Threatened Species Recovery Hub

National **Environmental Science** Programme

Action Plan for Australia's Imperilled Plants 2021

J. Silcock, T. Collingwood, T. Llorens and R. Fensham

The University of Queensland Australia
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une University of New England
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Cover Image: TOP: *Daviesia cunderdin.* Image: J and F Hort for Bert Hort
BOTTOM LEFT TO RIGHT: *Petrophile latericola*. Image: Andrew Crawford; *Solanum orgadophilum*. Image: Teghan Collingwood; *Borya mirabilis*. Image: Noushka Reiter

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Executive Summary

Australia’s flora is globally distinctive, with more than 90% of its >22,500 native vascular plant species found nowhere else in the world. Humans have observed, utilised, celebrated and altered the Australian flora for at least 65,000 years. Anthropogenic changes to the vegetation have accelerated since European colonisation beginning 230 years ago, most drastically through extensive land clearing for agriculture and urbanisation, introduction of alien plants, animals and diseases, and the interruption of ecological processes such as fire regimes, erosion and hydrology. Despite these massive upheavals, plants do not share the parlous recent extinction record of Australia’s mammal fauna, with a recent analysis identifying only 12 plants (<0.05% of the total flora) that are likely to be extinct.

Nevertheless, plants comprise more than two-thirds of nationally-listed threatened species, and the population trends and management requirements of the majority of these are poorly documented. Given the sheer number of threatened plants occurring in Australia, it was not feasible to provide comprehensive profiles on all threatened species. Instead, detailed profiles were compiled for the 50 Australian plant species identified as having the highest imminent extinction risk – termed the ‘imperilled’ plants – due to severe continuing declines. These species were identified through extensive literature review and >100 expert interviews.

This Action Plan aims to help prevent extinctions of Australia's imperilled flora through collation of existing knowledge and clear statement of required recovery actions. We also identify critical information gaps compromising conservation status assessments and management. The Action Plan also provides a clear baseline for charting the trajectory of our imperilled flora. The data upon which this plan was developed were current at the end of 2020. The plan was released in early 2021.

Chapter 1 outlines the context and aims of the Action Plan. Chapter 2 details methods and definitions used in the Plan, including explanations of information provided in each species profile. Chapter 3 presents an overview of the 50 imperilled species, including regions and habitats where they are concentrated and the threats to their survival. The majority of Australia’s imperilled species occur in heavily-cleared and fragmented habitats, and are now restricted to a handful of subpopulations in small remnants that are vulnerable to ongoing loss and degradation. Many species are not recruiting, and the reasons for this are often not well understood particularly with regard to germination biology and appropriate disturbance regimes. The imperilled species that occur in relatively intact habitat are typically severely impacted by a variety of interacting threats, notably altered disturbance regimes and the plant diseases myrtle rust *Austropuccinia psidii* and phytophthora *Phytophthora cinnamomi.*

Chapter 4 contains the 50 species profiles. Each profile includes photographs, brief descriptions, distribution overview including map, population trends (including time-series monitoring data where available), summary of habitat and ecology, assessment of threat impacts, and assessments against International Union for Conservation of Nature (IUCN) criteria. Current recovery actions and objectives are identified, as well as future management and research needs. All profiles were reviewed by between one and seven experts. Chapter 5 summarises recovery actions, research required and management priorities to prevent extinctions of Australia’s imperilled species.

This Action Plan highlights five key areas that will underpin and advance conservation of Australia’s flora:

1. Continue and expand site-based conservation of imperilled species. Numerous recent examples show that targeted, long-term and adequately-funded recovery actions have halted declines in population abundance of some highly threatened species.
2. Ensure that monitoring is consistent, repeatable and uses species-appropriate methods, to allow confident interpretation of population trends in response to threats and management actions.
3. Expand targeted surveys and research on poorly-known species where threats and/or declines are inferred or suspected.
4. Support taxonomic research to clarify the status of potentially imperilled species.
5. Review this Plan in 10 years to inform the trajectory of imperilled plant species, encompassing the plants included here and others that may subsequently be assessed as imperilled.

About the authors

Jen Silcock has studied threatened species and rangeland ecology across Australia for the past 15 years. She has researched some iconic and intriguing plant communities including desert springs, mulga shrublands and stony hills, and enigmatic fauna species including Night Parrots, Yellow-Footed Rock Wallabies and the Greater Bilby. Since 2016, she has focused on threatened Australian plant conservation through the NESP Threatened Species Recovery Hub.

Teghan Collingwood has spent the past two years with the NESP Threatened Species Recovery Hub documenting the conservation status of Australia's flora. This included the first comprehensive IUCN Red List assessment of Australian eucalypts for the Global Trees Campaign, assessing myrtle rust dieback in the Wet Tropics and compiling numerous threatened species nominations.

Tanya Llorens has worked extensively researching the ecology and genetics of Australian plant species, particularly in the context of habitat fragmentation. With the Department of Biodiversity, Conservation and Attractions, she helps to coordinate the conservation management of threatened plants in Western Australia, including species listings, recovery planning and provision of scientific and policy advice.

Rod Fensham does research related to the ecology and conservation of native vegetation at the Queensland Herbarium. He also teaches and supervises students at the University of Queensland. He disseminates his findings not only by publishing but also through conservation planning, policy and practice.

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1. Introduction

The Australian flora is distinctive, with more than 90% of its >22,500 native vascular plant species occurring nowhere else in the world (Chapman 2009; Fensham and Laffineur 2019). This diversity evolved over millions of years in response to changing climatic conditions and continental drift (Rossetto 2015). Nutrient-poor soils, minimal altitudinal relief and large-scale disturbance events have driven the diversification of the Australian flora, which has endured through a period of relatively long geographic isolation (Rossetto 2015). Australia's flora today retains elements of Gondwanan rainforests but is dominated by sclerophyllous species, including over 1000 *Acacia* species and more than 800 eucalypts (*Angophora, Corymbia* and *Eucalyptus* species). Biogeographic barriers have created unique vegetation communities, such as those that evolved on isolated mountain peaks or in tiny desert springs. Plant diversity and endemism are disproportionately high in particular areas, notably the Southwest Australian Floristic Region and the Forests of East Australia, which are recognised as global biodiversity hotspots (Mittermeier *et al.* 2011).

The Australian flora includes the spectacular (spring wildflowers of south-western WA), iconic (desert ghost gums, giant boabs of the Kimberley), biogeographically intriguing (the wollemi pine and Central Australian cabbage palm), bizarre (orchids with cunning and deceptive sex-lives), painful (stinging trees and the ubiquitous burrs of the inland), and increasingly, gourmet (saltbush, mountain pepper-berry, quandong, Davidson plum). A select few species are also widely cultivated in gardens and public spaces. However, with these notable exceptions, the vast majority of Australia's plants are cryptic, seldom-observed and poorly-known. The rate of 'discoveries', with an estimated 250 flowering plant taxa newly described each year in Australia (Chapman 2009), is testament to the relatively poorly-known nature of our flora in a scientific sense. However, this was not always the case.

Humans have observed, utilised, celebrated and altered the Australian flora since their arrival at least 65,000 years ago (Clarkson *et al.* 2017). Over 4000 vascular flora species – nearly 20% of the scientifically-described flora – were, and some still are, used by Aboriginal people as food and medicine, and many more species were used as materials (Ens *et al.* 2017). Anthropogenic fire management (Gammage 2011; Yibarbuk *et al.* 2001), human niche construction (Lullfitz *et al.* 2017), modification of trees for resource extraction and ceremonial purposes (Black 1941; Morrison and Shepard 2013; Webber and Burns 2004), and the intentional dispersal and nurture of important plants (Silcock 2018) have collectively influenced the distribution and composition of vegetation communities and species.

European colonisation over the past 200 years has greatly accelerated anthropogenic changes to Australia's vegetation, most drastically through extensive clearing for agriculture and urbanisation, particularly in coastal and sub-coastal areas from Queensland to South Australia and in south-western Australia. Remnants in heavily cleared areas typically cover a fraction of their former extent, and are now subject to a range of threats, including weed invasion, increased herbivore densities, lack of appropriate disturbance regimes, changed hydrology, infrastructure maintenance, and pollution and run-off from adjacent land uses. Even seemingly intact vegetation can be negatively impacted by weeds, herbivores, altered fire and disturbance regimes, pathogens such as phytophthora (*Phytophthora* spp.) and myrtle rust (*Austropuccinia psidii*), and, increasingly, climate change. More than 12% of Australia's flora species are post-European naturalisations (Fensham and Laffineur 2019). While these include some destructive weeds, the vast majority live alongside native species and do not yet disrupt ecosystem function.

Vascular plants underpin the structure and function of all terrestrial ecosystems and comprise over 70% of nationally-listed threatened species in Australia. Australia's parlous record of species declines and extinctions since European colonisation is well-documented for mammals (Burbidge *et al.* 2008; McKenzie *et al.* 2007; Woinarski *et al.* 2015) and birds (Garnett *et al.* 2011; Szabo *et al.* 2012). The most recent conservation assessment of Australia's threatened flora (Silcock and Fensham 2018) provided a timely update to the preceding assessment undertaken more than two decades ago (Briggs and Leigh 1996). By compiling published information and expert knowledge, Silcock and Fensham (2018) identified plant species with high extinction risk based on documented declines, rather than rarity alone.

This assessment (Silcock and Fensham 2018), together with a re-assessment of extinction likelihood for presumed extinct taxa (Silcock *et al.* 2020), highlights that the Australian flora has fared relatively well despite the upheavals of European land management, in stark contrast to its fauna (Woinarski *et al.* 2019). Only 12 taxa are assessed as being probably extinct (Table 1), and a further 21 possibly extinct. The remaining 71 taxa currently presumed extinct have dubious taxonomy or occurrence in Australia, or are possibly extant and require further surveys to ascertain their status (Silcock *et al.* 2020). However the first continental analysis of trends of Australian threatened plants, combining data from 112 species at 600 sites, suggests that threatened plant populations have declined by almost three-quarters on average in two decades — much higher than that recorded for birds or mammals (Threatened Species Index 2020). This suggests that numerous plant species may be declining towards extinction.

This Action Plan aims to highlight the plight of Australia's most threatened plant species and outline research and management actions required to halt future extinctions.

Table 1. Presumed extinct plants in Australia. For more detail on each species, and the methodology used to assess extinction likelihood, see Silcock *et al.* (2020). EX, Extinct in the Wild; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; P1, Priority 1 Flora (Western Australia)

Species (Family)	EPBC Act (State)	Bioregion (State)	Lifeform	Last collected	No. collections (popns)	Notes
Almost certainly extinct in wild						
Allocasuarina portuensis (Casuarinaceae)	EN (EN)	Sydney Basin (NSW)	Shrub	1998	2 (1)	When first collected in 1986, population was 10 plants (eight females) over 100 m. By 1998, only two females remained. This original wild population is now extinct but translocated individuals survive
Streblorrhiza speciosa (Fabaceae)	Not listed (EX under IUCN)	Pacific Subtropical Islands (Norfolk Island)	Shrub	1830	3 (1)	Island vegetation grossly modified by feral herbivores. Possibility of some plants still in cultivation in Europe, but searches unsuccessful
Probably extinct						
Picris compacta (Asteraceae)	Not listed (EX)	Swan Coastal Plain (WA)	Annual forb	1941	2 (1)	Known from two collections, one presumed to come from a now-cleared alluvial freshwater wetland
Tetratheca fasciculata (Elaeocarpaceae)	EX (EX)	Avon Wheatbelt; Jarrah Forest (WA)	Perennial forb	1895	4 (2)	Habitat mostly cleared
Acacia kingiana (Fabaceae)	EX (EX)	Avon Wheatbelt (WA)	Shrub	1923	1 (1)	Habitat mostly cleared
Gentiana wingecarr-ibiensis (Gentianaceae)	EN (CR)	Sydney Basin (NSW)	Annual forb	2000	10 (2)	Cryptic/enigmatic, but no plants found in past 15 years and high degree of habitat modification
Gentianella clelandii (Gentianaceae)	Not listed (EN)	Naracoorte Coastal Plain (SA)	Annual forb	1947	2 (1)	Only known from one locality, collected in 1947; swamps have been modified and heavily grazed
Darwinia divisa (Myrtaceae)	Not listed (P1)	Avon Wheatbelt (WA)	Shrub	1965	1 (1)	Habitat mostly cleared
Prasophyllum colemaniarum (Orchidaceae)	VU (EX)	South East Coastal Plain (VIC)	Ground orchid	1924	2 (1)	Site of collection was well-known and regularly visited until 1970s when it was destroyed by rail upgrade
Deyeuxia appressa (Poaceae)	EN (EN)	Sydney Basin (NSW)	Perennial grass	1942	2 (2)	Habitat mostly cleared
Persoonia laxa (Proteaceae)	EX (EX)	Sydney Basin (NSW)	Shrub	1908	2 (2)	Failure to collect from such a well-botanised area for >100 years suggests it is extinct, especially given modification of its habitat
Solanum bauerianum (Solanaceae)	Not listed (EX)	Pacific Subtropical Islands (Lord Howe; Norfolk)	Shrub	1937	2 (8)	Not collected since 1830; high degree of habitat loss, and rats probably consumed fruits/seeds

1.1 Aims of this Action Plan

This Action Plan is modelled upon and designed to complement the recent Action Plans for Australia's Threatened Birds (Garnett *et al.* 2011 and in prep.), Mammals (Woinarski *et al.* 2014), and Lizards and Snakes (Chapple *et al.* 2019). Given the sheer number of rare and threatened plant species occurring in Australia (>1300 are listed as threatened at a national level and at least ten times this number as rare or threatened in State and Territory jurisdictions), it was not feasible to provide comprehensive reviews of the current conservation status of all threatened plants. Instead, detailed profiles were compiled for the 50 Australian plant species identified as having the highest extinction risk– hereafter termed the 'imperilled' plants. These species meet the criteria for 'category 5' circumscribed by Silcock and Fensham (2018).

Internationally accepted IUCN criteria (2019) have guided each assessment, and the information compiled can directly inform nominations under the Common Assessment Method (CAM), which is currently aligning conservation assessments between State and Federal jurisdictions.

Similar to the other Action Plans, this Action Plan aims to:

- Identify the plant species most urgently requiring conservation management to reduce their extinction risk;
- Provide a comprehensive and consistent review of the status of these species based on IUCN criteria;
- Identify management actions required to recover these species;
- Identify critical information gaps that compromise conservation status assessments and conservation management;
- Provide a baseline for charting changes in population parameters, trends and conservation status for our most imperilled flora.

2. Methods and definitions

2.1 Identification of imperilled species for inclusion in the Action Plan

Data were compiled on all Australian plant taxa listed as Critically Endangered and Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or State and Territory legislation, as per the methods described in Silcock and Fensham (2018). Seven species listed as Extinct that had been recently 're-discovered' were also included. Taxa that were not likely to meet Endangered criteria on a national level (i.e. are listed based on their distribution in one state, as is the case for numerous species in Victoria and New South Wales) were excluded, as were hybrids, varieties and those considered taxonomically dubious by relevant experts. The candidate list comprised 1135 taxa.

Sources of information included Australasian Virtual Herbarium records, recovery plans, conservation and listing advice, species profiles, reports, peer-reviewed literature and semi-structured interviews with 125 experts. These were conducted between February 2016 and November 2017. For each species, the following data were collated: conservation status (EPBC Act and State or Territory), bioregion occurrence (DAWE 2012), broad habitat preference, estimated number of subpopulations (defined as geographically isolated occurrences with infrequent dispersal between them (Keith 2000), total population estimate (where available, accurate estimates were often not available, so IUCN (2019) thresholds were used, i.e. <50, <250, <1000, <2500, <10 000 or >10 000; threats (divided into past, documented/current, and potential/suspected), evidence of decline (past and continuing), whether the taxon had been thoroughly searched for in suitable habitat (i.e. the likelihood that its current known distribution and abundance reflects its actual distribution and abundance), and references and/or experts consulted.

To identify the taxa most at risk of extinction, we focused on elucidating current population trends. Identifying population declines is difficult, due to the paucity of repeatable time-series monitoring data for the vast majority of the world's species and the long timeframes necessary to identify trends (Brummitt *et al.* 2015; Clark and Bjornstad 2004; Jenkins *et al.* 2003). There is seldom quantified evidence of species declines (Rayner *et al.* 2014) and threatened species lists tend to be dominated by narrow-range endemics with small distributions and/or population sizes (Burgman 2002; McIntyre 1992; Silcock *et al.* 2014). However, given that extinction is the end-point of unhalted population declines, and because intrinsically rare species may have ecological syndromes and breeding systems that are adapted to survival in small populations (Coates and Atkins 2001; Flather and Sieg 2007; Mace and Kershaw 1997; Yates *et al.* 2007), declining species should be the highest conservation concern.

Expert opinion was critical in assessing population trends, as consistent monitoring data spanning the time periods required to detect trends were rarely available (Silcock and Fensham 2018). Even where these time-series data were available, interpretation was often difficult. Expert opinion often differed from data trends, typically due to inconsistencies in monitoring techniques or survey comprehensiveness between years, discovery of new plants, and observations not available from simple population counts (e.g. demographic data or observations of threats). Expert observations and perceptions, when not supported by quantitative data, are also subject to inaccuracies and bias. We attempted to minimise subjectivity by using targeted and consistently phrased questions where experts were asked to justify or qualify their assessments of population trends and threats. Continuing declines were often not quantified (observed), so could also be suspected, inferred or projected (IUCN 2019) (e.g. based on decline in quality of habitat or observed lack of recruitment).

Taxa with evidence of continuing decline were then scored according to whether all subpopulations were declining, abundance of the taxon, magnitude and certainty of decline, and extinction risk. Silcock and Fensham (2018) identified 418 taxa with a documented, suspected or projected continuing decline. Of these, 55 taxa had documented continuing declines across all subpopulations and were considered to be at very high risk ('category 5') of extinction within three generations or 100 years, whichever was longer (IUCN 2019; Silcock and Fensham 2018). These species were the focus of this Action Plan.

Subsequent to the 2018 assessment, a further eight imperilled species have been identified and included in this Action Plan. Conversely, experts highlighted taxonomic uncertainty for six 'category 5' orchid taxa along with the shrub *Banksia vincentia*, which have been excluded. For these species, taxonomic work is considered the highest-priority conservation action. Subspecies have not been included in the Action Plan, with the exception of *Epilobium brunnescens* subspecies *beaugleholei*, which is the only subspecies of the taxon to occur in Australia (the other two occur in New Zealand). Three species – *Wikstroemia australis, Hibbertia tenuis* and *Prasophyllum murfetii* – have increased in abundance since 2016 due to management actions and, while still highly threatened and management-dependent, do not currently have severe ongoing declines across all subpopulations.

2.2 Compiling Action Plan profiles

The majority of this Action Plan comprises standardised accounts of the conservation status of Australia's most imperilled plants. Species profiles were compiled according to the data collated from 2016-17 by Silcock and Fensham (2018). Each profile was reviewed by relevant experts in 2020 to ensure the most current information was presented. The profile templates were adapted and modified from the Bird and Mammal Action Plans, and focused on presenting key IUCN thresholds and recovery actions. A summary and explanation of the information in the profiles is provided below.

Overview

A brief summary of the key information about the taxon including current listing status (IUCN, EPBC Act and State/Territory) and re-assessment of IUCN status.

Brief description

Short morphological description, including distinguishing features and reference to taxonomic authority.

Distribution

Known current (black squares) and former (grey squares) occurrences of the taxon shown on map with bioregion/s of occurrence shaded (dark grey for bioregions where species currently occurs, light grey for bioregions where species formerly occurred) (DAWE 2012). We used Australasian Virtual Herbarium data, with all records checked to ensure they were natural occurrences (i.e. not cultivated) and correctly geo-located. In some cases, detailed survey data were accessed to provide more accurate distribution maps. Translocated subpopulations are shown on the map as triangles (black where plants are extant; hollow where plants persist but there has been no recruitment, are in very low numbers or have been in the ground for <5 years thus it is too early to assess long-term performance; grey where translocation has failed).

Population estimate and trends

Current best estimates of subpopulation sizes and trends, including tenure of each subpopulation, were compiled. Where time-series monitoring data were available, these were tabulated. Translocated plants and subpopulations were shown in the tables, but did not contribute to IUCN assessments until they were considered self-sustaining. Translocations can sometimes show early signs of success, including recruitment in some instances, but can fail or remain strongly conservation-dependent after many years (Drayton and Primack 2012; Guerrant 2012; Jusaitis 2012). Here we define self-sustaining translocated subpopulations as having sufficient number of surviving plants to potentially establish a viable subpopulation (this differs depending on life history of the species, and is generally measured against naturally-occurring subpopulation abundance), and translocated plants having successfully recruited (IUCN 2019; Silcock *et al.* 2019). We also stipulate that translocated plants must have been in the ground for at least five years, and thus survived a wide range of seasonal conditions and threatening processes.

