). However, recent surveys have increased the known abundance on Mount Scott to minimum of 1,000 individuals (and possibly many more) following fires in 2019-2020 (P. Sheringham *in litt.* June 2023). A single plant has also been recorded near to Garrett Trig to the east of Mount Scott (Richards and Hunter 1997). The largest recorded patch of plants is found within the privately managed Bezzants Lease property that adjoins the north of Butterleaf National Park (Hunter 2020). On this property, which is managed in perpetuity for conservation, *M. costata* is abundant and widespread, with over 2,000 plants conservatively estimated following the 2019-2020 fires across several large outcrops and the intervening forest matrix (Hunter 2020; J. Hunter *in litt.* June 2023). Therefore, a conservative minimum of 3,000 plants are known from across the Butterleaf National Park and Bezzants Lease subpopulation.

In Warra National Park, southeast of Glen Innes, another large subpopulation spans two large summit outcrops approximately 1.5 km apart. Plants of *Muehlenbeckia costata* have here been recorded on outcrops exceeding 10 ha in size and above 1,100 m elevation (Hunter *et al.* 1998). At least 2,000 plants are estimated to have occurred across both outcrops following fire in 1994 (Hunter *et al.* 1998; Hunter 2005). Recent surveys following the 2019-2020 fires have shown this subpopulation was still present in high abundance following that event (J. Hunter *in litt.* June 2023), and the previous count of 2,000 plants is regarded as a conservative minimum abundance for the subpopulation.

To the west, another large subpopulation of *Muehlenbeckia costata* occurs at Mount Kaputar, east of Narrabri. Perched on the western limit of the NSW Northern Tablelands, plants here are only known from the highest parts of the Mount Kaputar massif, from the Governor to the summit of Mount Kaputar itself (G. Phillips pers. obs. April 2020, September 2020), covering an area of approximately 1.5 km^2. Plants are found around extensive trachyte outcrops as well as in the forest matrix in between, especially dominating areas of outcrop with a forest canopy and more sheltered slopes post-fire (G. Phillips pers. obs. April 2020, September 2020). There is estimated to be at least 2,000 plants across the summit area, with the species occurring in very high abundance in some areas (G. Phillips pers. obs. April 2020, September 2020).

Two small disjunct subpopulations are found on the southern and western limits of the species' known range. To the west there is a subpopulation of approximately 50 plants on the Willala Knobs sandstone formation within the Willala Aboriginal Area on the eastern edge of the Pilliga, south of Narrabri (Hunter 2011a). A single historical specimen voucher record is also known from the Wallerawang district northwest of Lithgow in the NSW Central Tablelands (BioNet 2023). The abundance and exact locality of this subpopulation remains unknown with the only confirmed collection made in 1901 (RBGDT 2023a). However, the subpopulation may persist given the potential for the species to remain undetected for extremely long periods in the soil seedbank (Hunter 1999) and the areas of suitable habitat that remain in the general area.

Considering all subpopulations, the current estimated minimum population size of *Muehlenbeckia costata* is 8,250 mature individuals (Table 1). However, *M. costata* is dependent on severe fire to initiate germination, with emergent plants apparently short-lived (Hunter *et al.* 1998). Hence, abundance and detectability are likely to decline with time since fire, which may influence interpretations of abundance and demographic change. Natural fluctuations occur in the population of *M. costata* depending on the fire regime, with the species reaching peak abundance 6–12 months post-fire and then persisting in the soil seedbank for decades (and potentially longer) between suitable fires (Hunter *et al.* 1998; Hunter 1999). This means that abundance estimates for sites with less frequent monitoring or observations, such as at Willala Aboriginal Area, have high error margins as the current records are dependent on the time of observation relative to the last hot fire event. Given this, the current estimate of 8,250 mature individuals is considered conservative, and there is potential for many more plants in unsurveyed areas as well as within known subpopulations depending on fire severity and spread during a wildfire event.

Area of Occupancy and Extent of Occurrence

The Area of Occupancy (AOO) of *Muehlenbeckia costata* is estimated to be 68 km^2 using 2 x 2 km grid cells, the scale recommended by IUCN (2022). The Extent of Occurrence (EOO) is estimated to be 47,932 km^2 and is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). Both EOO and AOO were calculated using ArcGIS (Esri 2015), enclosing all confirmed survey records and cleaned spatial datasets. Based on these estimates, *M. costata* has a highly restricted AOO and a widespread EOO.

Number of Locations

When the threat of adverse fire regimes is considered, particularly a reduction of sufficiently hot wildfires, the six subpopulations of *Muehlenbeckia costata* can be treated as six threat-defined locations, as per the IUCN definition (IUCN 2022). This is due to the reduction of wildfire incidences on the outcrops being the most serious plausible threat that results in the lowest number of locations for the taxon. The large distances between these locations are significant enough that each is considered a geographically distinct area where single wildfire events are unlikely to extend to any other location based on the fire history of the region (NSW NPWS 2022). This, combined with differing fire management strategies and priorities across differing national parks (NSW NPWS 2005a, 2005b, 2005c, 2013b), means each location will have different risk profiles for this threat.

Ecology

Habitat

Muehlenbeckia costata is typically found around freshly burnt montane rocky outcrops, with most occurrences above 1,100 m elevation (Hunter *et al.* 1998), though the westerly record at Willala is as low as 500 m elevation (Hunter 2011a). While it often occupies large outcrops with significant areas of bare rock (Hunter *et al.* 1998), the species has also been recorded within the forest and woodland matrix adjoining the outcrops at Mount Kaputar and Butterleaf (Hunter 2020; G. Phillips pers. obs. April 2020). Plants are mostly found on granite (Hunter *et al.* 1998), although have also been recorded on trachyte at Mount Kaputar and sandstone at Willala (Hunter 2011a, 2015). The plants often occur in shallow soils within cracks and fissures on outcrops and can come to completely dominate these habitats in the immediate post-fire period (G. Phillips pers. obs. March 2020, April 2020). Annual rainfall across the known sites ranges from 600 mm at Willala to 1,400 mm on the tablelands (Hunter 2011a).

Muehlenbeckia costata is commonly found in heath and mallee vegetation where it occurs on outcrops (Hunter *et al.* 1998). In these communities, it commonly co-occurs with *Leptospermum novae-angliae, Kunzea obovata, Brachyloma saxicola, Acacia latisepala, Dodonaea viscosa, Eucalyptus codonocarpa, Leucopogon neoanglicus, Allocasuarina rigida, Platysace lanceolata, Entolasia stricta, Lomandra longifolia, Gonocarpus oreophilus* and *Schoenus apogon* (Hunter *et al.* 1998). On rock outcrops it also co-occurs with the fire ephemeral *Monotaxis macrophylla* (Hunter 1999), which is also listed as threatened on the NSW *Biodiversity Conservation Act 2016*. In forested habitat areas, *M. costata* commonly co-occurs with *Eucalyptus campanulata, E. nobilis, E. williamsiana, E. obliqua, E. radiata, Allocasuarina littoralis, Hakea dactyloides, H. florulenta, Acacia binervia, Gonocarpus tetragynus* and *Lomandra longifolia* at Butterleaf (Hunter 2020) and *Eucalyptus dalrympleana, E. laevopinea, Solanum aviculare* and *Pelargonium inodorum* at Mount Kaputar (G. Phillips pers. obs. April 2020). At Willala, *M. costata* is found with *Corymbia trachyphloia, Capparis mitchellii, Acacia cheelii, Alphitonia excelsa, Cassinia sifton, Calotis cuneifolia, Dianella revoluta, Lomandra longifolia, Parsonsia eucalyptophylla, Paspalidium constrictum* and *Chenopodium cristatum*, and is the only confirmed place where *Muehlenbeckia rhyticarya* co-occurs (Hunter 2011a).

In NSW, *Muehlenbeckia costata* has been recorded in a number of Plant Community Types (PCTs) across the various subpopulations. These include Tenterfield Plateau Kunzea Scrub (PCT 3846) and Northeast New England Granites Outcrop Scrub (PCT 3842) at Bald Rock; Eastern New England Ranges Blackbutt Forest (PCT 3501) and Warra Rockplate Shrubland (PCT 4130) at Butterleaf; Eastern New England Leucogranite Mallee Scrub (PCT 3827) at Warra; Mount Kaputar Kunzea – Five Star Heath – Spur-winged Wattle shrubland on siliceous outcrops mainly in the Nandewar Bioregion (PCT 521) and Mountain Gum – Snow Gum grassy open forest at high latitudes in the Kaputar area of the Nandewar Bioregion (PCT 525) at Mount Kaputar; and Rusty Fig – Mock Olive – Red Ash dry rainforest on siliceous substrates in the Warrumbungle and Pilliga Scrub regions, Brigalow Belt South Bioregion (PCT 388) at Willala (Hunter 2005, 2006, 2011a; 2011b; 2020; G. Phillips pers. obs. March 2020, April 2020, September 2020; DPE 2022a, 2022b). However, *M. costata* is likely not confined to these PCTs and may be found within other PCTs that occur around known subpopulations. The PCTs that the species may occur in at Wallerawang are unknown.