We have followed the IUCN (2019) usage of the terms 'population' and 'subpopulation'; wherein 'population' is defined as the total number of individuals (mature and other life stages) of a taxon throughout its distribution. Population size only considers the number of 'mature individuals' (see below). Even where the taxon exists in subpopulations that could be considered biologically or ecologically distinct populations, when assessed under the IUCN criteria, these are referred to as subpopulations and population refers to total numbers (IUCN 2019).

Habitat and ecology

A summary of key information about habitat/s where the species grows, its biology and ecology.

IUCN Red List assessment data

This section tabulates the conservation parameters of the taxon relevant to the IUCN (2019) criteria and trends in these parameters, along with a qualitative rating of the degree of confidence in the values assigned to those parameters (high, medium or low). Translocated subpopulations were included in IUCN assessments where the translocation was considered self-sustaining in the long-term (i.e. had a comparable number of individuals, health and fecundity to naturally occurring subpopulations, had been in the ground for at least five years, and had produced viable offspring; Silcock *et al.* 2019). Key terms are defined explicitly by IUCN (2019) and outlined below.

Extent of Occurrence (EOO) measures the spatial spread of the areas currently occupied by the taxon using a convex hull (IUCN 2019), generated via GeoCat (Bachman *et al.* 2011). Records used in this calculation included herbarium specimens and expert survey records held in State databases, which are referenced in each taxon profile. To derive a consistent measure across species and ensure the EOO reflected current distribution, records from 2000-2020 (20 year period) were included. Subpopulations known to be extinct were excluded, while extant subpopulations that only had pre-2000 records were included.

Area of Occupancy (AOO) is a scaled metric that represents the area of suitable habitat currently occupied by a taxon. It was also calculated in GeoCat (Bachman *et al.* 2011), which determines the number of 2 × 2 km raster grid cells in which there are recent (post-2000) records (except where local extinctions are known to have occurred), then multiplies this tally by four to derive an estimate in square kilometres. This may markedly over-estimate the actual area occupied by highly specialised and restricted plant species, and in this instance, an estimate of the 'Actual Area of Occupancy' is provided in brackets.

Under IUCN (2019) guidelines, if the EOO is less than AOO (due to the grid square calculation method), it is increased to equal the AOO value. This is because AOO is defined as the area occupied within the EOO (IUCN 2019). In these cases, the original (actual) EOO is specified in brackets.

Number of mature individuals is the total number of individuals known, estimated or inferred to be capable of reproduction (IUCN 2019). Where accurate estimates were not available, IUCN thresholds were used: <50, <250, <1000, <2500, <10 000 or >10 000 (IUCN 2019). Individuals that cannot produce new recruits (e.g. plants reproductively suppressed by myrtle rust (*Austropuccinia psidii*) such that flower, fruit and seed production is extremely low and parent plants persist in greatly reduced densities with limited outcrossing probability) are not considered mature individuals. Reproducing units within a clone (i.e. ramets) are counted as separate 'mature individuals'. However, obtaining precise counts of clonal units is inherently challenging, and the most pragmatic approach was adopted (IUCN 2019). Translocated individuals must have been in the ground for at least five years and produced viable offspring (defined as offspring that have reached maturity or are likely to do so) before they are counted as mature individuals (IUCN 2019). Where there was any uncertainty or potentially differing interpretations, the method used to calculate mature individuals was justified.

Number of subpopulations is defined as the number of geographically and thus reproductively isolated occurrences with infrequent dispersal or genetic exchange between them (IUCN 2019; Keith 2000). In many cases, subpopulations were already delineated by species' experts in recovery plans, and these were adopted in the current Action Plan. However, there was often little information available on the dispersal capacity of a taxon. For species with highly mobile insect pollinators (e.g. *Eucalyptus dalveenica*) or bird-dispersed seed/fruit (e.g. *Rhodomyrtus psidioides*), subpopulations are likely to encompass a larger area and multiple distinct occurrences, when compared with taxa that have more limited seed-dispersal (e.g. *Grevillea caleyi*). In many cases (perhaps most pronounced in the heavily cleared Avon Wheatbelt of WA), species that previously comprised a single subpopulation have been fragmented into smaller subpopulations by land-use change, and we have assumed dispersal is limited between sites that now represent separate subpopulations.

Number of locations: a 'location' is defined as a geographically or ecologically distinct area in which a single threat could rapidly affect all individuals. While locations are typically guided by subpopulation occurrences, they may also comprise more than one subpopulation, or only part of a subpopulation. Where a taxon is affected by more than one threat, locations should be defined by considering the most serious plausible threat (IUCN 2019). The threat that determined the number of locations was shown in brackets in the IUCN Red List assessment data table in all profiles.

Where the main threatening process operates at a landscape scale, the number of locations is defined as the number of discrete management units applicable to the threatening process. The delineation of management units may relate to the ability of the species to disperse between areas affected by the threat, the capacity for the threat to transition between units, or areas where different management practices are utilised to mitigate the threat. Thus species threatened by the airborne pathogen myrtle rust, where all subpopulations occur within the climatic range of the pathogen, are assessed as a single location. Similarly, where climate change or drought is considered the major threat, all subpopulations are affected and considered a single location. By contrast, phytophthora (*Phytophthora* spp.) dieback is soil-borne and fronts may move gradually through an area of contiguous, susceptible vegetation. However, spread to an uninfested area separated by an ecological barrier (e.g. farmland or urbanisation) would require a specific transport vector. Such geographically-separated subpopulations would be considered multiple locations in relation to the threat of phytophthora.

For numerous imperilled species, long-term lack of recruitment is the main threatening process. In cases where this is due to landscape scale processes across the range of the species (e.g. long-term shifts in rainfall regime, or loss of pollinators or other essential ecosystem services), subpopulations are considered one location. If lack of recruitment is due to site-based factors, e.g. soil compaction or herbivory, or the reasons for lack of recruitment are not well-understood and potentially due to multiple factors, subpopulations are considered as separate locations.

Generation length is the average age of parents of the current cohort (i.e. newborn individuals in the population) (IUCN 2019). Generation length therefore reflects the turnover rate of breeding individuals in a population. Detailed demographic data are not available for most threatened plants, including length of reproductive period, survivorship and mortality. We have calculated generation length as:

$$\frac{\text{age at senescence} - \text{age at reproductive maturity}}{2}$$

These estimates are necessary as this time period is directly relevant to IUCN (2019) criteria, where declines are measured over 10 years or 3 generations, up to a maximum of 100 years, whichever is longer. Where no species-specific data were available, estimates were inferred based on closely-related members of the genus or recorded as 'unknown'.

Extreme fluctuations occur where population parameters (EOO, AOO, locations, subpopulations or number of mature individuals) vary widely, rapidly and frequently; typically where at least a 10-fold difference between the minima and maxima is evident (IUCN 2019). Criteria B and C include this sub-criterion to account for the positive relationship between variable population growth rates and extinction risk (Burgman *et al.* 2007). Extreme fluctuations vary in magnitude and frequency (which may be regular or sporadic), and occur over any timespan depending on the underlying cause. Short-term fluctuations that occur over seasonal or annual cycles are typically easier to detect than those that occur over longer timespans, such as those driven by rare events or climatic cycles such as *El Nino*.

If there is occasional dispersal between subpopulations, the degree of fluctuation should be measured over the entire population. Therefore, fluctuations within separate subpopulations that occur independently or asynchronously, are likely to become redundant when considered at the population scale. However, if the subpopulations are isolated (as for many plants), the degree of synchrony between the subpopulations is less important, and it is sufficient for the majority of subpopulations to undergo extreme fluctuations separately. If most of the subpopulations show fluctuations of an order of magnitude, the criterion would be met (regardless of the degree of fluctuations in total population size).

Assessors must be reasonably certain that fluctuations in the number of mature individuals represent changes in total population, rather than simply a flux of individuals between different life stages (IUCN 2019). For example, fires may stimulate mass recruitment from large persistent seedbanks when there were few mature individuals before the event. Mature plants may die out during the interval between fires, leaving a store of immature individuals (seeds) until they are stimulated to germinate by the next fire. Such cases do not fall within the definition of extreme fluctuations unless the seedbank can be exhausted by a single event or the species cannot persist without mature individuals. For example, serotinous obligate-seeders hold their seed in the canopy and the majority germinate after adults are killed by fire. Such species are prone to extreme fluctuations, as successive fires could cause a local extirpation if a second fire occurred before germinants reached reproductive maturity (IUCN 2019).

Detailed knowledge of seedbanks is lacking for many plants included in the Action Plan. Where there is assumed to be a persistent soil seedbank and/or fluctuations are not clearly evident in monitoring data (as is the case for the majority of Western Australian shrubs), we have assigned extreme fluctuations as 'not documented' with a 'medium' level of confidence. In cases where shrubs appear to be serotinous, extreme fluctuations are considered 'probable', also with a 'medium' confidence level. For short-lived forbs with extreme fluctuations documented and no evidence of long-lived seedbanks, e.g. *Ballantinia antipoda*, extreme fluctuations are accepted with a 'medium' level of confidence. Where there is evidence of a persistent seedbank, however, e.g. *Gentiana bredboensis*, extreme fluctuations are not considered likely because apparent fluctuations probably represent a flux of individuals between different life stages (IUCN 2019).

For ground orchids and other geophytes (e.g. *Solanum orgadophilum*), the number of flowering plants may vary greatly between years in response to environmental factors such as rainfall and time since fire or other disturbance. However, the number of mature individuals is likely to be relatively stable despite these apparent fluctuations, as many individuals would persist as non-flowering tubers or rhizomes below the ground. Thus extreme fluctuations are not likely to occur, and are considered 'not documented' with a 'medium' level of confidence.

Severely fragmented refers to the situation in which increased extinction risk to the taxon results from most of its individuals occurring in small and relatively isolated subpopulations. These small subpopulations may go extinct through demographic and genetic effects, with a reduced probability of recolonisation (IUCN 2019). Fragmentation can be 'natural' for species that are restricted to small patches of suitable habitat and have limited dispersal capacity, or can occur due to fragmentation of natural habitats.

A taxon can be considered severely fragmented if >50% of its total AOO is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance (IUCN 2019). If the species naturally occurs in small disjunct patches (e.g. species that occur in isolated desert springs and many rainforest species), habitat patches are not considered smaller than would be required to support a viable population, thus subpopulations are not considered 'severely fragmented' under IUCN criteria.

Continuing decline: is a recent, current or projected future decline which is liable to continue unless recovery actions are taken (IUCN 2019). Declines can be observed, estimated, inferred or projected. Projected declines must be justified and there must be a high degree of certainty that they will take place – merely 'plausible' future declines are not allowed (IUCN 2019). Declines are estimated for three generations or 10 years, whichever is longer (up to a maximum of 100 years) (IUCN 2019).

Current eligibility against IUCN Red List criteria

Assessment of the taxon's eligibility against IUCN Red List Criteria (IUCN 2019). For criteria A to E (Table 2), the taxon's eligibility is ranked as Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Data Deficient (DD) or Not Eligible, with a short justification provided.

Table 2. Summary of the five criteria (A-E) used to evaluate IUCN Red List status (IUCN 2019).

SUMMARY OF THE FIVE CRITERIA (A-E) USED TO EVALUATE IF A TAXON BELONGS IN AN IUCN RED LIST THREATENED CATEGORY (CRITICALLY ENDANGERED, ENDANGERED OR VULNERABLE).[1]

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3]*.

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation *[except A3]*

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

(d) actual or potential levels of exploitation

(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km^2	< 5,000 km^2	< 20,000 km^2
B2. Area of occupancy (AOO)	< 10 km^2	< 500 km^2	< 2,000 km^2
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented **OR** Number of locations	= 1	≤ 5	≤ 10

(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

(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals

C. Small population size and decline

	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) **(i)** Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(a) **(ii)** % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			

D. Very small or restricted population

	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	**D1.** < 1,000
D2. *Only applies to the VU category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	**D2.** typically: AOO < 20 km^2 or number of locations ≤ 5

E. Quantitative Analysis

	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

1 Use of this summary sheet requires full understanding of the *IUCN Red List Categories and Criteria* and *Guidelines for Using the IUCN Red List Categories and Criteria*. Please refer to both documents for explanations of terms and concepts used here.

Threats and threat impact

For each threat, the timing (past, ongoing or future; Table 3), its scope (proportion of the total population affected; Table 4) and severity (overall declines caused by the threat; Table 5) were adapted from the IUCN (2020) threat classification scheme to best represent threats to Australian plants. The timing, scope and severity of each threat were used to calculate a threat impact score (high, medium, low; Table 6). Where threat timing was 'past', the scope, severity and impact are not relevant to current or future conservation of the species. It is also difficult to assess threats retrospectively, so threat scope, severity and impact were not scored. If severity is considered negligible, impact is assessed as negligible. If scope and/or severity are unknown, the threat impact is also assessed as unknown.

Table 3. Threat timing categories and scores (adapted from IUCN 2020).

Timing	Explanation	Score
Past	Threat affected species in the past but has now ceased and is considered unlikely to return	n/a (not scored)
Ongoing	Current and documented threat to species	3
Suspended	Operated in the past; now suspended but could return in the future (e.g. populations that are now fenced from herbivores but fence requires ongoing maintenance)	2
Future	Considered possible that threat will impact population in future	1

Table 4. Threat scope categories and scores (adapted from IUCN 2020).

Scope	Explanation	Score
Whole	Affects >90% of population	3
Majority	Affects 50-90% of population	2
Minority	Affects <50% of population	1
Unknown	Insufficient information to assess scope of threat	Unknown (not scored)

Table 5. Threat severity categories and scores (adapted from IUCN 2020).

Severity	Explanation	Score
Very rapid	Causing or likely to cause very rapid declines (>30% over 10 years or 3 generations, whichever is longer)	3
Rapid	Causing or likely to cause rapid declines (20-30% over 10 years or 3 generations, whichever is longer)	2
Slow	Causing or likely to cause relatively slow but significant declines (<20% over 10 years or 3 generations, whichever is longer)	1
Negligible	Causing or likely to cause negligible or minor declines	0
Unknown	Insufficient information to assess severity of threat	Unknown (not scored)

Table 6. Final threat impact categories and scores (adapted from IUCN 2020) H, High; M, Medium; L, Low.

	ONGOING THREATS (score =3)			SUSPENDED THREATS (score =2)			FUTURE THREATS (score =1)		
Scope	Very rapid (3)	Rapid (2)	Slow (1)	Very rapid (3)	Rapid (2)	Slow (1)	Very rapid (3)	Rapid (2)	Slow (1)
Whole (3)	H	H	M	H	M	M	M	M	L
Majority (2)	H	M	M	M	M	L	M	M	L
Minority (1)	M	M	L	M	L	L	L	L	L

Current management

Current management of the taxon and its habitat is summarised, including whether there is a past or current recovery plan or other program or strategy, whether it occurs on land managed for conservation, and specific actions that are being undertaken for individual subpopulations.

Information required

Outlines the information required to address key knowledge gaps relating to the taxon, the specific actions required to gather this information, and the priority of these actions.

Management actions required

Outlines management required to ensure the taxon's persistence and facilitate its recovery, and the priority of these actions.

Experts consulted

Draft profiles were circulated to at least one and preferably multiple (where available), expert(s) for review.

3. Imperilled species: overview, threats and conservation assessments

3.1 Lifeforms, regions and habitats

More than two-thirds of imperilled species are long-lived trees and shrubs, eight are ground orchids, seven are perennial forbs (including one fern) and two are annual forbs. Imperilled species are concentrated where centres of endemism (Crisp *et al.* 2001) correspond with highly-modified agricultural and urban landscapes: the east, south-east and south-west of the continent (Figure 1). Imperilled species come from only 26 of Australia's 89 bioregions. Western Australia accounts for 15 species, all from the heavily-cleared and high-endemism Southwest Australian Floristic Region (Hopper and Gioia 2004), particularly the Avon Wheatbelt bioregion where seven imperilled species occur.

Eleven species are endemic to Victoria (including two that previously occurred in other States where they are now considered extinct). While six of these occur in heavily-cleared bioregions such as the Southern Volcanic Plain, South East Coastal Plain and Riverina, the other five are narrow-range mountain endemics that face a variety of intensifying threats. Thirteen species occur in New South Wales and 11 in Queensland (including five found in both States). Eight of these occur in South Eastern Queensland, where historic and ongoing land clearing for agriculture and urbanisation has been exacerbated by the recent arrival of myrtle rust. Tasmania has three species, and South Australia two (Figure 1).

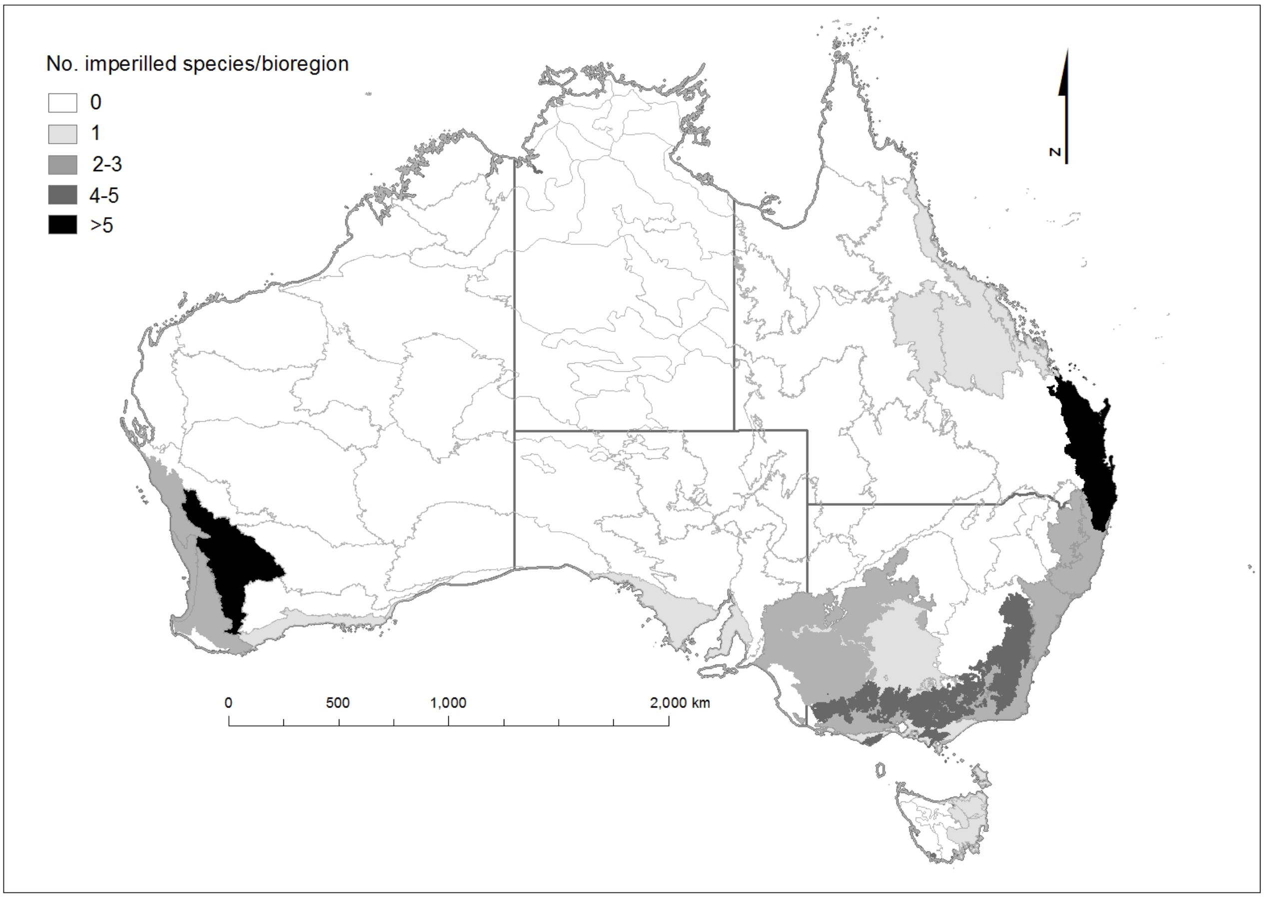


Figure 1. Number of imperilled species by biogeographic region (DAWE 2012), Australia.

Australia's drier regions are far less modified than more arable and populous regions, and adaptations of the flora to drought have conferred some resilience to introduced herbivores (Silcock *et al.* 2014). While there are numerous dryland shrubs and trees with limited or no recruitment, and some restricted species are at long-term risk of extinction as older plants senesce (Auld *et al.* 2015; Denham and Auld 2004), none were considered imperilled. The only imperilled arid zone species was the Great Artesian Basin spring endemic *Eriocaulon aloefolium*, which is restricted to a single spring wetland in central Queensland, is threatened by feral pigs and has poorly-understood disturbance requirements. Despite the large number of listed threatened species in bioregions with high endemism such as the Wet Tropics, these areas are less modified and have no imperilled taxa. Although Queensland's Brigalow Belt is highly modified, it has relatively few endemic species and thus fewer that are imperilled (Fensham *et al.* 2018).

Five habitat types spanning multiple regions harbour the highest numbers of imperilled taxa. Southern Australian heathlands and shrublands from Victoria to south-western Australia have been extensively cleared for agriculture. Many endemic species are now restricted to small fragmented remnants, and these account for 18 imperilled species. Although mountainous habitats are less impacted by land clearing and fragmentation and support many narrow-range endemics that are not declining (Silcock and Fensham 2017), 12 imperilled species occur in these habitats. The restricted distributions of these species, which are often confined to a single mountain peak or outcrop, renders them extremely vulnerable to local impacts (Burgman *et al.* 2007).

Wetlands often bear the brunt of changes in agricultural and urban landscapes. These ecosystems have been extensively cleared, had their hydrology altered, been sown to pasture species, and subjected to concentrated grazing pressure and weed invasion, and are now particularly vulnerable to the projected impacts of climate change (Burgin *et al.* 2016; Casanova and Powling 2014; Powell *et al.* 2015). Where endemic or restricted species occur in highly-modified wetlands they are often at risk of extinction, and eight such species are considered imperilled.

The temperate and subtropical fertile tussock grasslands and grassy woodlands of eastern and southern Australia have been extensively cleared for agriculture since European colonisation. Small, fragmented remnants now comprise Critically Endangered and Endangered Ecological Communities in Victoria, Tasmania, New South Wales and Queensland (Morgan *et al.* 2017). These remnants are mostly on roadsides, rail lines and in tiny reserves that are subject to a variety of interacting threats. Eight highly restricted species are considered imperilled in these habitats. Six species occur in subtropical rainforests of eastern Australia, and five are imperilled due to the introduced pathogen myrtle rust.

3.2 Threats

Ongoing habitat loss is a high impact threat for six imperilled species. However, over 60% of Australia's imperilled plants have suffered historical declines due to habitat clearance and now survive as fragmented subpopulations in small patches of remnant vegetation. These remnants are typically not managed for conservation, often occur in road and rail corridors, and are inherently vulnerable to further loss and degradation from infrastructure maintenance, weed invasion, edge effects (e.g. eutrophication, spray drift), high herbivore densities and human activities. In many cases ecological processes, particularly those driving recruitment (e.g. fire, pollinator activity), have been disrupted.

Many remnant shrub subpopulations are comprised of mature individuals with limited recruitment due to lack of fire or other disturbance, often exacerbated by herbivory and/or competition from weeds and native vegetation. Limited recruitment is a critical threat for 21 imperilled species. This represents an 'extinction debt' that will play out in the absence of active disturbance management as older plants senesce (Kuussaari *et al.* 2009). Moreover, some species may have fallen below a minimum viable population size for long-term persistence (Bulman *et al.* 2007; Traill *et al.* 2010). The period over which this extinction debt will be realised may be many decades, depending on life histories of plants involved and the size and condition of their remnant habitat (Guardiola *et al.* 2013; Koyanagi *et al.* 2017). Recent taxonomic work on ground orchids has described many new and highly restricted species, many of which now occur in small fragmented subpopulations sometimes numbering only a few plants (Swarts and Dixon 2009).

The other 40% of imperilled species occur in less heavily-modified habitats, mostly mountain ranges and upland rainforest. The threats to these species are species- and site-specific, and include infrastructure maintenance, native herbivores, insect borers, mites, and introduced pathogens. Declines of naturally-restricted species tend to be better documented than for those that are widespread, but causes of decline are not always understood. Most taxa are characterised by low recruitment and poor understanding of their seedbank ecology. Increased frequency, severity and changed season of wildfires is a major threat to species in some habitats, for example the Stirling Range in south-western Australia. The future impacts of climate change are also poorly understood, but for geographically restricted species are often predicted to be severe, particularly in concert with other threats (Auld and Leishman 2015; Petitpierre *et al.* 2016). Herbivores (domestic, feral and native) are a listed threat to many species, however, are only classified as a high impact threat (Table 6; IUCN 2020) for two imperilled species.

Two plant diseases are at the forefront of conservation concerns in Australia, and are directly responsible for the imperilled status of 10 species. The threat from phytophthora *Phytophthora cinnamomi*, a soilborne water mould pathogen that destroys the roots of infected plants, is well documented (Cahill *et al.* 2008; Shearer *et al.* 2007), particularly in the Eastern Stirling Range Montane Heath Community where numerous endemic taxa are threatened with extinction (Barrett and Yates 2015). Phytophthora has also been documented in forests of Victoria (Reiter *et al.* 2004; Weste 2003) and New South Wales (McDougall *et al.* 2003), and is responsible for continuing declines in five imperilled species, often in conjunction with other threats.

Myrtle rust, a plant disease caused by the introduced fungal pathogen *Austropuccinia psidii*, was first detected in New South Wales in 2010 and has now been observed on 382 (17%) of the 2253 native Myrtaceous taxa (Makinson *et al.* 2020). The impacts of myrtle rust are most pronounced in Australia's east coast rainforest flora, and vary from restricted leaf lesions to impaired fecundity (infection of growing shoots, flowers, fruit and seeds) and plant death (Makinson *et al.* 2020). Some restricted and already threatened species are extremely susceptible to infection including the naturally rare *Gossia gonoclada* and the undescribed *Lenwebbia* sp. Main Range (P.R.Sharpe+4877). Even more-widespread species such as *Gossia hillii, Rhodomyrtus psidioides* and *Rhodamnia maideniana* face sharp extinction trajectories due to severe impacts across their range (Fensham *et al.* 2020). Emerging research indicates myrtle rust is likely to interact with other ecological processes and threats (e.g. drought, fire, weed invasion) to exacerbate species declines in the future (Fernandez-Winzer *et al.* 2020a; Fernandez-Winzer *et al.* 2020b; Makinson *et al.* 2020; Pegg *et al.* 2017).

Climate change, specifically long-term drying trends, is ranked as a high impact threat to five imperilled species, and a potential future threat for many species mainly through decreasing winter rainfall trends in southern Australia, increased temperatures and drying in alpine areas.

3.3 Conservation assessments

All 50 species included in the Action Plan meet IUCN (2019) criteria for listing as Critically Endangered. The majority were eligible for listing as CR under criterion B (45 species) and criterion C (41 species). Thirty species were eligible for listing as CR under criterion D, meaning that they are known from <50 mature individuals (seven of these are known from <10). Fourteen species were eligible under criterion A, involving a quantified sharp decline. Only one species, *Grevillea caleyi*, had extinction probability quantified; all others were assessed as Data Deficient under criterion E.

Only six species had an EOO greater than 100 km^2, while 31 had an AOO <10 km^2. Thirty-two species are known from a single location, and all except five from <5 locations. All species had continuing declines observed, estimated, inferred and/or projected. The distributions of 39 species were considered severely fragmented, while extreme fluctuations (IUCN 2019) were considered likely or possible for only four species.

Conservation listings often underpin funding priorities as well as providing a level of protection from land clearing. Unfortunately, there is substantial misalignment between State and Federal listings, and erroneous or inconsistent listings under IUCN criteria, for the majority of imperilled species. Only 10 of the 50 species are listed as Critically Endangered under both Federal and State legislation. Twelve have consistent listings between jurisdictions, but are listed at lower categories than they are eligible for (i.e. Endangered or Vulnerable instead of Critically Endangered). The remaining 28 species listings are misaligned between jurisdictions, including 11 that are not currently listed as being of conservation concern under the EPBC Act. These findings underscore the value and urgency of the ongoing CAM process, which seeks to align listings under IUCN criteria.

Table 7. Summary of imperilled species and their IUCN assessment data. Note that all species meet IUCN criteria for listing as CR, and this is not shown in the Table. For some species, there are no high impact threats and reasons for decline are poorly understood or declines are being driven by multiple interacting medium-impact threats.

Taxon	Family	State	EOO (km^2)	AOO (km^2)	Locations	Mature* individuals	Continuing decline	High impact threat/s	EPBC Act	State status
Acacia leptoneura	Fabaceae	WA	4	4	1	2	Observed & projected	Lack of recruitment/lack of disturbance; roadside impacts; low genetic diversity	CR	CR
Acacia pharangites	Fabaceae	WA	8	8	1	13	Observed & projected	Lack of recruitment/lack of disturbance	EN	CR
Acacia volubilis	Fabaceae	WA	2255	60	17	182	Observed & projected	Lack of recruitment/lack of disturbance	EN	CR
Antrophyum austro-queenslandicum	Pteridaceae	QLD; NSW	8	8	1	39	Observed	Drought/climate change	CR	EX
Ballantinia antipoda	Brassicaceae	VIC	20	20	1	22,381	Observed & projected	None	EN	EN
Banksia fuscobractea	Proteaceae	WA	4	4	2	43	Observed & projected	Infrastructure maintenance; extractive industries	CR	CR
Banksia montana	Proteaceae	WA	12	12	2	0	Observed & projected	Introduced pathogens (Phytophthora); too-frequent fire	EN	CR
Borya mirabilis	Boryaceae	VIC	4	4	1	70	Observed & projected	Inappropriate disturbance regimes; low genetic diversity; introduced pathogens (Phytophthora); competition	EN	EN
Caladenia amoena	Orchidaceae	VIC	8	8	3	<50	Observed & projected	Climate change	EN	EN
Caladenia busselliana	Orchidaceae	WA	13	12	3	<50	Observed & projected	Lack of recruitment; human activity	EN	CR
Caladenia luteola	Orchidaceae	WA	26	8	2	127	Observed & projected	Lack of recruitment	CR	CR
Caladenia pumila	Orchidaceae	VIC	4	4	1	2	Observed & projected	Lack of recruitment; low genetic diversity	CR	EN
Calochilus richiae	Orchidaceae	VIC	4	4	1	<10	Observed & projected	Illegal collection/human trampling	EN	EN
Commersonia erythrogyna	Malvaceae	WA	4	4	1	0	Observed & projected	Lack of recruitment/inappropriate fire regimes; climate change	EN	CR
Daviesia bursarioides	Fabaceae	WA	74	20	6	44	Observed & projected	Lack of recruitment/inappropriate fire regimes	EN	CR
Daviesia cunderdin	Fabaceae	WA	4	4	1	13	Observed & projected	Lack of recruitment/inappropriate fire regimes; drought; infrastructure maintenance; rabbits	EN	CR
Epilobium brunnescens subsp. *beaugleholei*	Onagraceae	VIC	4	4	1	<50	Observed & projected	None	VU	VU

Taxon	Family	State	EOO (km^2)	AOO (km^2)	Locations	Mature* individuals	Continuing decline	High impact threat/s	EPBC Act	State status
Eremophila pinnatifida	Scrophulariaceae	WA	74	16	6	19	Observed & projected	Lack of recruitment/inappropriate fire regimes	EN	CR
Eremophila subangustifolia	Scrophulariaceae	WA	4	4	1	81	Observed & projected	Lack of recruitment/inappropriate fire regimes	CR	CR
Eriocaulon aloefolium	Eriocaulaceae	QLD	4	4	1	1,588	Projected	Feral herbivores	Not listed	EN
Eucalyptus dalveenica	Myrtaceae	QLD	4	4	1	244+	Inferred & projected	Habitat loss	Not listed	CR
Eucalyptus imlayensis	Myrtaceae	NSW	4	4	1	80	Observed	Dieback (unknown cause); lack of recruitment	EN	CR
Eucalyptus morrisbyi	Myrtaceae	TAS	45	8	1	43	Observed & projected	Climate change; grazing/browsing; insect defoliation.	EN	EN
Gentiana bredboensis	Gentianaceae	NSW	4	4	1	<300	Observed & projected	Competition/lack of fire; feral herbivores	CR	CR
Gossia gonoclada	Myrtaceae	QLD	193	48	3	<50	Observed & projected	Introduced pathogens (myrtle rust); low genetic diversity; lack of recruitment	EN	EN
Gossia hillii	Myrtaceae	QLD; NSW	265600	592	1	<50	Observed & estimated	Introduced pathogens (myrtle rust)	Not listed	Not listed
Grevillea caleyi	Proteaceae	NSW	56	56	3	<3,000	Observed & projected	Habitat loss; inappropriate fire regimes; seed predation	EN	CR
Grevillea calliantha	Proteaceae	WA	24	24	6	27	Observed & projected	Lack of recruitment/inappropriate fire regimes	EN	CR
Grevillea hodgei	Proteaceae	QLD	4	4	1	<250	Observed & projected	Hybridisation	Not listed	CR
Grevillea sp. Gillingarra (R.J. Cranfield 4087)	Proteaceae	WA	4	4	1	21	Observed & projected	Infrastructure maintenance	CR	CR
Hibbertia circinata	Dilleniaceae	NSW	4	4	1	<250	Inferred & projected	Introduced pathogens (phytophthora)	Not listed	CR
Kelleria bogongensis	Thymelaeaceae	VIC	4	4	1	<500	Observed & projected	Feral vertebrate pests (horses)	VU	EN
Lenwebbia sp. (Main Range P.R. Sharpe+4877)	Myrtaceae	QLD; NSW	2049	44	1	<50	Observed & estimated	Introduced pathogens (myrtle rust)	Not listed	CR
Petrophile latericola	Proteaceae	WA	16	16	5	171	Observed & projected	Inappropriate fire regimes/lack of recruitment; introduced pathogens (Phytophthora)	EN	CR
Phebalium daviesii	Rutaceae	TAS	4	4	1	25	Observed & projected	Domestic stock; lack of recruitment	CR	EN
Pimelea cremnophila	Thymelaeaceae	NSW	4	4	1	<100	Observed	Lack of recruitment; vertebrate pests (introduced and native)	Not listed	CR

Taxon	Family	State	EOO (km²)	AOO (km²)	Locations	Mature* individuals	Continuing decline	High impact threat/s	EPBC Act	State status
Pimelea venosa	Thymelaeaceae	NSW	4	4	1	0	Observed	None	EN	EN
Pomaderris delicata	Rhamnaceae	NSW	19	8	2	<100	Observed & projected	Infrastructure maintenance	CR	CR
Prasophyllum correctum	Orchidaceae	VIC	8	8	1	<15	Observed & projected	Inappropriate disturbance regimes/ competition; lack of recruitment	EN	EN
Prasophyllum laxum	Orchidaceae	SA	4	4	1	<50	Observed	None	CR	CR
Prasophyllum tunbridgense	Orchidaceae	TAS	65	16	3	<50	Projected	Habitat loss	EN	EN
Pultenaea sp. Genowlan Point (NSW 417813)	Fabaceae	NSW	4	4	1	40	Observed	Inappropriate fire regimes/lack of recruitment	CR	CR
Rhodamnia maideniana	Myrtaceae	QLD; NSW	<100	<50	1	<50	Observed & projected	Introduced pathogens (myrtle rust)	Not listed	CR
Rhodomyrtus psidioides	Myrtaceae	QLD; NSW	<100	<50	1	<50	Observed & estimated	Introduced pathogens (myrtle rust)	CR	CR
Senecio behrianus	Asteraceae	VIC; SA (X); NSW (X)	13459	22	4	<250	Observed & projected	Habitat loss; altered hydrology	EN	EN
Solanum orgadophilum	Solanaceae	QLD	8	8	3	<5,000	Observed & projected	Habitat loss; infrastructure maintenance; inappropriate disturbance regimes	Not listed	CR
Sphaerolobium acanthos	Fabaceae	VIC	30	16	4	<70	Observed & projected	Vertebrate pests (feral goat, deer); infrastructure maintenance	CR	Rare
Spyridium fontis-woodii	Rhamnaceae	SA	4	4	1	13	Observed & projected	Inappropriate disturbance regimes/ lack of recruitment	Not listed	EN
Spyridium furculentum	Rhamnaceae	VIC	12	12	1	<250	Observed & projected	Introduced pathogens (Phytophthora); drought/climate change	EN	EN
Zieria exsul	Rutaceae	QLD	130	24	4	<250	Projected	Habitat loss; infrastructure maintenance	Not listed	CR

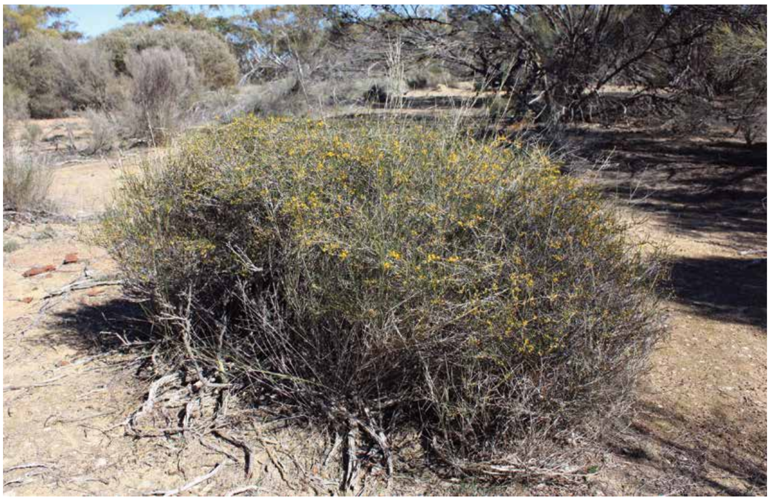
* Translocated individuals are not included unless the translocated subpopulation is considered self-sustaining (IUCN 2019).

4. Imperilled species profiles

This section presents accounts for the 50 Australian plant taxa identified as imperilled.
Profiles are ordered alphabetically. Explanations and definitions for all fields are provided in Chapter 2.

Acacia leptoneura Benth. [FABACEAE]
Slender-nerved acacia






Acacia leptoneura (clockwise from top left) flower buds, globular inflorescences, grading occurring immediately adjacent to one of two extant plants in narrow remnant, and growth habit (images: Joel Collins).

Overview

Acacia leptoneura is currently known from two individuals. One occurs on a very narrow road verge adjacent to cropping land and the other in a slightly larger patch of degraded remnant vegetation. Recovery options are limited as propagation has been unsuccessful and the genetic diversity is probably very low.