In Queensland, *Muehlenbeckia costata* has been recorded in Regional Ecosystems 13.12.1 (*Eucalyptus campanulata* open forest to woodland on igneous rocks), 13.12.2 (*Eucalyptus andrewsii, E. youmanii* woodland on igneous rocks) and 13.12.6 (Shrubland and/or heath with areas of bare/lichen covered rocks +/- emergent Eucalypts on igneous rocks) within Girraween National Park (DES 2023).

Life History, Growth and Generation Length

Muehlenbeckia costata is an obligate seeding species dependent on the passage of hot fire to complete its short lifecycle (Hunter *et al.* 1998), with no plants ever recorded without a preceding spring or summer fire. Times between recorded mass germination events are often 10–30 years apart (Table 2), although the longest recorded time between fires inferred to be sufficiently hot enough to trigger germination at any known site is approximately 55 years at the Willala subpopulation (NSW NPWS 2022). This suggests that the species can remain dormant in the soil seedbank for several decades, if not much longer (Hunter 1999).

Table 2 – Wildfire history of all known subpopulations of *Muehlenbeckia costata* (NSW NPWS 2022). Nil records following fire are either due to the fires not affecting the outcrops or on a lack of any records of the species in the subsequent 4–5 year periods. The Wallerawang subpopulation is excluded as the unknown locale prevents accurate assessment of fire history.

Subpopulation	Fire	Time of Fire	*M. costata* subsequently recorded	Additional References
Girraween/Bald Rock		1966	Y	Blake 1971; Watson and Wardell Johnson 2004
		September 1980	Unknown	Watson and Wardell Johnson 2004
		September 1989	Unknown	Watson and Wardell Johnson 2004
		October 1994	Y	Hunter 1995; Watson and Wardell-Johnson 2004
	Bald Rock	November 2002	N	
	Boonoo Boonoo	October 2007	N	
	Wallangarra	February 2019	Y	G. Phillips pers. obs. March 2020
Butterleaf		1979-1980	Unknown	
		November 1994	Y	Richards and Hunter 1997; RBGDT 2023a
	Carrot Farm Rd	December 2019	Y	Hunter 2020; P. Sheringham *in litt.* June 2023
Warra		1990-1991	Unknown	
		November 1994	Y	Hunter *et al.* 1998; RBGDT 2023a
	Cramptons	October 2001	N	

	Crown Mountain	December 2019	Y	J. Hunter *in litt.* June 2023
Mount Kaputar		1951-1952	Unknown	
		1957-1958	Unknown	
		1974-1975	Y	RBGDT 2023a
		1984-1985	Y	RBGDT 2023a
	Paleroo Creek	January 2007	Y	BioNet 2023
	Kaputar	November 2019	Y	G. Phillips pers. obs. April 2020
Willala		1951-1952	Unknown	
	Kerringle	December 2006	Y	Hunter 2011a

Muehlenbeckia costata recruits *en masse* immediately following a hot fire (Hunter *et al.* 1998). Following a germination event, flowering follows after only 2–3 months and continues throughout the typical 1–3-year lifespan, with female plants also continually producing fruit over a similar timeframe (Hunter *et al.* 1998; Hunter 1999, 2006, 2011). The species then succumbs quickly at the end of the lifecycle, with most plants contracting a rust fungus prior to and during senescence, which rapidly kills off the aboveground plants (Hunter *et al.* 1998). This susceptibility to disease late in the lifecycle is thought to be a cost of the species' high reproductive output, with Hunter (2006) suggesting that the energy spent maximising growth and fruiting possibly lowers resistance to pathogens. Within two years from the time of fire, most plants have fully senesced (Hunter *et al.* 1998), though persistent individuals have been recorded up to 4–5 years after fire (Hunter 2006, 2011; G. Phillips pers. obs. August 2023).

During its short lifetime, *Muehlenbeckia costata* grows rapidly. After only 4–5 months of growth, plants can have stems up to 2 m long and at peak growth after only 12 months, a single plant can have stems 5 m long and be able to climb onto other vegetation up to 4 m high (Hunter *et al.* 1998; Hunter 1999). This results in a single plant being able to dominate an area of approximately 10 m diameter, which can produce many hundreds to thousands of seeds that are released at their maturity to replenish the soil seedbank (Hunter 1999; G. Phillips pers. obs. March 2020, April 2020). Plants of this size dominate the ground layer across large areas, with almost continuous patches of 1–2 ha in size having been observed 12–18 months post-germination (G. Phillips pers. obs. March 2020, April 2020). During the rapid growth phase, *Muehlenbeckia costata* appears to be resilient to frosts, daytime temperatures of over 40°C and/or intense drought conditions following germination not seeming to be adversely affected in either growth or fecundity (Hunter *et al.* 1998; G. Phillips pers. obs. March 2020).

Given the rapid aboveground lifecycle and dominance of the soil seedbank life stage in *Muehlenbeckia costata*, generation length can be calculated by primary juvenile period plus the half-life of seeds in the seedbank or the median time from release to germination (IUCN 2022). The species has been observed to have 25–28 years between mass germination events on multiple occasions (Table 2).

Reproductive and Seed Ecology

Muehlenbeckia costata is dioecious, with male and female flowers borne on separate plants (Hunter *et al.* 1998). The flowers on both sexes are small, inconspicuous, and green with no petals. This species is primarily likely to be wind pollinated as for other *Muehlenbeckia* (Wodehouse 1931). However, large numbers of insects such as small flies, ladybeetles (Coccinellidae), and ants have been observed visiting inflorescences in peak flower on *M. costata* and related species (Schuster *et al.* 2011; G. Phillips pers. obs. March 2020) and may therefore play an additional role in pollination. The presence of extrafloral nectaries on the petioles are thought to assist in the attraction of insect pollinators, which crawl over the plant searching for the nectar, pollinating the flowers in the process (Schuster *et al.* 2011).

The seeds of *Muehlenbeckia costata* develop within a fleshy perianth that turns bright orange/red at maturity (Hunter *et al.* 1998). This makes birds and lizards primary candidates for dispersal across and between habitat areas (Hunter *et al.* 1998). Lizards, particularly skinks, are common on the outcrops on which *M. costata* lives (Hunter *et al.* 1998) and are known to disperse seeds over short distances of up to 10 m in other *Muehlenbeckia* species (Wotton *et al.* 2016).Aboriginal people may have also eaten the fruits, and thus moved seeds, as they did in other *Muehlenbeckia* species with similarly fleshy perianths (Cribb and Cribb 1975).

Muehlenbeckia costata appears to have complex seed dormancy which enable the seeds to persist long-term in the soil seedbank and germinate in the post-fire environment when conditions are most suitable. Despite possessing a hard seed coat, many *Muehlenbeckia* species do not possess physical dormancy, but instead have physiological dormancy requiring environmental cues for germination (South Australian Seed Conservation Centre 2018a, 2018b, 2018c; Wotton 2018). However, *M. costata* does appear to have increased germination rates when scarified (Hunter 1999), indicating some level of physical dormancy may be present. *Muehlenbeckia costata* appears to primarily require soil heating and exposure to smoke for germination: Hunter (1999) found weak evidence of greater germination rates following smoke treatment and heating for 10 minutes at temperatures from 80°C to as high as 120°C, than in controls and after heating without smoke treatment. These temperatures are representative of the conditions experienced by the top 1–2 cm of soil in high intensity wildfires (Bradstock and Auld 1995). This shows that high intensity fires may result in the strongest germination. Despite relatively high levels of seed viability estimated at 63% (Hunter 1999), laboratory tests to date have never managed higher than 6% overall germination (Hunter 1999; RBGDT 2023b), suggesting that more complex physiological dormancy mechanisms with currently unknown triggers may be present. Tests have indicated spring and summer temperatures produce higher germination rates than winter and autumn temperatures (RBGDT 2023b), however further work is required to understand if such chemical or seasonal cues are required on top of soil heating for natural germination.