Conservation status

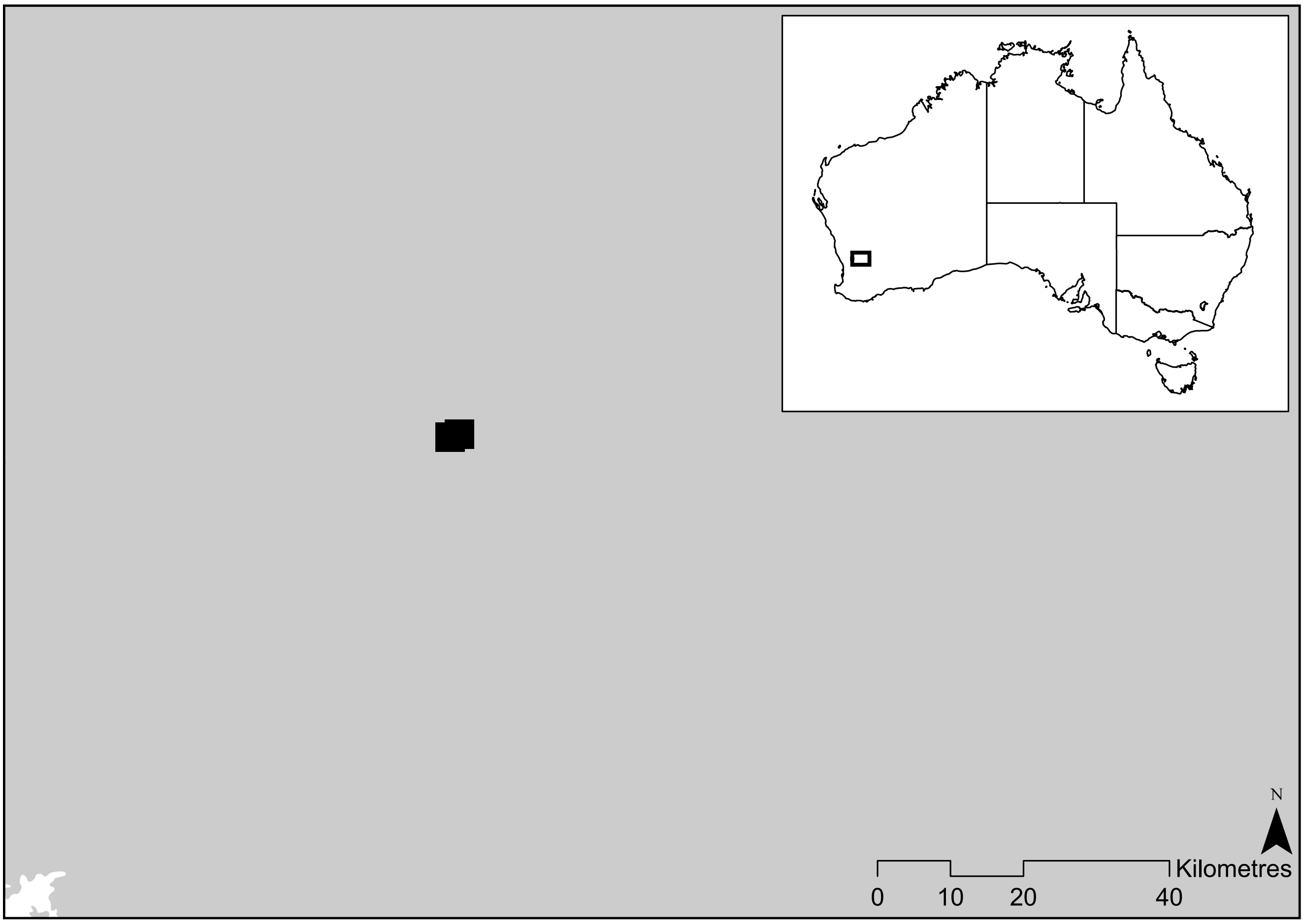
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Prostrate, spreading shrub 0.6 m high and 2.2 m wide with terete, strigose branchlets covered in straight, closely-appressed hairs (Maslin 2001). Phyllodes are circular in cross section, 3-7.5 cm long and 1 mm wide with 16 slightly raised nerves and appressed hairs at the base. Inflorescence a globular head of 20-30 flowers, occurring singly or in pairs, ca. 5 mm wide, on stalks 4-6 mm long (Maslin 2001). *Acacia leptoneura* is similar to *A. subflexuosa*, but has 16-nerved phyllodes rather than 8-nerved phyllodes, and a glabrous ovary rather than one covered with appressed-puberulous hairs (Cowan and Maslin 1999).

Distribution

Acacia leptoneura is known from two sites separated by 1 km in a very restricted area northeast of Dowerin in the Avon Wheatbelt bioregion of south-western Western Australia (Department of the Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution of *Acacia leptoneura* (black squares) in the Avon Wheatbelt bioregion (shaded grey) in south-western Western Australia (DAWE 2012; DBCA 2020).

Population estimate and trends

Acacia leptoneura is currently known from two mature individuals. There are very few historical collections of the species, indicating it was probably always rare (Australasian Virtual Herbarium 2020). The type specimen of *A. leptoneura* was collected by J. Drummond (unnumbered) before 1838 from the Swan River colony area, and described by Bentham in 1842 (Maslin 2001). At the time, Drummond lived on a property called Hawthornden, located a few km north of Toodyay near Bolgart (B Maslin pers.comm. 2020). Although no precise locality for the original collection is given, it was probably made in an area of sandplain country called the Guangan, near Bolgart, which has since been cleared extensively for agriculture (B Maslin pers.comm. 2020). In 1839, Drummond recollected the species (assigned the number '303'), probably from the same individual or location as the type specimen (B Maslin pers.comm. 2020).

Acacia leptoneura was known only from the historical Drummond collections until a single individual was located in 2008 (Department of Environment and Conservation 2012). Another individual was located in 2010, raising the population size to two individuals 1 km apart (DEC 2012). The species occurs at one location given the range of threats that simultaneously affect both plants, and could rapidly cause the species' extinction.

Extensive targeted searches of road and nature reserves in the Dowerin, Amery and Bolgart areas have been undertaken without success (Threatened Species Scientific Committee 2015). The species was also not located during previous flora surveys within several nature reserves in the Dowerin region, plus private property in the Wattenguttin area (TSSC 2015). No recruitment has been observed.

Acacia leptoneura monitoring data, 2008-2019 (DBCA 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 (road reserve)	2008: 1 (0) 2009: 1 (0) 2010: 1 (0) 2016: 1 (0) 2019: 1 (0)	Decreasing
2 (private property)	2010: 1 (0) 2016: 1 (0) 2019: 1 (0)	Decreasing

Habitat and ecology

Acacia leptoneura occurs on grey to brown sandy loams over laterite with calcareous white rock nearby (AVH 2020; DEC 2012). The species grows amongst degraded shrubland of *Hakea scoparia, Melaleuca* sp. and *Santalum acuminatum* (Subpopulation 1) and open mallee with *Eucalyptus leptopoda, Allocasuarina acutivalvis, A. campestris, Eremaea xcodonocarpa, M. sclerophylla* and *Hypocalymma angustifolium* (Subpopulation 2; AVH 2020; DEC 2012). Flowers have been observed in August, with fruit maturing in November and December.

Based on the ecology of *A. subflexuosa, A. leptoneura* may live for 10-15 years and is a disturbance opportunist (DEC 2012; TSSC 2015). Like other species in the genus, it is probable that fire kills adult plants but stimulates germination of soil-stored seed. Seedbank dynamics are poorly-understood. Soil-stored seed is probably not exhaustible by a single event, and therefore extreme fluctuations cannot be confirmed (IUCN 2019). It is also possible the species may re-sprout after fire (B Maslin pers.comm. 2020).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (<1 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.004 km^2) Decreasing	High High
No. of locations (key threat) Trend	1 (all threats) Decreasing	High High
No. of subpopulations Trend	2 Decreasing	High High
No. of mature individuals Trend	2 Decreasing	High High
Generation length	5 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; continuing decline projected in AOO, EOO and number of locations; and continuing decline observed in quality of habitat and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	The majority of *A. leptoneura* habitat has been cleared for agriculture, with <6% of bushland remaining in the Central Wheatbelt (Wheatbelt NRM 2015). Remaining habitat is severely fragmented, with 94% of habitat patches <10 ha (WNRM 2015). The two *A. leptoneura* plants occur in very small patches of degraded vegetation.
Lack of recruitment *Ongoing*	Whole	Rapid	High	The species has been known from only two individuals since it was relocated in 2008. No recruitment has been observed and all attempts to germinate seed *ex situ* have been unsuccessful. Fire or disturbance is probably fundamental for germination of soil-stored seed. Despite prolific flowering, very few pods have been observed on the species (wild plants and herbarium specimens), indicating that outcrossing, which is severely limited by the existence of two plants, is required for seed production (B Maslin pers.comm. 2020).
Road maintenance *Ongoing*	Whole	Rapid	High	Subpopulation 1 occurs on a narrow road verge and Subpopulation 2 occurs in a small patch of remnant vegetation surrounded by roads. At both sites the species is vulnerable to road maintenance activities including grading, herbicide drift, drainage channel construction, slashing and road realignment.
Small population size/ low genetic diversity *Ongoing*	Whole	Rapid	High	Given the species is known from two individuals, the genetic diversity is likely to be below that required to maintain a viable population. The two individuals are vulnerable to genetic effects such as inbreeding depression, and stochastic events such as prolonged drought.
Introduced herbivores *Ongoing*	Majority	Unknown	Unknown	Herbivory and ground disturbance by rabbits, and domestic stock grazing, was a past threat to Subpopulation 2, which has now been fenced. Subpopulation 1 remains unfenced and vulnerable to herbivores, however impacts on the plants are not well-documented.
Invasive weeds *Ongoing*	Whole	Unknown	Unknown	Invasive weeds (especially perennial grasses) have been documented at both subpopulations, but impacts are not well-documented.

Current management

- Recovery actions have been identified in an interim recovery plan (DEC 2012).
- The species does not occur in any conservation reserves. Local landholders are aware of the species and their conservation obligations to protect it.
- Subpopulation 2 has been fenced for many years in partnership with Greening Australia.
- Seed was collected (590) from the single roadside individual in 2012 (A Crawford pers.comm. 2020). In 2015, 100 seeds were collected from this plant and 560 from the nearby plant in remnant bushland (A Crawford pers. comm. 2020). Seed germination trials have been undertaken under controlled conditions, however all have been unsuccessful. Translocation options are very limited (D Jolliffe pers.comm. 2016).
- Targeted surveys have been conducted in several possible refuges for the species.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect known/potential habitat in appropriate conservation agreements.
- Determine mechanisms for recruitment of soil-stored seed and/or *ex situ* seed germination to facilitate augmentation of subpopulations and translocation to sites of secure tenure.

Information required

Theme	Specific actions	Priority
Population surveys	Monitor response of subpopulations to threats and management actions.	High
Ex situ conservation/translocations	Continue research into *ex situ* propagation methods. If an appropriate reserve of viable seed or cuttings is obtained, investigate methods for translocation or augmentation of naturally occurring subpopulations.	High High
Genetic diversity	Undertake research to better understand the genetic diversity of the species.	High
Lack of recruitment/inappropriate fire regimes	Undertake research to better understand the recruitment requirements of the species. Undertake research into seed viability, including the pollination mechanism and longevity of soil-stored seed. Determine the role of disturbance including fire (smoke/heat) in seed germination. Identify an optimal fire regime to increase the abundance of the species.	High High High Medium

Management actions required

Theme	Specific actions	Priority
Lack of recruitment/inappropriate fire regimes	Trial planned burn nearby extant individuals of *A. leptoneura* to determine whether this will trigger natural regeneration. If successful, strategically expand area where planned burns are applied ensuring mature individuals are not burnt.	High
Ex situ conservation/translocations	Collect seed and propagate plants from extant individuals and new recruits (if burn trial successful) with view to reinforce natural subpopulations. When feasible, reinforce wild subpopulations with propagated individuals to increase population abundance, and implement translocations into secure suitable habitat.	High High
Habitat protection	Protect known habitat of the species on private land in appropriate conservation agreements.	High
Grazing	Continue to exclude herbivores from Subpopulation 2, and investigate options for excluding herbivores from Subpopulation 1.	High
Invasive weeds	Manage any invasive weeds within the subpopulations and habitat of the species, particularly after disturbance.	Medium
Extension and awareness	Maintain engagement with relevant landholders that are custodians of the species. Raise awareness with other stakeholders in the area in an attempt to locate additional subpopulations.	Medium

Experts consulted

Bree Phillips, Andrew Crawford, Tanya Llorens and Bruce Maslin.

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Acacia pharangites Maslin [FABACEAE]
Wongan gully wattle

Acacia pharangites (clockwise from top left) inflorescences, habitat at Wongan Katta (Wongan Hills; images: Joel Collins) and seedpods (image: Andrew Crawford).

Overview

Acacia pharangites is known from two subpopulations at Wongan Katta (Wongan Hills) in the Avon Wheatbelt and has undergone a recent decline as mature individuals senesce in the absence of recruitment. Recruitment has been observed following a small burn and localised flooding, indicating the species depends on disturbance for population maintenance. The main subpopulation occurs on private land where implementation of suitable fire regimes is limited due to the inaccessible habitat and lack of firebreaks.

Conservation status

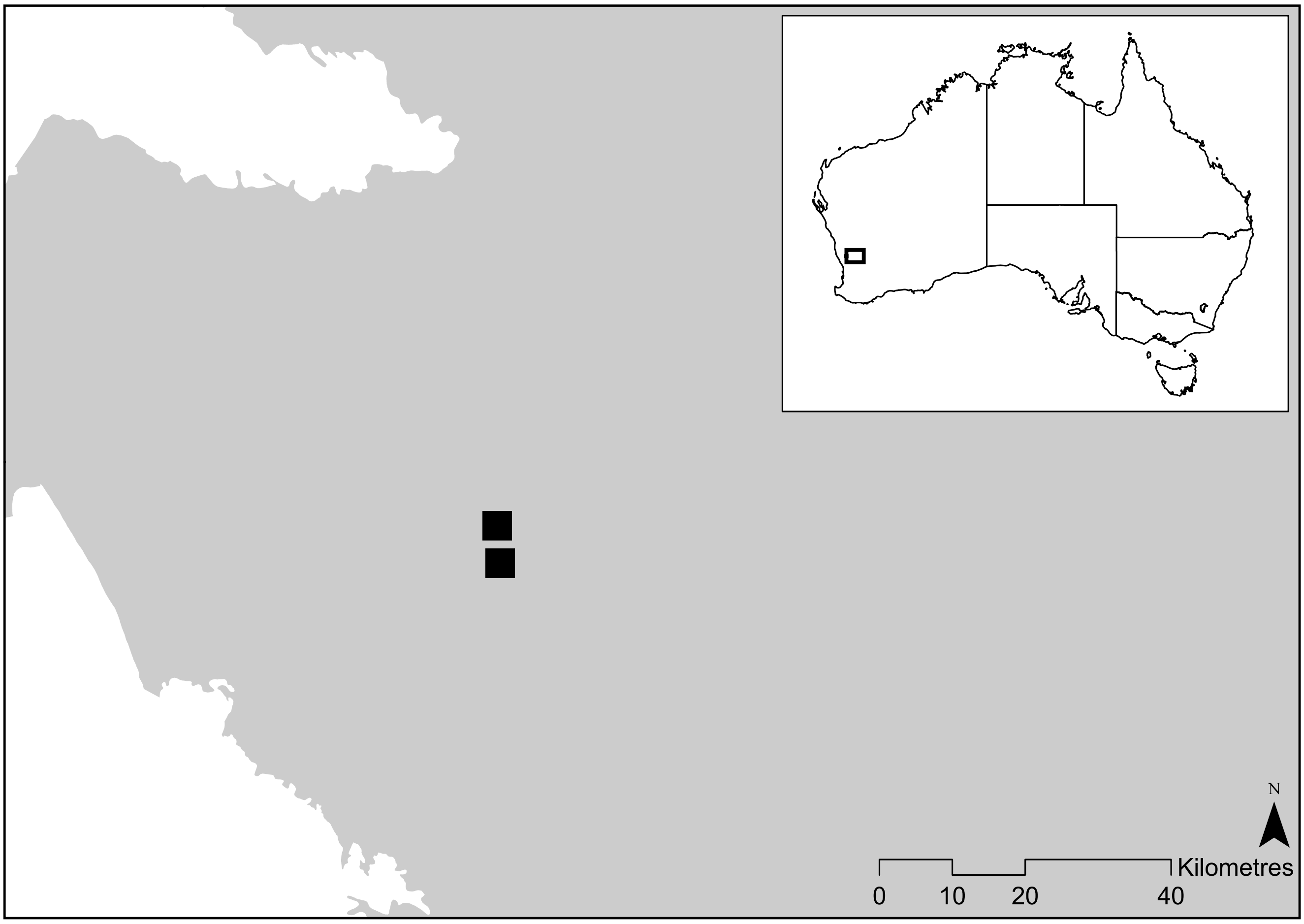
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Spindly, erect shrub to 4 m high with slightly rough grey bark (Maslin 1982). Branches have a thick, waxy and powdery coating towards the ends and raised stem projections/scars where phyllodes have fallen. Phyllodes are erect, straight to shallowly-curved, circular in cross-section, 15-40 mm long and 1 mm wide. Inflorescences comprise 1-2 reduced racemes with approximately 25 golden flowers. Fruit are linear hairless pods to 7 cm that are strongly raised over the seeds (Maslin 1982).

Distribution

Acacia pharangites is known from a very narrow range near Wongan Katta (Wongan Hills) within the Avon Wheatbelt bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Biodiversity, Conservation and Attractions 2020; Department of Agriculture, Water and the Environment 2012).



Current distribution of *Acacia pharangites* (black squares) in the Avon Wheatbelt bioregion (shaded grey) of south-western Western Australia (AVH 2020; DAWE 2012; DBCA 2020).

Population estimate and trends

Acacia pharangites is currently known from two subpopulations. The species was first collected in 1976, and comprised 329 individuals when surveyed in 1980 and 333 in 1988 (AVH 2020; Department of Environment and Conservation 2009). In 1992, only 11 plants were recorded, increasing to 137 in 2001 and declining to eight in 2019 (DBCA 2020). A separate smaller subpopulation of 26 plants was found in 2005, but only five plants were recorded in 2015 (DBCA 2020; DEC 2009). Targeted surveys in surrounding areas have not located additional subpopulations.

Acacia pharangites monitoring data, 1980-2019 (DBCA 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1* Wongan Katta (Wongan Hills) (private property)	1980: 329 1988: 333 1992: 11 1997: 20 1999: 36 2000: 107 2001: 137 (1) 2004: 44 2007: 23 2019: 8 (31)	Decreasing
2 Wongan Hills Nature Reserve (nature reserve)	2005: 26 2013: 11 2014: 7 2015: 5	Decreasing

*Includes four sites.

Habitat and ecology

Acacia pharangites occurs on highly restricted greenstone-derived soils at Wongan Katta (Wongan Hills). The main subpopulation occurs in a sheltered gully along a seasonally dry creek, while the smaller subpopulation occurs on a ridgetop (B Phillips pers.comm. 2019). Associated species include *A. acuminata, A. congesta, Allocasuarina campestris, Calothamnus quadrifidus* subsp. *asper* and *Melaleuca radula*. Flowering occurs between August and November.

Acacia pharangites relies on disturbance to stimulate germination of soil-stored seed, with recruitment recorded after fire and flooding (B Phillips pers.comm. 2019). Subpopulations are typically even-aged cohorts approaching senescence without juvenile plants, although in more open habitat, juvenile plants have been recorded around a dead adult (A Crawford pers.comm. 2020). At one subpopulation, fire stimulated germination of four sown seeds, but soil-stored seed did not respond, indicating that it may not remain viable over long periods (B Phillips pers.comm. 2019).

The population abundance of *A. pharangites* fluctuates between life stages as the persistent seedbank germinates *en masse* following disturbance, and the single-aged cohorts eventually reach senescence and die. However, the seedbank is probably not exhaustible by a single event, and therefore extreme fluctuations cannot be confirmed (IUCN 2019). Longevity of the species is unknown, but individuals may live for up to 10 years based on monitoring data, and therefore generation length is likely <5 years.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	8 km^2 (<0.9 km^2) Decreasing	High High
Area of occupancy (actual) Trend	8 km^2 (0.5 km^2) Decreasing	High High
No. of locations (key threat) Trend	2 (lack of disturbance) Stable	High High
No. of subpopulations Trend	2 Stable	High High
No. of mature individuals Trend	13 Decreasing	High High
Generation length	<5 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented; continuing decline projected in AOO, EOO and number of locations; and continuing decline observed in quality of habitat and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Approximately 95% of vegetation has been cleared for agriculture within the species' distribution (DEC 2009). The species is considered severely fragmented as all subpopulations are small and occur in isolated remnants.
Lack of disturbance (fire, flood) *Ongoing*	Whole	Rapid	High	Recruitment is stimulated by disturbance (has been observed following fire and flooding) and is currently insufficient to maintain population abundance. The population declined from 333 in 1988 to 13 mature individuals by 2019 as mature individuals senesced. Fire is difficult to implement as there are no robust firebreaks to contain fire spreading into farmland. *Acacia pharangites* occurs at two locations when assessed against this threat as delineated by land tenure, which determines fire management.
Domestic stock grazing *Ongoing*	Majority	Negligible	Negligible	One subpopulation occurs on private property and grazing has been observed, although the impact of this threat has not been quantified (DEC 2009). Monitoring of seedlings indicated that grazing does not limit seedling growth post-recruitment (B Phillips pers.comm. 2019).
Seed predation *Ongoing*	Whole	Unknown	Unknown	Seed predation has been observed, although the impact of this threat has not been quantified (DEC 2009).

Current management

- Recovery actions have been identified (DEC 2009).
- One subpopulation is protected in Wongan Hills Nature Reserve while the other is on private grazing land.
- Seed has been collected and held by the Western Australian Seed Centre.
- The species forms part of the living collection at Kings Park and Botanic Gardens, with 27 plants from seven clones (nine plants in the Conservation Garden and 18 in the nursery collection).
- Recruitment trials have been undertaken, indicating fire stimulates recruitment, although germination occurred from sown seed rather than seed naturally occurring in the seedbank (B Phillips pers.comm. 2019). Seedlings were not impacted by grazing after germination, indicating grazing does not limit post-recruitment growth (B Phillips pers.comm. 2019). A prescribed burn is planned at the nature reserve population within the next 5 years.