Threats

Previously identified threats to *Muehlenbeckia costata* include adverse fire regimes, particularly the exclusion of suitably hot fire for extended periods, trampling where the species occurs on trails, road maintenance where the species abuts roads and tracks, and browsing by Feral Goats (*Capra hircus*) (Hunter *et al.* 1998; OEH 2021). Another more recently identified threat is weed invasion by competing disturbance-promoted species such as Inkweed (*Phytolacca octandra*; G. Phillips pers. obs. March 2021). However, there is no current evidence that these threats are causing continuing decline in the population of *M. costata*. Recent surveys at the Bald Rock, Mount Scott and Warra sites following post-fire germination events in 2019 revealed no reductions in population sizes since post-fire surveys in 1995 or in the extent or quality of habitat after extreme fire conditions following severe, long-term drought from 2017-2019 (Hunter 2020; G. Phillips pers. obs. March 2020, April 2020; P. Sheringham *in litt.* June 2023).

It is unclear if other possible future threats such as increased occurrences of drought and increasing temperatures due to climate change are to threaten *Muehlenbeckia costata*. On multiple occasions, subpopulations of the species have been observed during intense drought conditions and multiple hot days above 40°C following germination events, with growth and seed output seemingly unaffected (Hunter *et al.* 1998; G. Phillips pers. obs. March 2020). The species' rapid growth cycle, high fecundity, continual output of seed, extremely long-lived soil seedbank and complex seed dormancy mechanisms appear to confer a wide tolerance to extreme conditions, possibly driven by the relatively harsh environment on the outcrops where it has evolved. This means that there is insufficient evidence that any currently identified threats are causing continuing decline in the species, and any future threats are uncertain in their effect.

Adverse Fire Regimes

High-interval fire regimes may adversely affect the population of *Muehlenbeckia costata* if suitably hot wildfires are excluded from known subpopulations over long periods of time. *Muehlenbeckia costata* is completely reliant on intense fires to germinate and complete its lifecycle (Hunter *et al.* 1998), with laboratory testing showing that most seeds only germinate at soil temperatures above 80°C (Hunter 1999). Temperatures as high as 120°C can still stimulate recruitment, and this aligns with observations whereby more intense wildfires result in higher *in situ* abundances (Hunter *et al.* 1998; Hunter 2020; G. Phillips pers. obs. March 2020). This means that a reduction in the occurrence of intense fires may disrupt the lifecycle of *M. costata* by limiting germination events and diminishing subsequent recruitment for the species.

Increased occurrences of lower intensity or out-of-season fires may also disrupt the lifecycle of *Muehlenbeckia costata* by limiting the magnitude of successive germination events. In species that rely on residual, dormant soil seedbanks, the heat of lower intensity burns may not be sufficient to stimulate recruitment (Bradstock and Auld 1995), meaning germination events may become less frequent and the subsequent redevelopment of the soil seedbank limited. Fire mitigation works, such as hazard reduction burning in the surrounding forest matrix, aim to diminish the intensity of wildfires in the landscape, including those that affect the outcrops on which *M. costata* grows (Hunter *et al.* 1998). Significant patches of plants in the Warra and Mount Kaputar subpopulations are currently mapped in areas available for such hazard reduction burning and have been included in such burns in the past (NSW NPWS 2005c, 2013b, 2022). This management regime may therefore result in population reductions for *M. costata* over time if severe wildfire occurrences were to become less frequent on the rocky outcrops and in surrounding areas as a result.

However, observations following the 2019-2020 fire season indicate that the population of *Muehlenbeckia costata* is not currently experiencing any decline because of these processes (Table 3). Fires of high intensity and large scale affected the Girraween/Bald Rock, Butterleaf, Warra and Mount Kaputar subpopulations in 2019 (Table 2; NSW NPWS 2022), and the abundances at the burnt sites were estimated to be higher than previously estimated maximums in every case (Table 3). Furthermore, new patches of *M. costata* were found within and adjacent to known subpopulations following the 2019 fires, including within the adjoining forest matrix in which the species was previously not known to occur (Hunter 2020; G. Phillips pers. obs. April 2020, September 2020). This indicates that the species might be expanding its range with more intense fires.

Table 3 - Increases in recorded maximum abundance in sites burnt severely in 2019 for which previous abundance data is available.