- Seedlings have been caged at multiple sites to protect against grazing with ongoing monitoring.
- Juvenile plants are being monitored to determine the time to reproductive maturity (B Phillips pers.comm. 2019).
- Engagement with relevant landholders has been undertaken to ensure obligations to protect the species are understood.

Conservation objectives

- Monitor and maintain known subpopulations.
- Detect more subpopulations through targeted surveys.
- Protect known/potential habitat in appropriate conservation agreements.
- Increase and maintain population abundance at both sites via a fire management plan, with controlled burns at suitable intervals and intensities to stimulate seedling recruitment.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and fire ecology. The length of time soil-stored seed can remain viable is of particular relevance.	High
Ex situ conservation/translocations	Identify sites of suitable habitat with secure tenure for establishing translocated populations.	High
Population surveys	Monitor response of subpopulations to threats and management actions.	High
	Undertake targeted surveys in other suitable habitat to locate additional subpopulations, particularly after disturbance.	Medium

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect habitat of the species on private land in appropriate conservation agreements.	High
Ex situ conservation/translocations	Propagate individuals in an *ex situ* collection to support future translocation efforts. Ensure collection represents maximum range of genetic diversity possible.	High
	Augment wild subpopulations with propagated individuals to increase population abundance, and implement translocations to secure suitable habitat.	High
Lack of recruitment/ inappropriate fire regimes	Implement and maintain a fire management strategy to promote recruitment at both subpopulations.	High
Grazing	Reduce grazing pressure by domestic stock/ native herbivores via fencing or other suitable methods, particularly after disturbance.	Medium
Invasive weeds	Manage any invasive weeds within the subpopulations and habitat of the species, particularly after disturbance.	Medium
Extension and awareness	Maintain engagement with relevant landholders that are custodians of the species. Raise awareness with other stakeholders in the area in an attempt to locate additional subpopulations.	Medium

Experts consulted

Bree Phillips, Andrew Crawford and Tanya Llorens.

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Acacia volubilis F.Muell. [FABACEAE]
Tangled wattle, tangle wattle



Acacia volubilis yellow inflorescences and 'tangled' phyllodes (top left), seed (right; images: Andrew Crawford), and individual persisting along a narrow road verge (bottom left; image: Joel Collins).

Overview

Acacia volubilis occurs in small, fragmented subpopulations, predominantly along degraded roadsides. Plants are long-lived and have very low seed production, but germination of soil-stored seed has been observed in areas where mechanical disturbance has occurred. Translocations have been implemented with some success and are considered the only long-term recovery option given the tenuous habitat.

Conservation status

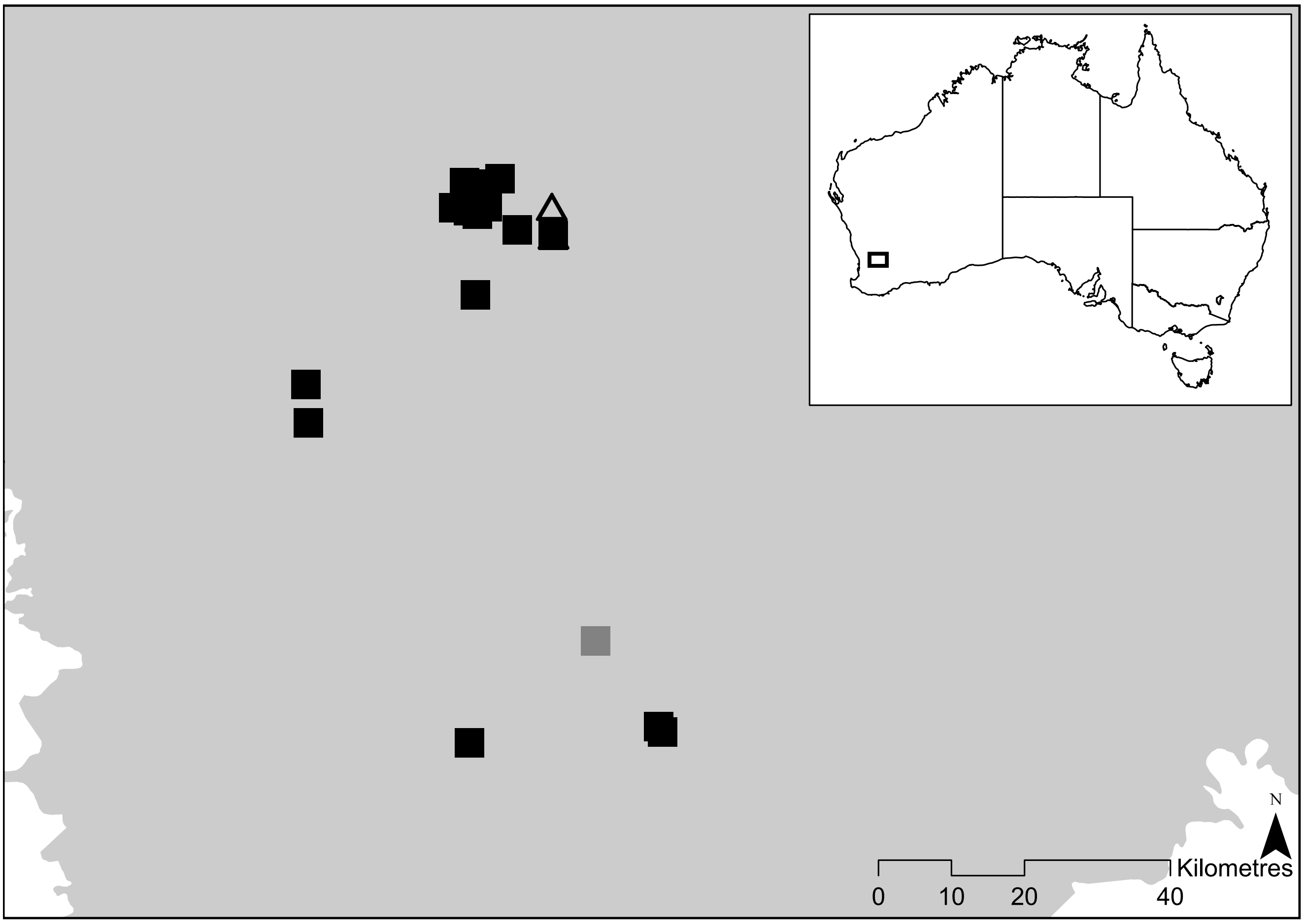
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Small dome-shaped shrub to 1 m tall and 40 cm wide with twisted, ridged branches (Harris and Brown 2003). Phyllodes are few and distant to 9 mm long and 1 mm wide, are curved or straight and resemble branchlets (Maslin 2001). Each phyllode has 5 nerves with a prominent mid-rib (Maslin 2001). Inflorescence is globular and relatively large, with 10-17 yellow flowers (Maslin 2001). Fruit are red-brown curved pods to 3 cm long and 2-3 mm wide, seeds are conical with a terminal aril (Harris and Brown 2003).

Distribution

Acacia volubilis is known from a very restricted distribution in the Cunderdin-Tammin area of the Avon Wheatbelt bioregion in south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current (black squares) and historic (grey square) distribution of *Acacia volubilis* including a translocated subpopulation that is not yet self-sustaining (hollow triangle) in the Avon Wheatbelt bioregion (shaded grey) of south-western Western Australia (AVH 2020; DAWE 2012; DBCA 2020; Silcock *et al.* 2019).

Population estimate and trends

Acacia volubilis was described by Mueller in 1877 from a specimen collected by Julia Wells from 'Boxvale', probably near Quairading (AVH 2020; Maslin 1995). The species was presumed extinct until it was relocated near Cunderdin in 1996 (Harris and Brown 2003). By 2003, *A. volubilis* was known from 94 individuals over 11 subpopulations. Additional subpopulations were located during subsequent surveys, and the species is currently known from 182 mature individuals in 17 subpopulations (DBCA 2020). There are also 40 mature individuals surviving in one translocated subpopulation, which has had multiple plantings (238 plants) since 2004 (Silcock *et al.* 2019). Recruitment is minimal, but can occur clonally via root suckering and from seed, although seed-set is very low (Harris and Brown 2003). Targeted surveys have been conducted within the range of the species and it is unlikely additional subpopulations will be found.

Acacia volubilis monitoring data, 1996-2018 (DBCA 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1* N of Cunderdin (shire road reserve)	1996/7: 8 (1) 2001: 5 (2) 2010: 9 2012: 8 2016: 50	Increasing (roadside disturbance – habitat in poor condition)
2* N of Cunderdin (shire road reserve/private property)	1997: 20 1998: 34 2001: 24 2003: 34 2010: 32 2012: 29 2017: 24 (2) 2018: 7	Decreasing
3 N of Cunderdin (shire road reserve)	1997: 5 2000: 8 2001: 6 2005: 11 (6) 2010: 23 2012: 24 (4) 2016: 8	Decreasing
4 N of Cunderdin (shire road reserve)	1997: 1 2000: 1 2005: 1 2010: 0 2012: 0	Decreasing
5 N of Cunderdin (only data for subpopulation 5A shown) (shire road reserve)	1997: 20 2000: 34 (2) 2005: 40 (10) 2010: 78 2012: 78 (9) 2016: 52 2017: 51 (3)	Decreasing (with fluctuations)
6 SW of Cunderdin (shire road reserve)	1998: 1 2000: 1 2001: 1 2010: 2 2016: 14	Increasing (roadside disturbance – poor condition)
7 NE of Cunderdin (shire road reserve)	2000: 4 2005: 5 2008: 3 2010: 6 2012: 2	Stable
8* NE of Cunderdin (shire road reserve and private property)	2005: 4 2010: 6 2012: 6	Stable
8 (T^) NE of Cunderdin (nature reserve)	2006: 10T 2010: 38T 2012: 34T 2019: 40T (26T)	Stable, but not yet self-sustaining
9 NE of Cunderdin (shire road reserve)	2000: 3 2010: 3 2012: 6	Stable

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
10 N of Cunderdin (shire road reserve)	2001: 1 2010: 0 2012: 0 2017: 0	Decreasing
11 N of Cunderdin (shire road reserve)	2001: 3 2010: 14 2012: 8 2017: 8 (1)	Decreasing
12 NE of Cunderdin (shire road reserve)	2005: 3 2006: 13 2008: 4 2010: 4 2012: 2	Decreasing
13 S of Cunderdin (shire road reserve)	2007: 3 2010: 12 2012: 13 2016: 11 2018: 12	Stable
14 SW of Cunderdin (shire road reserve)	2009: 1	Unknown
15 SE of Cunderdin (shire road reserve)	2009: 4 2018: 10	Unknown
16 SE of Cunderdin (shire road reserve)	2009: 4 2011: 4 2016: 3	Decreasing
17 N of Cunderdin (road reserve)	2011: 2 2013: 2 2017: 2	Decreasing

Translocated individuals/subpopulations (T). *Within Subpopulations 1, 2 and 8 there are several separate sites; data has been presented where counts are available for all sites within a year. ^Multiple plantings have been made at this site, totalling 238 individuals since 2004.

Habitat and ecology

Acacia volubilis occurs in mallee shrubland and heath over laterite or sheet granite in variable soils of brown, red, yellow or grey sandy loams to loamy clays (Harris and Brown 2003). Associated species include *Allocasuarina humilis*, *Callitris arenaria, Daviesia cunderdin, Grevillea hookeriana*, *Hakea* spp. and *Leptospermum erubescens*.

Flowering occurs between June and July and is typically abundant, although no pollination has been observed during surveys (Harris and Brown 2003). Immature pods often accumulate beneath plants further indicating a lack of pollination. Low seed-set may reflect the long life-span of the plant (D Jolliffe pers.comm. 2017), which is also known to reproduce clonally via rhizomes (Harris and Brown 2003). Seed viability has been very high (100%) under laboratory conditions, and natural germination of soil-stored seed has been observed in recently graded and burnt areas. Seed dispersal appears to be localised, with new recruits often beneath parent plants (Harris and Brown 2003). Extreme fluctuations in mature individuals are unlikely as adults can probably re-sprout following fire, and there is also a persistent seedbank (IUCN 2019). The generation length of *A. volubilis* is not known, but is likely to be long (>15 years).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	2255 km^2 Decreasing	High High
Area of occupancy (actual) Trend	60 km^2 (<1 km^2) Decreasing	High High
No. of mature individuals Trend	182 (+40T translocated) Decreasing	Medium High
No. of locations (key threat) Trend	17 (lack of disturbance) Decreasing	High High
No. of subpopulations Trend	17 (+1T translocated) Decreasing	High High
Generation length	<15 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	EN: EOO <5000 km^2; AOO <500 km^2; severely fragmented; and continuing decline observed and projected in EOO, AOO, area/extent/quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(ii)	CR: <250 mature individuals; continuing decline observed and <50 mature individuals in each subpopulation. N.B: Subpopulation 5 has had >50 plants since 2010 (51 in 2017) due to recruitment following mechanical disturbance, but habitat condition is extremely poor with high levels of disturbance and ongoing clearing risk, meaning that imminent declines in this subpopulation are likely (T Llorens pers.comm. 2020).
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture has resulted in the decline and fragmentation of available habitat for the species, with 97.4% of vegetation in the Cunderdin Shire being cleared (Godfrey *et al.* 2003). *Acacia volubilis* is considered severely fragmented as all subpopulations are very small and isolated by cleared land.
Mining *Past*	n/a	n/a	n/a	One subpopulation occurs on the edge of a disused sand mine.
Lack of recruitment/ inappropriate disturbance regimes *Ongoing*	Whole	Rapid	High	Recruitment is low across all subpopulations although germination and juvenile plants have been observed after fire and grading. Disturbance appears essential for population maintenance. The species occurs at 17 locations when assessed against this threat, which can be managed at the subpopulation scale, according to land tenure.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Infrastructure maintenance *Ongoing*	Majority	Rapid	Medium	Most subpopulations occur on degraded road reserves and activities including grading, chemical spraying, drainage channel construction and mowing can damage mature individuals and prevent recruitment. Several subpopulations were damaged during road maintenance and fence construction during 1998 and 2001 (Harris and Brown 2003). Plants have been sprayed by herbicide during weed control on a number of occasions (Godfrey *et al.* 2003; B Phillips pers.comm. 2020).
Invasive weeds *Ongoing*	Whole	Slow	Medium	All subpopulations are small and occur in degraded habitat surrounded by farmland that facilitates weed invasion. Invasive weeds can increase competition and alter fuel loads.
Absence of pollinators *Ongoing*	Whole	Slow	Medium	All subpopulations are small and occur in degraded habitat patches with little other native vegetation. Lack of recruitment may be associated with low pollination rates as native pollinators are infrequent or absent throughout the range of the species.
Deliberate destruction *Ongoing*	Minority	Very rapid	Medium	A landholder allegedly destroyed plants in one subpopulation; this is still under investigation (B Phillips pers.comm. 2020).
Browsing (feral, native, domestic) *Ongoing*	Majority	Slow	Medium	Browsing by rabbits, macropods and domestic stock limits plant growth, especially for juveniles. Some subpopulations have been fenced.

Current management

- Recovery actions have been identified (Harris and Brown 2003).
- Relevant stakeholders have been notified of the species' presence and their conservation obligations. Markers have been installed at roadside subpopulations to avoid damage during infrastructure maintenance activities.
- Some subpopulations on private property have been fenced to exclude browsers. Baiting has been undertaken to control rabbits.
- Seeds (991) from five subpopulations are stored in the Western Australian Seed Centre, Threatened Flora Vault. Germination trials have been undertaken.
- Translocation to private property commenced in 2004 with plants propagated from seed and cuttings. Subsequent plantings were undertaken in 2006, 2010, 2013 and 2018. Seedlings were fenced and watered for all plantings. Overall survival was 22% (40 mature individuals) in 2019.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat outside road reserves in conservation agreements. Increase the area of potential suitable habitat in conservation estate.
- Increase habitat quality of all known subpopulations, especially factors that may increase pollinator abundance.
- Establish self-sustaining translocated subpopulations in secure land tenure.
- Increase the number of mature individuals and subpopulations in the wild.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production limitations, germination requirements and habitat suitability for translocations. Mechanisms influencing the quantity of seed produced are of particular importance.	High
Ex situ conservation/translocations	Undertake research to better understand factors that increase survivorship of translocated plants.	High
	Investigate options for additional translocations to secure and suitable land tenure.	High
Inappropriate disturbance regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High
Population surveys	Monitor subpopulations to determine response to threats and management actions.	High
	Targeted surveys in historic locations and other suitable habitat to locate additional subpopulations, especially after disturbance.	Medium

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect subpopulations on private land in appropriate conservation agreements.	High
	Increase the area of suitable/potential habitat in conservation estate.	High
Inappropriate disturbance regimes	Implement suitable disturbance to promote generation of seed to maintain/increase population abundance. Control invasive weeds and herbivores post-disturbance.	High
Habitat quality	Improve habitat quality and connectivity for remnant subpopulations via revegetation, invasive weed and rabbit control and fencing.	High
Ex situ conservation/translocations	Continue to collect and store seed for propagation, representing maximum range of genetic diversity possible.	High
	Continue propagation program to support ongoing translocation efforts.	High
Extension and awareness	Raise awareness of the species and its habitat with relevant stakeholders in an attempt to locate additional subpopulations and protect existing subpopulations.	Medium

Experts consulted

Bree Phillips, Andrew Crawford, Leonie Monks and Tanya Llorens.

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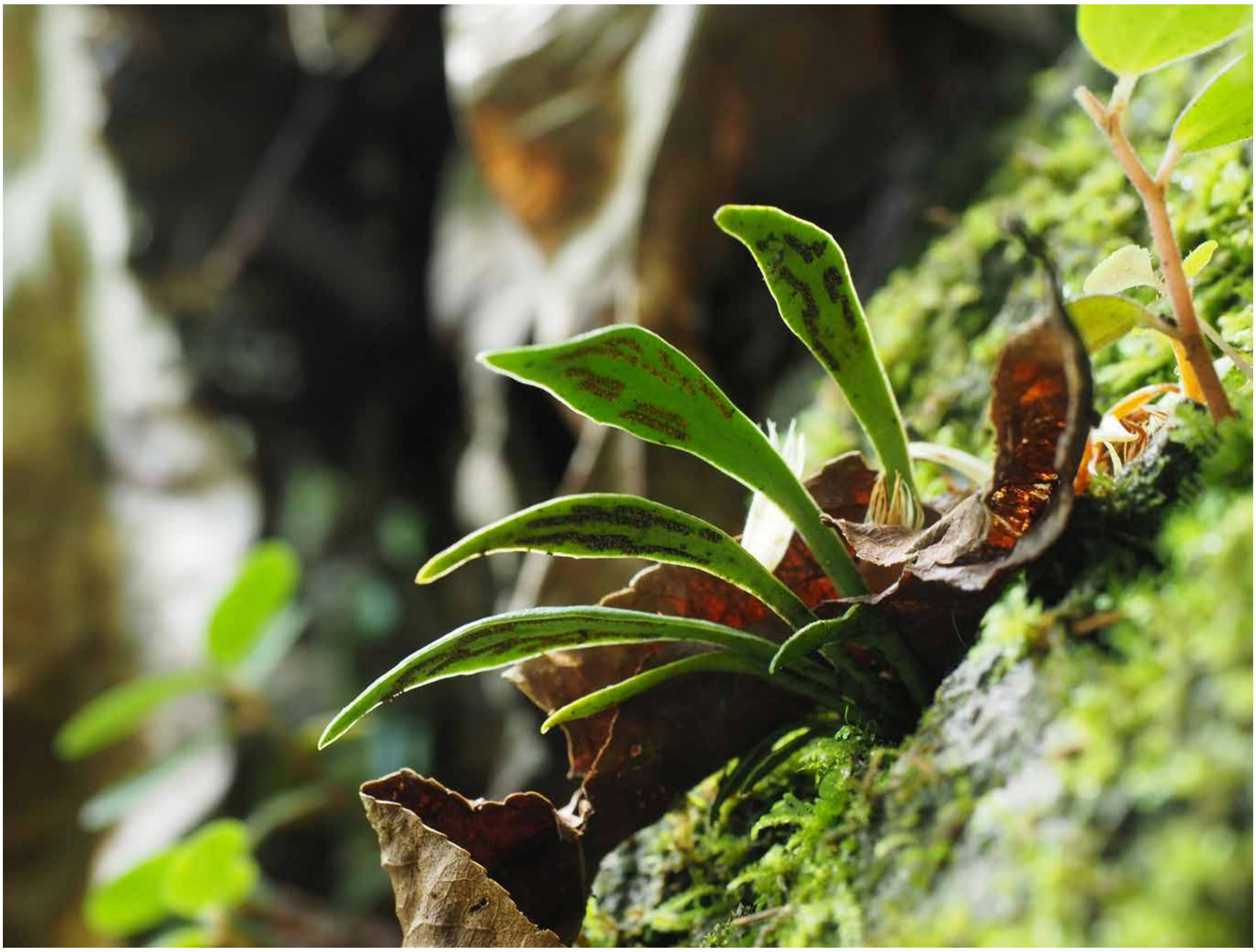
Antrophyum austroqueenslandicum D.L.Jones [PTERIDACEAE]
Border ranges lined fern, Lamington ox tongue fern



Antrophyum austroqueenslandicum, showing the diagnostic sporangia pattern along the lateral veins of fronds (image: Lui Weber).

Overview

Antrophyum austroqueenslandicum was considered extinct until it was relocated in 2015. The species is cryptic, but appears to have very specific habitat requirements that have been useful in locating two additional subpopulations. However, additional intensive searches indicate the species and its habitat are exceedingly rare. If the threat of illegal collection can be controlled, the species would benefit from re-introduction to its type locality at Yerralahla (Blue Pool) in Woonoongoora (Lamington National Park).

Conservation status

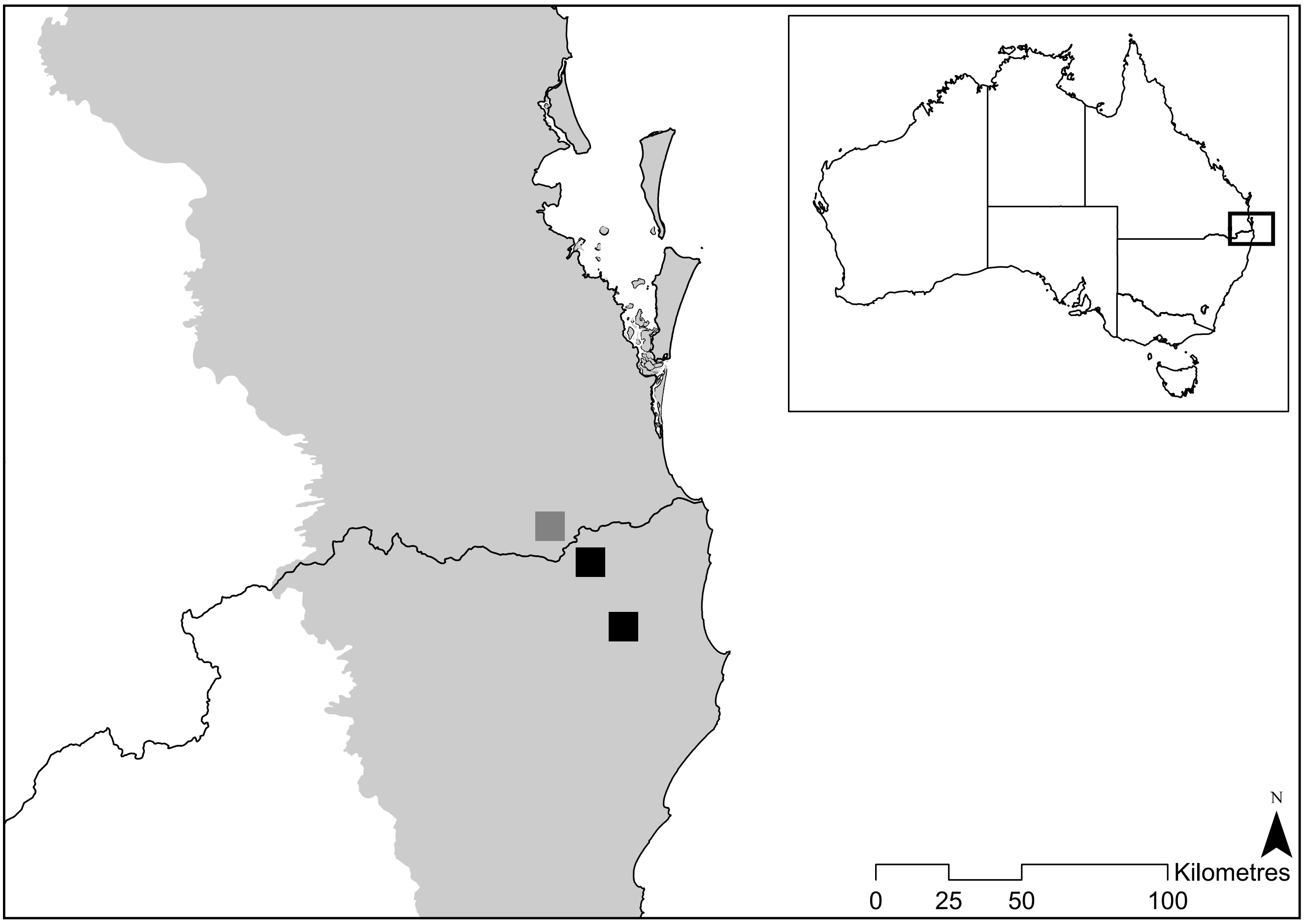
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016 (NSW)	Not listed
Nature Conservation Act 1992 (Qld)	Extinct in the Wild
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Epiphytic or lithophytic fern with small fronds that have a prominent, narrow winged stripe 2-7 cm long (Jones 1998). Short sori occur on the lateral veins (Jones 1998). The oblanceolate shape of the fronds, lacking lobes, and the diagnostic sporangia pattern following veins on the underside of fertile adult fronds are distinctive and mean that the species is unlikely to be confused with other ferns (L Weber pers.comm. 2016). This species is the only sub-tropical member of the genus.

Distribution

Antrophyum austroqueenslandicum is known from a very narrow range near Tyalgum, Woonoongoora (Lamington National Park) and the Nightcap Range in the South Eastern Queensland bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Queensland Herbarium 2020; L Weber pers. comm. 2020).



Current (black squares) and historic (grey square) distribution of *Antrophyum austroqueenslandicum* in the South Eastern Queensland bioregion (shaded grey) of Queensland and New South Wales (AVH 2020; DAWE 2012; QH 2020; L Weber pers.comm. 2020).

Population estimate and trends

Antrophyum austroqueenslandicum is currently known from ca. 47 mature individuals over three sites. In 1983, less than 5 individuals were recorded growing on rocks at Yerralahla (Blue Pool) in Woonoongoora (Lamington National Park) (AVH 2020; Queensland Herbarium 2020). Most of these are thought to have been collected by fern enthusiasts, with the last known plant dying *in situ* (P Bostock pers.comm. 2019). Despite searching, no additional plants were found and it was listed as Extinct under Queensland's *Nature Conservation Act 1992* in 2006.

In 2015, 65 individuals were recorded on a single boulder 8.5 km away at Tyalgum (NSW), on freehold land under a conservation agreement. Only 34 individuals remain, with juveniles accounting for most of the losses (L Weber pers. comm. 2020). Targeted surveys revealed another subpopulation of eight individuals in 2017, and five more were located 2 km away on private property in 2019 (L Weber pers.comm. 2020). The species is cryptic and habitat can be remote, indicating additional subpopulations probably occur. However, the absence of the species even within suitable habitat (which is also uncommon) indicates *A. austroqueenslandicum* is extremely rare (L Weber pers. comm. 2020).

Antrophyum austroqueenslandicum monitoring data, 2015-2019 (L Weber and J Mallee, unpublished data; QH 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Yerralahla (Blue Pool) (national park)	1986: present 2006: 0 2019: 0	Presumed extinct
2 Tyalgum (private property)	2015: 55 (incl. juveniles) 2016: 65 (incl. juveniles) 2018: 46 (incl. juveniles) 2020: 34 (most are mature)	Decreasing
3 Mt Jerusalem (national park)	2017: 8 (20 mid-aged + 30 juveniles) 2019: 8 (20 mid-aged + 30 juveniles) 2020: 8 (7 mid-aged)	Decreasing
4 Nightcap Range (private property)	2019: 5 2020: 5	Unknown

Habitat and ecology

Antrophyum austroqueenslandicum occurs on naturally restricted andesite boulders in lowland subtropical rainforest (L Weber pers.comm. 2019). Associated species include *Asplenium australasicum, A. harmanii, Psilotum nudum* and *Microsorum scandens. Antrophyum austroqueenslandicum* apparently requires a highly-specific micro-climate of sunlight, moisture and nutrients (L Weber pers.comm. 2019). The species grows in areas with high humidity; adjacent to streams, gullies or springs, with one record as a tree epiphyte (L Weber pers.comm. 2019; P Bostock pers. comm. 2020). The absence of *A. austroqueenslandicum* in many areas of apparently suitable habitat may be due to inundation by floodwater, which is known to dislodge and kill plants (L Weber pers.comm. 2019).

As with other ferns, *A. austroqueenslandicum* has a sporophyte and gametophyte generation, but the generation length is unknown. It is possible the gametophyte stage can persist in the absence of mature individuals, but duration is unknown. Spores of most ferns are desiccation resistant (e.g. Lopez-Pozo *et al.* 2019), and therefore extreme fluctuations are not likely. Moisture is required for fertilisation and dispersal, with the very small spores dispersed long distances by wind and water. Although naturally fragmented in small subpopulations, the species has highly dispersive spores and occurs in relatively intact habitat so is not considered severely fragmented (IUCN 2019).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	21 km^2 Decreasing	Medium High
Area of occupancy (actual) Trend	12 km^2 (0.001 km^2) Decreasing	Medium High
No. of mature individuals Trend	47 Decreasing	Medium High
No. of locations (key threat) Trend	1 (drought/climate change) Stable	Medium Medium
No. of subpopulations Trend	3 Stable	Medium Medium
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	No	Medium
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented and 1 location; and continuing decline observed and projected in EOO, AOO, area, extent and quality of habitat, number of locations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Habitat conversion due to agriculture has caused changes to hydrology and promoted the spread of invasive weeds that negatively impact the fine-scale habitat niche of this species.
Illegal collection *Suspended*	Majority	Very rapid	Medium	Illegal collection from Yerralahla (Blue Pool) is thought to be responsible for the species' local extinction at this site. Considering the rarity of the species, all subpopulations remain vulnerable to this threat, although there is no evidence that collection is currently occurring, and two subpopulations occur on private property.
Drought/climate change *Ongoing*	Whole	Rapid	High	Forty-three individuals were lost due to drought from 2019-2020, mostly juveniles (L Weber pers.comm. 2020). A fire burnt within 30 m of the subpopulation in Mt Jerusalem NP in 2019 (L Weber pers.comm. 2020). Given the species' highly specific microclimate requirements, climate change is considered a threat to all subpopulations simultaneously (one location) if it results in a reduction in annual average rainfall, more extreme droughts, more extreme fire weather and/or extreme flood events. Extreme rainfall, drought and fire weather are projected to increase with high certainty in the region over the next 100 years (Dowdy *et al.* 2015).
Infrastructure maintenance *Ongoing*	Majority	Rapid	Medium	The Tyalgum subpopulation occurs near a roadside and is vulnerable to road widening and associated maintenance activities. The subpopulation located in Mt Jerusalem NP is vulnerable to herbicide drift associated with infrastructure maintenance (L Weber pers.comm. 2019).
Invasive weeds *Ongoing*	Majority	Rapid	Medium	Weeds, especially lantana invade the habitat of *A. austroqueenslandicum* and alter the micro-climate required by the species by shading and altering fuel loads and thus fire regimes (L Weber pers.comm. 2019). Invasive weeds are an important threat for the subpopulation at Nightcap Range (L Weber pers.comm. 2019).
Stochastic events *Ongoing*	Whole	Rapid	Medium	This species occurs along watercourses and therefore may be adversely affected by random flooding events. Individuals have been lost during flood events (L Weber pers. comm. 2019).

Current management

- There is no recovery plan for this species.
- This species is protected within Mt Jerusalem NP and on private land managed for conservation at Tyalgum.
- There is ongoing weed management and monitoring by the landholders at the Tyalgum subpopulation (L Weber pers.comm. 2019).

Conservation objectives

- Monitor and maintain known subpopulations.
- Reduce the collective impacts of threatening processes on the species.
- Detect more subpopulations through targeted surveys.
- Increase the number of subpopulations in the wild via translocation into suitable habitat and reintroduction to the type locality.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the life history and ecology of the species including genetic diversity, disturbance responses, reproductive requirements and habitat requirements. Information regarding habitat requirements will be informative for managing extant subpopulations and guiding translocation efforts.	High
Ex situ conservation/translocations	Undertake research to determine propagation and germination methods.	High
	Establish a genetically representative conservation collection, with view to propagate individuals for ongoing translocation program (if feasible).	High
	Undertake surveys to identify potential suitable habitat for translocations into secure tenure.	High
Population surveys	Monitor known subpopulations to determine trends in response to recovery actions and threats.	High
	Undertake targeted surveys within suitable habitat to locate additional subpopulations.	Medium

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Trial propagation to establish a genetically-representative *ex situ* collection.	High
	Propagate sufficient individuals to augment extant subpopulations and undertake translocations.	High
	Plan and implement translocation program to re-establish population at Yerralahla (Blue Pool) and other suitable habitat within the species' range.	High
Habitat protection	Protect known habitat on private land in appropriate conservation agreements.	High
Invasive weeds	Manage invasive weeds at known subpopulations in conjunction with private landholders and National Park rangers.	High
Extension and awareness	Establish/ maintain engagement with private landholders where the species occurs to ensure management activities are appropriate for the species.	High
	Raise awareness of the species with relevant stakeholders in an attempt to find more subpopulations.	High

Experts consulted

Lui Weber, Justin Mallee, Peter Bostock and Gavin Phillips.

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Ballantinia antipoda (F. Muell.) E.A. Shaw [BRASSICACEAE]
Southern shepherds purse, southern ballantine, ballantine


Ballantinia antipoda flowers and foliage (left; image: Neville Walsh) and forming mats in shallow soils on Leanganook (Mt Alexander; right; image: Paul Foreman).

Overview

Ballantinia antipoda is a monotypic endemic historically known from numerous locations in Victoria and a single subpopulation in Tasmania. The species is now presumed extinct in Tasmania and restricted to Leanganook (Mt Alexander) in central Victoria. This cryptic plant undergoes extreme population fluctuations in response to seasonal conditions, but the number of subpopulations continues to decline and its range is contracting. Reasons for decline are not well-understood, but the species occurs in a highly disturbed area with a predicted drying trend under climate change.

Conservation status

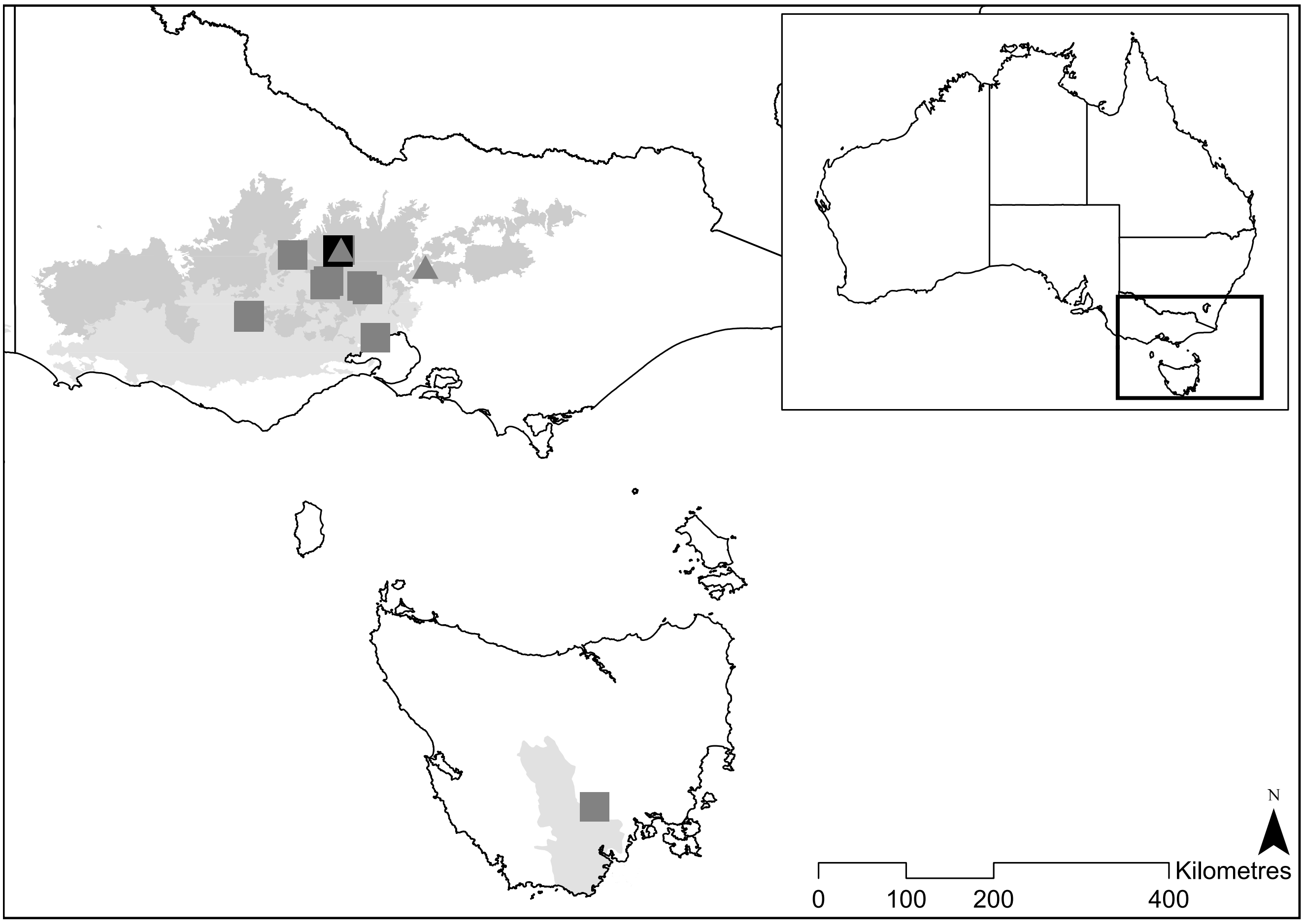
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Flora and Fauna Guarantee Act 1988 (Vic)	Threatened
Advisory list of Rare or Threatened Plants in Victoria	Endangered
Threatened Species Protection Act 1995 (Tas)	Extinct
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Cryptic, prostrate annual herb to 10 cm with sparsely-hairy stems that arise from a rosette of spoon-shaped basal leaves (Hewson 1982). Leaves along stem are dentate or entire (Hewson 1982). White flowers occur on stalks 5-10 mm long arranged in racemes or corymbs. Sepals to 1 mm long and petals to 2 mm long. Fruit elliptical and 3-5 mm long, with ellipsoidal, compressed seeds 1 mm long (Hewson 1982). *Ballantinia antipoda* is the only species in its genus.

Distribution

Ballantinia antipoda historically occurred in the Southern Volcanic Plain and Victorian Midlands bioregions of Victoria, with two records from the 1840s in the Tasmanian Southern Ranges bioregion (Department of Agriculture, Water and the Environment 2012; Department of Environment, Land, Water and Planning 2020; Australasian Virtual Herbarium 2020). The species is now absent across much of its former range and is restricted to Leanganook (Mt Alexander) in the Victorian Midlands of central Victoria.



Current (black square) and historical (grey squares) distribution of *Ballantinia antipoda* in the Victorian Midlands (shaded dark grey) and Southern Volcanic Plain (shaded light grey) bioregions of Victoria, and the Tasmanian Southern Ranges bioregion (shaded light grey) in Tasmania (AVH 2020; DAWE 2012; DELWP 2020). Translocations have been undertaken but have been unsuccessful (grey triangles; Silcock *et al.* 2019).

Population estimate and trends

Ballantinia antipoda was presumed extinct until 1983, when 19 sites were located at Leanganook (Mt Alexander) (Nevill and Camilleri 2010). The species is currently known from 10 subpopulations at this site (P Foreman pers.comm. 2020). *Ballantinia antipoda* forms mats and these 'patches' are considered a more meaningful estimate of abundance rather than the number of individuals. The most current population estimate is 22 381 mature individuals over 104 discrete patches (Foreman 2014). This has decreased from an estimated 57 000 in 2013, but increased from 11 500 in 2011 (Foreman 2014). Despite these year to year fluctuations that are linked to winter rainfall, the number of sites has exhibited an overall decline since 1983. This decline is caused by a range of threats that are simultaneously affecting all subpopulations despite localised management, and therefore the species occurs at one location. Augmentations were undertaken at two sites at Leanganook (Mt Alexander) and the species was introduced to Tallarook State Forest, but all were unsuccessful in the long-term (Silcock *et al.* 2019).