Site	Subpopulation	Pre-2019 maximum abundance estimate	Post-2019 maximum abundance estimate	References
Bald Rock	Girraween/Bald Rock	600 (Feb 1995)	1,000+ (Feb 2020)	Hunter 2006; G. Phillips pers. obs. March 2020
Mount Scott	Butterleaf	300 (Feb 1995)	1,000 (Jan 2022)	Hunter *et al.* 1998; P. Sheringham *in litt.* June 2023
Warra National Park	Warra	2,000 (Feb 1995)	2,000+ (Sept 2020)	Hunter *et al.* 1998; J. Hunter *in litt.* June 2023
Kaputar Summit	Mount Kaputar	"few plants" (Dec 2007)	2,000 (Apr 2020)	G. Phillips pers. obs. April 2020; G. Steenbeeke pers. comm. August 2023

The New England and North West region in which *Muehlenbeckia costata* occurs is projected to become hotter, have fewer colder nights under 2°C annually, more hot days over 35°C annually and an increase in average and severe fire weather by 2079 (CSIRO and BOM 2022; AdaptNSW 2023). Additionally, fire weather is predicted to become harsher in the East Coast and Central Slopes regions through the 21st century (CSIRO 2023). Therefore, it is highly plausible that more frequent severe fires driven by these changes in climate will affect the *M. costata* population in the future, potentially increasing the number of and strength of germination events, and diminishing the threat of exclusion of sufficiently hot fires.

Historically, fires of strong enough intensity to stimulate recruitment episodes in *Muehlenbeckia costata* have been infrequent across the rock outcrops it occupies (Table 2; Hunter *et al.* 1998). This, coupled with the species' ability to persist for decades within the soil seedbank (Hunter 1999), shows that the species can survive over very long fire return intervals. Therefore, given the recent observed trends of population expansion, heightened opportunities for severe wildfires into the future, and that recent severe wildfires make the species' habitat more prone to further severe wildfires (Barker *et al.* 2021), exclusion of severe wildfires is not currently considered to be causing any reduction in habitat or number of mature individuals of *M. costata*. Future decline through this mechanism is also uncertain given the promotive effects of severe wildfire on the species.

Conversely, the shortening of return fire intervals is often found to contribute to decline in populations of obligate seeding species (DAWE 2022). However, the extremely rapid lifecycle of *Muehlenbeckia costata*, whereby the substantial soil seedbank is replenished within a 2–3-year window, indicates that the species also possesses capacity to persist in a regime of more frequent severe fires, despite the episodic, disturbance-driven recruitment cycle which typically indicates sensitivity to shortened fire intervals (Enright *et al.* 2015). Given current return intervals for wildfire in the regions where *M. costata* occurs are typically 10–30 years (Table 2), and that incidences of severe fire affecting the rocky outcrops are likely to be even less regular than that (J. Hunter *in litt.* September 2023), increases of fire frequency of up to 30% in line with the worst future climate projection scenarios (IPCC 2023) will be unlikely to adversely affect the recruitment cycle of the species. Therefore, more frequent occurrences of severe fire as projected into the future are considered unlikely to result in decline of *M. costata*.

Weed Invasion

While Inkweed has been observed germinating *en masse* within the same habitat following the February 2019 fire at the Bald Rock National Park site, numbers of *Muehlenbeckia costata* thus far seem unaffected, with the two species co-existing (G. Phillips pers. obs. March 2020). Inkweed is also present at other sites; however, it is not considered to be a serious competitor for *M. costata* based on observations to date (J. Hunter *in litt.* September 2023). *Muehlenbeckia costata* seems to be able to easily outlast Inkweed, with plants of the former seen around Mount Norman in Girraween National Park 4 years post-fire, whereas no sign of prior Inkweed infestation remained (G. Phillips pers. obs. August 2023). Fire-promoted weeds such as Inkweed are also less tolerant of more intact, less disturbed sites that are not nutrient enriched (Thomsen and Leishman 2005), so areas of *M. costata* that occur in intact forest and those away from higher visitation areas such as at Butterleaf and Warra may not be at the same level of risk of competition from Inkweed. Therefore, Inkweed invasion is considered only a plausible future threat to *M. costata*, and not one that is likely to rapidly drive the species to extinction.

Trampling and Road and Track Maintenance

Muehlenbeckia costata can be affected by trampling by bushwalkers where plants occur on or adjacent to trails, and the clearing of plants for road and track maintenance (OEH 2021). Walking tracks bisect stands of *M. costata* in the Girraween/Bald Rock and Mount Kaputar subpopulations (G. Phillips pers obs. March 2020, September 2020, August 2023), and some incidental trampling of plants may occur following mass germination events at these sites. Additionally, a major access road abuts the Mount

Kaputar subpopulation (G. Phillips pers. obs. April 2020) and maintenance works may result in damage to individuals at times as well as provide an avenue for future weed invasion (OEH 2021). However, these threats are highly localised and are considered trivial in magnitude at both a subpopulation level, and relative to the full population of *Muehlenbeckia costata*. Tracks in Bald Rock, Girraween and Mount Kaputar National Parks typically avoid the densest patches of *M. costata*, crossing the bare granite slabs and not the vegetated pockets in which *M. costata* grows, with little damage seen even during times of high visitation while plants are aboveground (G. Phillips pers obs. March 2020, September 2020). The access road at Mount Kaputar also only adjoins a *c.* 100 m length of the 1.5 km^2 area the species occupies, meaning that maintenance activities are unlikely to significantly affect the subpopulation. This means that trampling and track and road maintenance are considered minor threats to *M. costata*, and are not considered to be contributing to continuing decline.