Monitoring has been sporadic since the species was relocated, but has become more systematic with the implementation of a recovery plan (Nevill and Camilleri 2010). The first complete census was undertaken in 2011 (and subsequently 2013 and 2014) and identified a number of significant and previously undocumented subpopulations. One of these occurred on private property adjoining the regional park (Foreman 2014). The persistence of the species here appeared tenuous, where it has been absent since 2014 and is presumed extinct (P Foreman pers.comm. 2020). Additional targeted searches of suitable habitat in the Leanganook (Mt Alexander) region have failed to locate additional subpopulations.

Formal monitoring has not been undertaken since 2014. However, recent observations from incidental visitation indicate the larger, higher-elevation sites are stable, while the smaller, lower-elevation sites are vulnerable to altered hydrology and competition.

Habitat and ecology

Historically, *B. antipoda* was known from dry stony sites and streambanks (Tasmania) and moss mats in the granite mountains of the Victorian Volcanic Plain. Some records also suggest the species occurred on basalt rocks, possibly on 'stony rises' with water seepage (Learmonth 2015).

Currently, *B. antipoda* occurs as a component of moss mats dominated by *Breutelia affinis* in skeletal soils over outcropping granite (Neville and Camilleri 2010). Associated species include *Bartramia papillata, Rosulabryum billardierei, Campylopus introflexus, Grimmia pulvinata* and *Polytrichum juniperinum* (Nevill and Camilleri 2010). Aspect, micro-hydrology and disturbance are important components of habitat suitability (Foreman 2011). At higher altitudes (>525 m) *B. antipoda* occurs in sheltered areas with continuous cool-season seepage (Foreman 2011). At lower altitudes, competition seems to be important, as the species becomes less common amongst robust grasses.

Ballantinia antipoda is a short-lived species with a generation length of <12 months. It germinates in winter and flowers appear by September, which are thought to be insect pollinated. As the moss mats begin drying, the wind-dispersed seed matures and accumulates in the skeletal soils amongst the dry moss (Learmonth 2015). Although some seed appears to persist in the seedbank beyond 12 months, the majority germinates following autumn and winter rains (Foreman 2011). There are some areas where the seedbank appears to have been exhausted, leading to local extirpations that cause extreme fluctuations in population abundance and area of habitat occupied.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	20 km^2 (5.2 km^2) Decreasing	High High
Area of occupancy (actual) Trend	20 km^2 (0.6 km^2) Decreasing	Medium High
No. of locations (key threat) Trend	1 (all threats) Stable	High High
No. of subpopulations Trend	10 Decreasing	Medium (fluctuates) High
No. of mature individuals Trend	22 381 Decreasing	Medium (fluctuates) High
Generation length	<1 year	High
Extreme fluctuations	Documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)c(i-v)	CR: EOO <100 km^2; severely fragmented and 1 location; continuing decline observed and projected in AOO/EOO, area, extent and quality of habitat, number of locations and subpopulations; and extreme fluctuations in the number of mature individuals and AOO.
C	Not eligible: >10 000 mature individuals.
D2	VU: <5 locations ; and plausible future threats that could drive taxon to EX in a very short time.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture and urbanisation has resulted in the decline and severe fragmentation of available habitat for the species.
Grazing and trampling (sheep, cattle, rabbits) *Past*	n/a	n/a	n/a	Grazing by domestic stock and rabbits (which historically occurred in high densities throughout the range of *B. antipoda*) is considered the major cause of extinction in Tasmania (Leigh *et al.* 1984), and may have contributed to local extinctions in Victoria.
Grazing and trampling (feral animals) *Suspended*	Majority	Slow	Low	Rabbits, feral pigs, deer and goats are present on Leanganook (Mt Alexander) and surrounds in low numbers. Some patches of *B. antipoda* have been fenced to reduce herbivory. Current impact of introduced animals is negligible, however ongoing monitoring and control is necessary.
Human activities and disturbance *Ongoing*	Majority	Rapid	Medium	The population of *B. antipoda* occurs in an area subject to high visitation and infrastructure pressures and is vulnerable to trampling, vehicle damage and altered hydrology from inappropriately placed tracks and firebreaks.
Invasive weeds *Ongoing*	Minority	Rapid	Medium	*Poa bulbosa* is an aggressive coloniser of areas with shallow soil and seasonal drying patterns; there is evidence to suggest it is encroaching into a number of moss mats containing *B. antipoda*. Upslope weed infestations can adversely impact micro-hydrology of moss mats.
Grazing and trampling (native animals) *Ongoing*	Majority	Negligible	Negligible	Macropods browse and trample subpopulations, and white-winged choughs upturn moss-mats while foraging, but current impacts of native animals seem negligible. Disturbance caused by choughs may assist in maintenance of suitable habitat (Seidel *et al.* 2005).
Too-frequent fire *Ongoing*	Majority	Unknown	Unknown	Most of Leanganook (Mt Alexander) has been burnt in recent years, but sheltered habitats may have protected the moss mats from burning. One large patch of *B. antipoda* disappeared after an escaped fuel reduction burn in 2009, but this was apparently recovering by 2015. Fire may also increase erosion, weed invasion and changes in micro-hydrology with implications for habitat suitability, but these impacts are not well understood.
Climate change *Future*	Whole	Rapid	Medium	Recruitment of *B. antipoda* depends on the timing and intensity of winter rainfall, and the severity of desiccation of moss mats and the thin soil layer in the previous dry period. The habitat of *B. antipoda* is predicted to become hotter, spend more time in drought and experience a decrease in winter rainfall (Grose *et al.* 2015).

Current management

- Recovery actions have been identified in a recovery plan (Nevill and Camelleri 2010) and reviewed by Foreman (2011; 2014a).
- Translocation to areas of suitable habitat on Leanganook (Mt Alexander) and at Talarook State Forest have been attempted and evaluated (Foreman 2014b) with limited success. Seed collection and translocation efforts are ongoing, focusing on locations beyond Leanganook (Mt Alexander).
- *Ballantinia antipoda* is protected within Mt Alexander Regional Park and weed and rabbit control are undertaken regularly. An additional subpopulation occurs on private property not managed for conservation.
- Local community groups have been involved in monitoring, field days and weed control over the past decade, and conservation of the species has been promoted through interpretative signage and extension activities. It is also one of the few threatened plants in Australia to feature in a children's book, *Landing With Wings* by Trace Balla (Balla 2020).

Conservation objectives

- Monitor and maintain known subpopulations.
- Improve habitat quality at known subpopulations and in other areas of potentially suitable habitat via fire management, weed control, exclusion of human activities and modification of micro-hydrology.
- Propagate species and establish *ex situ* subpopulations, with view to re-introduce to historic areas and other suitable habitat (a number of sites in south-eastern Australia including Tasmania).

Information required

Theme	Specific actions	Priority
Population surveys	Given the species is prone to fluctuations and a new subpopulation was located in 2013, further surveys at known and historic sites are recommended after sufficient winter rains.	High
	Monitor response of subpopulations to threats and management actions.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
	Determine the length soil-stored seed can remain viable.	High
Habitat quality	Undertake research to better understand the impact of fire, invasive weeds and disturbance on *B. antipoda* to inform appropriate management strategies.	High
Ex situ conservation/ translocations	Determine requirements to successfully propagate the species *ex situ*.	High
	Determine requirements for successful translocation.	Medium

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Collect and store seed of *B. antipoda* for conservation.	High
	Propagate species in *ex situ* collection in preparation for re-introduction across the historical range of the species.	High
Habitat protection and restoration	Maintain fences around known subpopulations to protect from foot traffic, bike tracks and vehicle damage. Maintain track closures to minimise foot and vehicle traffic in the area, and realign existing tracks if necessary. Avoid creation of new tracks or firebreaks within 100 metres of known subpopulations.	High
	Ongoing weed and feral animal monitoring and management.	High
	Implement a fire management plan at Leanganook (Mt Alexander) and any future translocation sites.	High
	Protect habitat of species on private property within appropriate conservation agreement.	Medium

Theme	Specific actions	Priority
Extension and awareness	Raise awareness of the species with relevant stakeholders in an attempt to locate additional subpopulations and protect known subpopulations.	Medium

Experts consulted

Paul Foreman, Karly Learmonth, Neville Walsh and Richard Schahinger.

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Banksia fuscobractea (A.S.George) A.R.Mast & K.R.Thiele [PROTEACEAE]
Dark-bract banksia

Banksia fuscobractea conflorescence and foliage (image: Andrew Crawford).

Overview

Banksia fuscobractea is known from two small roadside subpopulations at ongoing risk of habitat degradation through roadworks, gravel extraction and invasive weeds. Conservation actions have been implemented but declines continue despite some recruitment and fluctuations. The species is also susceptible to phytophthora *Phytophthora cinnammoni* under laboratory conditions. Seed has been collected and translocations to secure tenure may be considered in the future.

Conservation status

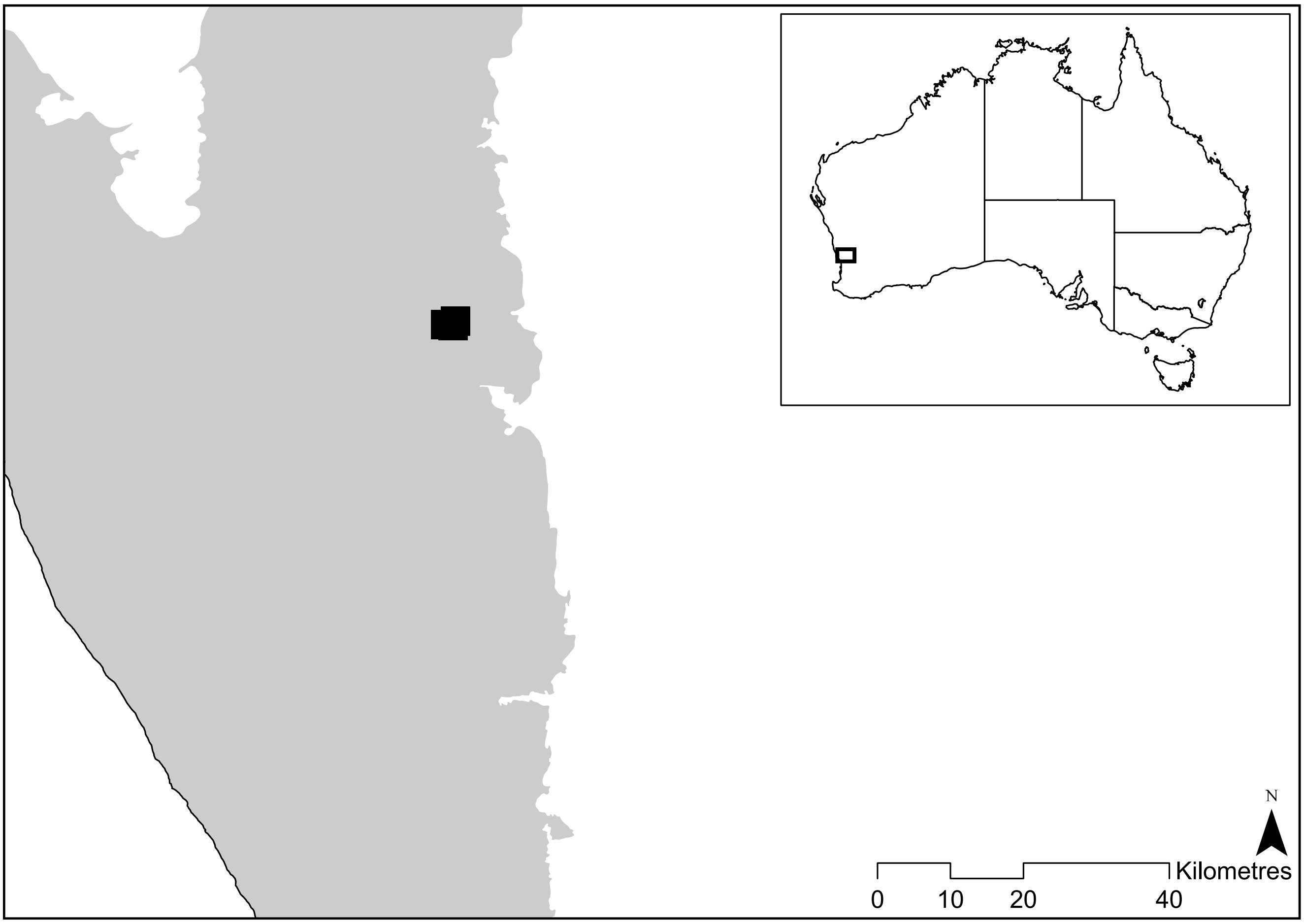
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List	Critically Endangered

Brief description

Erect, prickly shrub to 1 m tall with densely hairy stems (George 1996). Leaves cuneate and serrate with 4-9 teeth on each side of the leaf margins. Petiole 5-10 mm long, lamina 4-7 cm long and 1-3 cm wide, glabrous above and below, with slightly recurved or flat margins. Conflorescence terminal or on a short lateral branchlet, with hairy, linear involucral bracts that are dark brown towards the apex, and 180-190 flowers. Each flower has a pale yellow perianth, cream pistil 22-26 mm long, and narrow, rusty-brown pollen presenter to 1 mm long. Three or four follicles 9-12 mm long develop on each head (George 1996). *Banksia fuscobractea* differs from the similar *B. cuneata* by having dark brown involucral bracts, more flowers per head, a grey perianth limb and smaller, darker pollen presenter (George 1996).

Distribution

Banksia fuscobractea is known from two sites within 2 km near Gillingarra within the Swan Coastal Plain bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution (black squares) of *Banksia fuscobractea* in the Swan Coastal Plain bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020).

Population estimate and trends

Banksia fuscobractea was first recorded during a survey of remnant vegetation in 1983 (Department of Environment and Conservation 2008). When it was described (George 1996) only two small subpopulations were known; on a narrow road verge and on private property. Time-series monitoring has been sporadic from 1991 to present, but indicates the species is declining (DBCA 2020; DEC 2008). There were 96 mature individuals in 2004 and 58 by 2010. The majority of individuals occurring on private property were cleared between 2006 and 2007 when property ownership changed, as the new owners were not made aware of the species (DEC 2008); equating to a population reduction of ca. 50% over 3 years (2004-2007). Only 43 mature individuals remain (DBCA 2020). Targeted surveys by specialist staff were undertaken during the flowering seasons of 1999 and 2001, but no additional subpopulations have been located (DEC 2008).

Banksia fuscobractea monitoring data, 1985-2020 (DBCA 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1b*,c (road reserve)*	1999: 25 2004: 49 (17) 2007: 40 (23) 2008: 48 (not recorded) 2010: 50 (17) 2011: 48 (13) 2016: 35 (10)	Decreasing
2* (road reserve/private property)*	2001: 17 2004: 47 (0) 2007: 9 (1) 2008: 12 (0) 2010: 8 (13)	Decreasing

* Subpopulations 1a/1b and 2a/2b have been combined.

Habitat and ecology

Banksia fuscobractea occurs in gravelly-sandy soils over laterite amongst dense, low heath, usually along ridges (DEC 2008). Associated species include *Allocasuarina humilis, B. kippistiana, Hakea incrassata, H. scoparia, Calothamnus sanguineus, Acacia stenoptera* and *Adenanthos cygnorum* (DEC 2008).

Banksia fuscobractea does not have a lignotuber (George 1996) and is probably killed by fire. The seed of *B. fuscobractea* is stored in the canopy and released after fire (DEC 2008), so extreme fluctuations are considered probable, although not evident in monitoring data (IUCN 2019). Recruitment has also been observed shortly after mechanical disturbance during gravel extraction and fence construction (DEC 2008). Open areas may be important for seed germination and survival (DEC 2008). Recruitment can also occur in the absence of disturbance, with 10 juveniles present in 2016. Laboratory trials found 95-100% of fresh seeds germinated without any treatment (DEC 2008). The generation length of this species is not precisely known but monitoring data indicates >10 years.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.4 km^2) Stable	High High
Area of occupancy (actual) Trend	4 km^2 (<0.1 km^2) Stable	High High
No. of mature individuals Trend	43 Decreasing	High High
No. of locations (key threat) Trend	2 (infrastructure maintenance) Stable	High High
No. of subpopulations Trend	2 Stable	High High
Generation length	10 years	Low
Extreme fluctuations	Probable	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	EN: >50% reduction observed within 3 generations (ca. 50% from 2004-2007); causes may not be reversible; based on direct observation.
B1+2ab(iii,v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented; and continuing decline observed and projected in area/extent and quality of habitat and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture has resulted in the decline and fragmentation of available habitat for the species. The species is considered severely fragmented as all remaining subpopulations are small and isolated amongst a cleared landscape.
Infrastructure maintenance *Ongoing*	Whole	Rapid	High	Both subpopulations occur on road reserves and are vulnerable to maintenance activities including grading, drainage construction, clearing, chemical spraying and grading. One subpopulation occurs partly on private property and within a firebreak and may be impacted by maintenance activities. The species occurs at two locations when assessed against this threat, as management activities are determined by land tenure.
Extractive industry *Ongoing*	Majority	Rapid	High	The species occurs on lateritic gravels and is vulnerable to gravel extraction. Twenty-five plants were destroyed in the past due to gravel extraction activities.
Lack of appropriate disturbance *Ongoing*	Majority	Slow	Medium	Natural disturbance events are limited within the very small patches of remnant habitat where the species occurs. Disturbance such as fire facilitates recruitment, although if too frequent, may deplete both adult abundance and seed reserves.
Invasive weeds *Ongoing*	Whole	Slow	Medium	Both subpopulations are small and occur in degraded roadside remnants where invasive weeds occur. Invasive weeds increase competition and alter fuel loads and thus fire regimes, which may have substantial impacts on recruitment and overall abundance.
Introduced pathogens *Future*	Whole	Rapid	Medium	*Banksia fuscobractea* is highly susceptible to phytophthora infection under artificial conditions (Shearer *et al.* 2013). The presence and impact of this pathogen is yet to be investigated for wild *B. fuscobractea* subpopulations.

Current management

- Recovery actions are identified in the conservation advice (Department of Environment, Water, Heritage and the Arts 2009) and recovery plan (DEC 2008).
- The portion of Subpopulation 2 on private land has been fenced following a clearing incident in 2007.
- Seed has been collected from both subpopulations and is stored at the Western Australian Seed Centre. There are currently 1069 seeds in storage from Subpopulation 1 and 110 seeds from Subpopulation 2. Collections from Subpopulation 1 were made in 1994, 1996, 2000 and 2011 from 10-29 plants, and collections from Subpopulation 2 were made in 2011 and 2012 from two plants. Testing indicated that between 95 and 100% of seed collected from Subpopulation 1 was germinable.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Increase the number of mature individuals and subpopulations in the wild via translocations.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in suitable habitat to locate additional subpopulations. Continue to monitor known subpopulations in response to threats and management activities.	High High
Introduced pathogens	Determine whether the phytophthora is present in the habitat of the species. Determine *in situ* management actions to mitigate the impacts of phytophthora.	High High
Disturbance ecology	Undertake research to document the disturbance ecology of the species. Determine methods to increase population abundance via disturbance.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements, response to disturbance and habitat suitability for translocations.	Medium
Ex situ conservation/ translocations	Identify areas of habitat on secure tenure that are suitable for translocations.	Medium

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known and potential habitat in appropriate conservation agreements.	High
Introduced pathogens	Implement and maintain disease hygiene measures to protect subpopulations against possible infection by phytophthora.	High
Lack of appropriate disturbance	If feasible, implement fire management plan to increase recruitment and population abundance over the long-term.	High
Ex situ conservation/ translocations	Maintain and expand *ex situ* seed collections to represent maximum range of genetic diversity possible. Propagate plants from seed to augment wild population or translocate to secure tenure.	High Medium
Invasive weeds	Manage invasive weeds within known subpopulations, particularly after disturbance.	Medium

Experts consulted

Andrew Crawford, Tanya Llorens and Niall Sheehy.

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Banksia montana (C.A.Gardner ex A.S.George) A.R.Mast & K.R.Thiele [PROTEACEAE]
Stirling Range dryandra

Banksia montana amongst montane heath at Koi Kyenunu-ruff (Stirling Range National Park; image: Sarah Barrett).

Overview

Banksia montana is known from four mountain peaks in the Critically Endangered montane thicket community of the Stirling Range. The interacting threats of phytophthora *Phytophthora cinnamomi* dieback, too-frequent fires and herbivory are causing rapid declines across all subpopulations, with climate change predicted to exacerbate this. Recovery hinges on management actions including phytophthora management, fire management, fencing and translocations.