Browsing by Feral Goats

Browsing by feral goats (*Capra hircus*) has been identified as a possible threat to *Muehlenbeckia costata*, particularly during times of drought that coincide with plants being above ground (OEH 2021). *Muehlenbeckia* species are considered highly palatable to goats (Simmonds *et al.* 2000) and goats are known to be present at the Butterleaf and Mount Kaputar subpopulations (NSW NPWS 2016, 2021). However, no adverse effects have yet been recorded on *M. costata* in either of these areas subjected to browsing by goats over multiple germination events, and emergent plant numbers and fruit production appears unhindered by any browsing (Hunter 2011b, 2020; G. Phillips pers. obs. April 2020, September 2020). Goats are actively controlled at both Butterleaf and Mount Kaputar (NSW NPWS 2016, 2021). TGoats may pose a threat in future if their numbers were to increase.

Assessment against IUCN Red List criteria

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

Criterion A *Population size reduction*

Assessment Outcome: Data Deficient.

Justification: There is no current evidence of population reductions in *Muehlenbeckia costata*. Surveys at several sites following the most recent germination events in 2019 revealed no reductions in the mature population or extent or quality of habitat after extreme fire conditions following severe, long-term drought compared to past abundance estimates (Hunter 2020; G. Phillips pers. obs. March 2020, April 2020; P. Sheringham *in litt.* June 2023). Fires of high intensity and large scale affected the Girraween/Bald Rock, Butterleaf, Warra and Mount Kaputar subpopulations in 2019 (NSW NPWS 2022), and the abundances at the burnt sites were estimated to be higher than previously estimated maximums in every case. Furthermore, new patches of *M. costata* were found within and adjacent to known subpopulations following the 2019 fires, including within the adjoining forest matrix in which the species was previously not known to occur (Hunter 2020; G. Phillips pers. obs. April 2020, September 2020). This indicates that the species may be expanding its local extent with more intense fires and is not considered to be undergoing current decline or be prone to future population reductions and so does not meet the thresholds for listing under Criterion A.

Criterion B *Geographic range*

Assessment Outcome: Criterion not met.

Justification: *Muehlenbeckia costata* has a highly restricted geographic distribution. The Extent of Occurrence (EOO) has been calculated as 47,932 km^2, not meeting the thresholds for listing. The Area of Occupancy (AOO) has been calculated as 68 km^2 The species could therefore qualify for listing under Criterion B if at least two of three other conditions are 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: Met for Vulnerable due to having six threat-defined locations.

   Justification: *Muehlenbeckia costata* is found at six threat-defined locations when considering the most serious plausible threat of adverse fire regimes, particularly a reduction of sufficiently hot wildfires to trigger germination events.

   Muehlenbeckia costata is not considered severely fragmented as most known individuals are found in large subpopulations and all subpopulations are considered viable.

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

   Assessment Outcome: Not met.

   Justification: Continuing decline is not evident in the known subpopulations of *Muehlenbeckia costata* despite potential threats. Adverse fire regimes may contribute to decline in the population of *M. costata* if suitably hot wildfires are excluded from known subpopulations over long periods of time. *Muehlenbeckia costata* is reliant on intense fires to germinate and complete its lifecycle (Hunter *et al.* 1998), and so a reduction in the occurrence of intense fires may disrupt the lifecycle of *M. costata* by limiting germination events and diminishing subsequent recruitment for the species. Furthermore, increased occurrences of lower intensity fire may also disrupt the lifecycle of *M. costata* as the ground fuels required to sufficiently heat the soil and maintain heat long enough to break dormancy will not be allowed to build up over time. However, observations following the 2019-2020 fire season indicate that the population of *M. costata* is not currently suffering any decline because of these processes. It is also highly plausible that more frequent severe fires driven by changes in climate will affect the *M. costata* population in the future (CSIRO and BOM 2022; AdaptNSW 2023), potentially increasing the number of and strength of germination events, and diminishing the threat of exclusion of sufficiently hot fires. Competition by disturbance-promoted weed species such as Inkweed (*Phytolacca octandra*), trampling and road and track maintenance, and browsing by feral goats are also noted as plausible threats, however, there remains no direct evidence of any of these threats causing continuing decline in the abundance or habitat of *M. costata*, nor is there certainty that they will do so in the future. As such, all identified threats to *M. costata* are considered only to be plausible future threats, not satisfying the definition for continuing decline (IUCN 2022).

c) Extreme fluctuations.

Assessment Outcome: Not met.

Justification: *Muehlenbeckia costata* is not considered prone to extreme fluctuations. While the species does fluctuate dramatically in the number of aboveground individuals between germination-stimulating fire events, this likely represents a flux of individuals between the soil seedbank and mature life stages, and not a change in the total population for the species. Therefore, *M. costata* does not meet the definition of extreme fluctuations (IUCN 2022).

Criterion C Small population size and decline

Assessment Outcome: Criterion not met.

Justification: The current population estimate for *Muehlenbeckia costata* is a minimum of 8,250 mature individuals, meeting the threshold for listing as Vulnerable. In addition to this threshold, at least one of two other conditions must be met to qualify for listing under Criterion C. These conditions 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: The is no evidence of continuing decline in the number of mature individuals in *Muehlenbeckia costata*. Surveys following the most recent germination events in 2019 revealed no reductions in the mature population or extent or quality of habitat after extreme fire conditions following severe, long-term drought compared to past abundance estimates (Hunter 2020; G. Phillips pers. obs. March 2020, April 2020; P. Sheringham *in litt.* June 2023). Additionally, it is also highly plausible that more frequent severe fires driven by changes in climate will affect the *M. costata* population in the future (CSIRO and BOM 2022; AdaptNSW 2023), potentially increasing the number of, and strength of germination events and continuing recently observed expansions of range into forest habitats (Hunter 2020; G. Phillips pers. obs. April 2020, September 2020). This means that within a three-generation timeframe of 75.6–84.9 years, no decline in mature individuals has occurred, nor is it projected to occur into the future.

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

Assessment Outcome: Not met.

Justification: Continuing decline is not evident in the number of mature individuals of *Muehlenbeckia costata*, and is currently not projected to occur in the future.

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: Four of the known subpopulations of *Muehlenbeckia costata* are estimated to have >1,000 mature individuals (Hunter *et al.* 1998; Hunter 2020; G. Phillips pers. obs. April 2020; P. Sheringham *in litt.* June 2023).

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

Assessment Outcome: Not met.

Justification: *Muehlenbeckia costata* has a spread of mature individuals across subpopulations, with the largest known subpopulation (Butterleaf) currently estimated to possess approximately 36% of known mature individuals.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Not met.

Justification: *Muehlenbeckia costata* is not considered prone to extreme fluctuations. While the species does fluctuate dramatically in number of aboveground individuals between germination-stimulating fire events, this likely represents a flux of individuals between the soil seedbank and mature life stages, and not a change in the total population for the species. Therefore, *M. costata* does not meet the definition of extreme fluctuations (IUCN 2022).

Criterion D Very small or restricted population

Assessment Outcome: Criterion not met.

Justification: *Muehlenbeckia costata* is currently estimated to have a minimum population of at least 8,250 mature individuals.

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

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

Assessment Outcome: Not met

Justification: *Muehlenbeckia costata* is currently estimated to have a minimum population of at least 8,250 mature individuals.

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

Assessment Outcome: Not met.

Justification: *Muehlenbeckia costata* occurs at six threat-defined locations and has an estimated AOO of 68 km^2. In addition, there are no threats currently known that may rapidly drive the species to Critically Endangered or Extinct within a rapid timeframe of less than one generation (25.2–28.3 years).

Criterion E Quantitative Analysis

Assessment Outcome: Data deficient.

Justification: Currently there are not enough data to undertake a quantitative analysis to determine the extinction probability of *Muehlenbeckia costata.*

Conservation and Management Actions

Muehlenbeckia costata sits within the keep-watch management stream of the SoS program as it is regarded as being on track to be secure from extinction in the long-term and no active management is currently prioritised for the species (DPE 2023).

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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:
Muehlenbeckia costata was found to be ineligible for listing as a threatened species as none of the Clauses were met.

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: 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: Not met

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