Conservation status

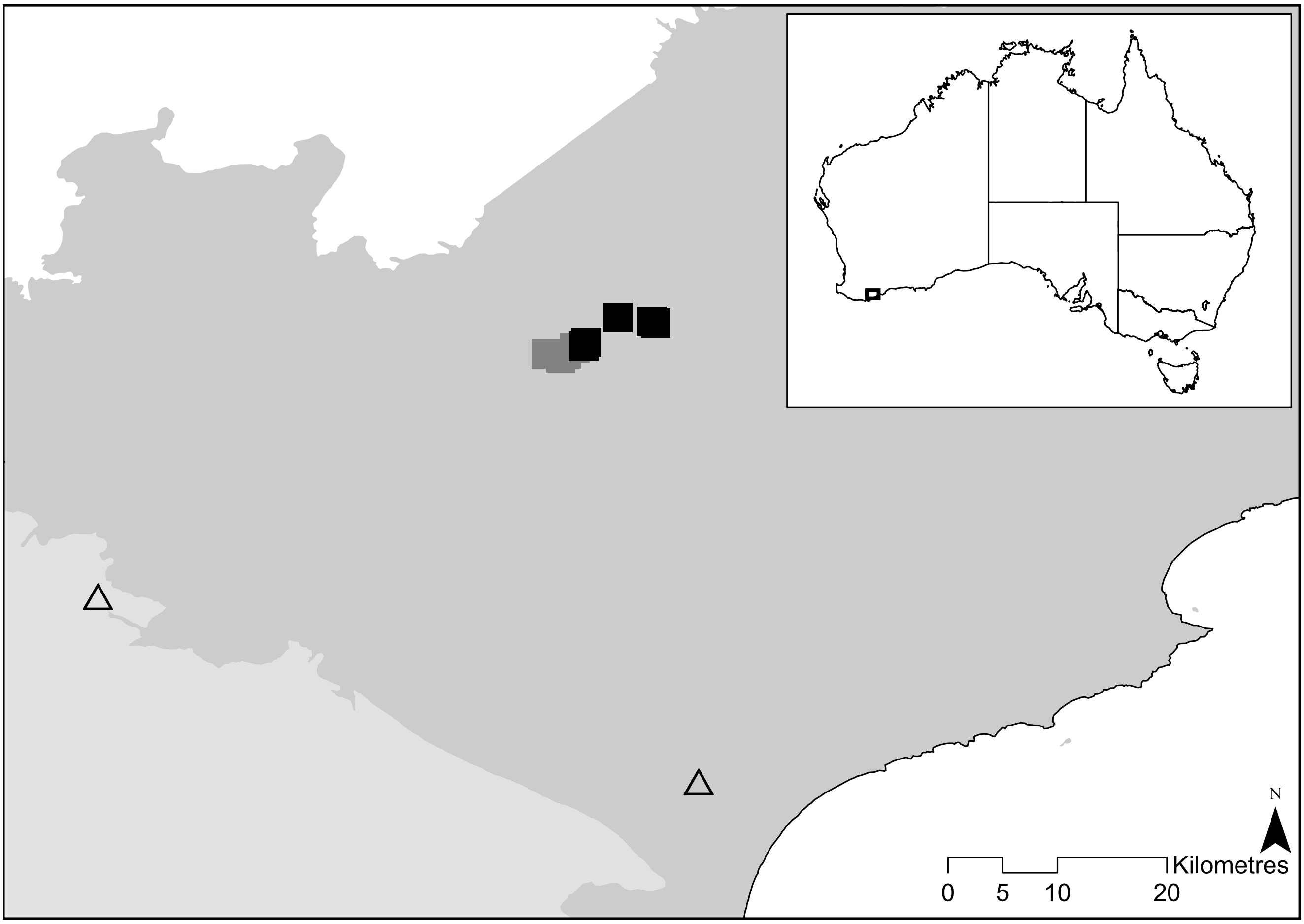
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List	Critically Endangered

Brief description

Erect woody shrub to 2.5 m (George 1996). Leaves twisted, 8-25 cm long and 6-11 mm wide, with 35-60 deep, elongated, triangular lobes on each side that slightly overlap at the base (George 1996). The inflorescence of 50-60 yellow flowers is sessile and borne on old wood. Upper stems and fruits are covered in short red hairs (George 1996). The leaves of *B. montana* are considerably more leathery than the similar *B. plumosa* and *B. pseudoplumosa* (George 1996).

Distribution

Banksia montana is known from a very narrow area along the peaks of Koi Kyenunu-ruff (the Stirling Range) within the Esperance Plains bioregion of south-western Western Australia (Department of Agriculture, Water and the Environment 2012). It is considered extinct from one peak, and has been translocated to two sites outside its natural range (Australasian Virtual Herbarium 2020; Department of Biodiversity, Conservation and Attractions 2020).



Current (black squares) and historic (grey squares) distribution of *Banksia montana* in the Esperance Plains bioregion (shaded dark grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020). The species has been introduced to two additional sites (hollow triangles) including the Jarrah Forest bioregion (shaded light grey), although these subpopulations are not yet self-sustaining (Silcock *et al.* 2019).

Population estimate and trends

Banksia montana was first collected in 1964 from Bular Mial (Bluff Knoll) in Koi Kyenunu-ruff (the Stirling Range). Intensive surveys between 1996 and 2004 located four additional subpopulations and it is unlikely additional subpopulations exist (S Barrett pers.comm. 2020). By 2000, one subpopulation was extinct, with 137 mature individuals and 39 juveniles over four subpopulations remaining. After a fire in spring 2000, the population declined again to 55 mature individuals. This fire failed to stimulate recruitment at subpopulations that had been previously burnt in 1991 (Barrett and Yates 2015). Declines continued with only 34 plants in 2016, and after another fire in autumn 2018 only eight mature individuals persisted. Seedling germination did occur after this fire, however many of these, along with the eight mature individuals were killed by fire in 2019. There are no mature individuals currently persisting in the wild, equating to a population reduction of >90% over 18 years (2001-2019). Although a number of juvenile plants are now present at the four subpopulations, including reinforcement translocations to three subpopulations in 2018 (S Barrett pers. comm. 2020), it is not known whether they will survive to reproduce due to ongoing threats. Population monitoring has been ongoing since 1997, recording number of plants, recent deaths, threat impacts, canopy, flowering, fruiting and plant health (S Barrett pers.comm. 2019).

A seed orchard was established at Luscombe's Seed Orchard in 2003, alongside another translocated subpopulation at Benmore Tree Farm in 2010 (Silcock *et al.* 2019). Over several years, 138 and 48 seedlings have been planted at these sites, respectively. As of 2019/20, 65 and two plants were surviving but recruitment was absent (Barrett *et al.* 2011; R Dillon pers.comm. 2020) and these subpopulations are not yet considered self-sustaining.

Banksia montana monitoring data, 1995-2020 (DBCA 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Bular Mial (Bluff Knoll) (national park)	1995: 21 (0) 2004: 7 (15) 2018: 4T 2020: 0 (630) (34T)	Decreasing
2 Coyanarup (national park)	2000: 0 (0) 2018: 0 (16T) 2020: 0 (13T)	Presumed extinct
3 Kyanorup (national park)	2000: 0 (0) 2020: 0	Presumed extinct
4 Pyungoorup (national park)	1996: 23 (0) 2004: 19 (0) 2018: 7 2020: 0 (9)	Decreasing
5 Isongerup (national park)	1997: 13 (1) 2004: 3 (0) 2018: 0 2020: 0 (204)	Decreasing
6 East Bluff (national park)	1996: 61 (8) 2004: 16 (1) 2018: 1 (23T) 2020: 0 (14) (15T)	Decreasing
7 (T) Luscombes Seed Orchard (private property)	2003-2010: (138T*) 2019: 65T	Unknown
8 (T) Benmore Tree Farm (private property)	2010-2013: (48T*) 2016: 21T 2020: 2T	Decreasing

Translocated individuals/subpopulation (T). *Total number of seedlings planted over multiple years.

Habitat and ecology

Banksia montana occurs in dense montane heath on mountain summit areas at 900-1080 m above sea level (Gilfillan *et al.* 2008). It grows in sandy clay loam soils amongst rocks in the Critically Endangered Eastern Stirling Range Montane Heath and Thicket vegetation community. Flowering occurs between January and March (Gilfillan *et al.* 2013).

Banksia montana is serotinous, killed by fire and cannot re-sprout (Gilfillan *et al.* 2008). This species is characterised by a canopy-stored seedbank, rather than being stored in the soil. Some inter-fire recruitment is also likely as a result of occasional seed dehiscence in the absence of fire (S Barrett pers.comm. 2020). Following fire, seeds are released from the canopy for germination and seedlings must reach reproductive maturity before the next fire for the population to be maintained. Flowering and seed production vary between individuals and years, and may reflect plant age, health and pollination effectiveness (Gilfillan *et al.* 2008). Fruit and seed persist in the canopy for several years before disintegrating (S Barrett pers.comm. 2019). In 2000, 116 individuals were killed by fire and only 13 seedlings emerged post-fire (Gilfillan *et al.* 2008). After the fire in 2018, considerably higher levels of germination occurred, although subsequent fires in 2019 killed the last mature individuals along with 36 seedlings at two subpopulations (S Barrett pers.comm. 2019). Extreme fluctuations are probable as the majority of seed is stored in the canopy and can be exhausted in a single fire event (IUCN 2019).

The time to reproductive maturity is at least 9 years after germination and individuals have lived for at least 30 years (Gilfillan *et al.* 2008), but time to senescence is probably longer. The generation length is estimated as >10 years.

The *Banksia montana* mealybug (*Pseudococcus markharveyi*), which is directly dependent on *B. montana*, was discovered in 2007 and is listed as Critically Endangered in Western Australia and on the IUCN Red List (Gullan *et al.* 2013).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	12 km^2 (4.5 km^2) Decreasing	High High
Area of occupancy (actual) Trend	12 km^2 (<1 km^2) Decreasing	High High
No. of mature individuals Trend	0 Decreasing	High High
No. of subpopulations Trend	4 Decreasing	High High
No. of locations (key threat) Trend	2 (phytophthora) Decreasing	High High
Generation length	>10 years	Medium
Extreme fluctuations	Probable	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2ae	CR: >80% reduction observed within 3 generations (>90% from 2000-2019); causes have not ceased and may not be reversible; based on direct observation and effects of introduced pathogens.
B1ab(i-v)c(iv)	CR: EOO <100 km^2; severely fragmented; continuing decline observed and projected in EOO, AOO, quality of habitat, number of locations and subpopulations, number of mature individuals; and extreme fluctuations in number of mature individuals.
C1+2a(i)b	CR: <250 mature individuals; >25% decline in 1 generation (>90% from 2000-2009); continuing decline observed and projected; <50 mature individuals in each subpopulation; and extreme fluctuations in number of mature individuals.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Introduced pathogens *Ongoing*	Majority	Very rapid	High	*Banksia montana* is highly susceptible to phytophthora (Shearer *et al.* 2013). The habitat of three of four wild subpopulations is infested by phytophthora, and the pathogen has already caused one extirpation (Barrett and Yates 2015; Gilfillan *et al.* 2008). Some healthy individuals persist amongst infested vegetation. Phytophthora is also likely to impact *B. montana* indirectly by altering vegetation structure (Barrett and Yates 2015). Although naturally restricted and fragmented, *B. montana* is also severely fragmented as all subpopulations are reduced and isolated due to phytophthora with limited possibility of recolonisation following local extinctions (IUCN 2019).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Inappropriate fire regimes *Ongoing*	Whole	Rapid	High	*Banksia montana* is a serotinous obligate-seeder with a long juvenile period; recommended fire intervals are >18 years (Gilfillan *et al.* 2008). Most areas of the montane thickets burnt in various combinations of the 1972, 1991, 2000, 2018 and 2019 fires. The 2000 fire caused high mortality and little recruitment (Gilfillan *et al.* 2008). The 2018 fire reduced the population to eight mature individuals, and none remained after the 2019 fire, although there has been some seedling germination (S Barrett pers.comm. 2019).
Herbivory (browsing) *Ongoing*	Majority	Slow	Medium	*Banksia montana* is vulnerable to browsing by the native quokka, especially after fire (Rathbone and Barrett 2017). Forty percent of seedlings that emerged post-fire in 2001 were heavily browsed (Gilfillan *et al.* 2008). Maintaining intact fencing requires considerable effort in these remote and very windy rocky areas. New fencing was required for seedlings form the 2019 fire. Ongoing survey is required to check for any seedlings that have been missed and need fencing (T Llorens pers.comm. 2020).
Human activities *Future*	Minority	Slow	Low	Bushwalkers are thought to have contributed to phytophthora spread in the area, and may also impact individuals via trampling and increased erosion.
Climate change *Future*	Whole	Slow	Low	Climate change may alter the unique climatic conditions of the region and reduce the area of suitable habitat for *B. montana* (Monks *et al.* 2019).

Current management

- Recovery actions have been identified in a recovery plan (Gilfillan *et al.* 2008).
- This species occurs in Stirling Range National Park, which is managed for conservation.
- Approximately 9000 seeds were collected from 1994-2018 and stored in the Threatened Flora Seed Centre in Perth. Limited germination trials have been undertaken. Tissue culture and propagation from cuttings have been unsuccessful, although research to develop tissue culture techniques is ongoing (S Barrett pers.comm. 2019).
- Reinforcement translocations were implemented in three subpopulations in 2018. A disease-free seed orchard was established in 2003, with seed being banked in preparation for future translocations (Monks *et al.* 2019). Irrigation has been re-activated at this site to improve plant health and reproduction (S Barrett pers.comm. 2020). A second seed orchard at Benmore Tree Farm was established in 2010 with 48 seedlings planted over several years (T Llorens pers.comm. 2020).
- Fire management strategies aim to exclude fire from the habitat of the montane heath habitat (S Barrett pers. comm. 2020).
- Phosphite has been applied at all extant subpopulations from 1997-2020 (S Barrett pers.comm. 2019).
- All mature and juvenile plants were fenced to protect from browsing in the early 2000s, with extensive fencing undertaken in 2018, 2019 and 2020 to protect seedlings from herbivory (S Barrett pers.comm. 2019).

Conservation objectives

- Monitor and maintain known subpopulations.
- Establish additional, viable *ex situ* subpopulations in disease-free areas on secure tenure.
- Increase abundance of extant population by reducing the collective impacts of threats through ongoing phosphite spraying, phytophthora hygiene, fence maintenance, exclosures around new subpopulations, reinforcement translocations and ongoing strategic planned burns.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake monitoring at all subpopulations (extant and presumed extinct) to document response to threats and management actions.	High
Ex situ conservation/translocations	Identify additional sites suitable for translocation. A limited number of phytophthora-free mountaintops occur in Koi Kyenunu-ruff (the Stirling Range) but these are outside the historical and current distribution of the species.	High
	Continue reinforcement translocations following an evaluation of the success of 2018 plantings.	High
Introduced pathogens	Identify/develop phytophthora resistant genotypes through screening and tissue culture. Augment wild subpopulations with resistant genotypes.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, seed predation and germination requirements.	High

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Maintain seed orchard and expand *ex situ* subpopulation to represent the maximum amount of genetic diversity possible. Bank seed in preparation for future translocations to disease-free locations.	High
Introduced pathogens	Maintain disease hygiene measures at all subpopulations including signage, restricting access and phosphite application.	High
	Continue aerial phosphite application to mitigate disease impact. This may have co-benefits for *Andersonia axilliflora, Darwinia, collina, Latrobea colophona, Leucopogon gnaphalioides* and *Persoonia micrantha*.	High
Herbivory (browsing)	Maintain and expand exclusion fencing to protect seedlings, juveniles and mature individuals from herbivory, especially after recruitment events following fire.	High
Inappropriate fire regimes	Implement fire management strategies to exclude fire from the habitat of the montane heath habitat to allow vegetation structure to recover and B. montana to complete its life cycle (S Barrett pers.comm. 2020). Fire is required for germination and return intervals for *B. montana* are recommended at >18 years (Gilfillan *et al.* 2008).	High

Experts consulted

Sarah Barrett, Leonie Monks and Rebecca Dillon.

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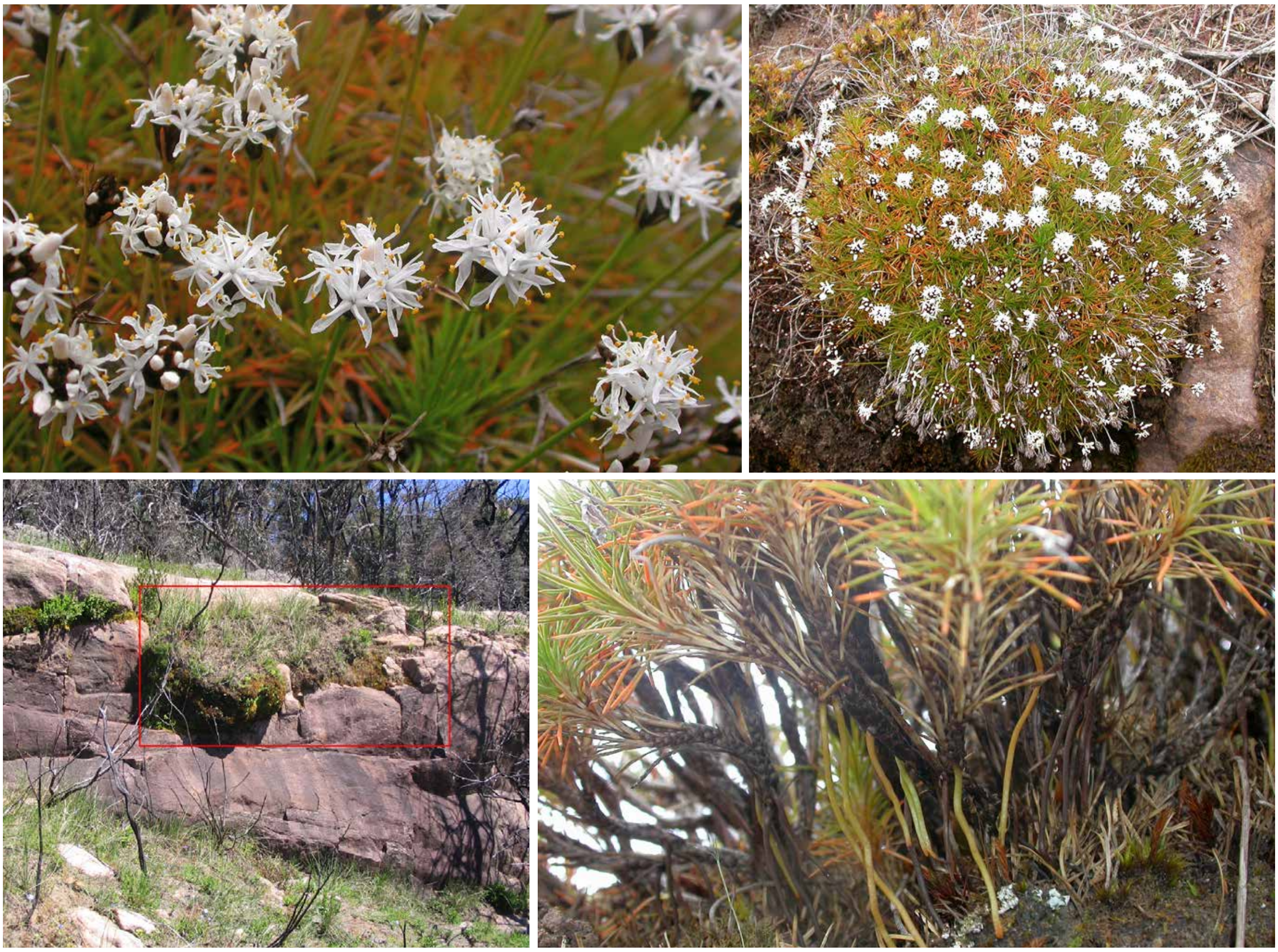
Borya mirabilis Churchill [BORYACEAE]
Grampians pincushion-lily



Borya mirabilis (clockwise from top left) flowers, habit, ramets (images: Neville Walsh, State Botanical Collection, Royal Botanic Gardens Victoria), and rock ledge habitat (image: Noushka Reiter).

Overview

Borya mirabilis is a 'resurrection plant' known from a single population comprising four colonies on a rock ledge in Gariwerd (Grampians National Park). Each colony comprises multiple clonal ramets and the species is almost infertile. Phytophthora *Phytophthora cinnamomi* has exacerbated existing declines due to drought, erosion, herbivore disturbance and competition with native species post-fire. The species was translocated to a disease-free area where it was reproducing clonally, but all plants had died by 2019 due to lack of site maintenance. Priority recovery actions are regular monitoring and management of the population, establishing an *ex situ* subpopulation and surveys to locate additional genetic individuals.

Conservation status

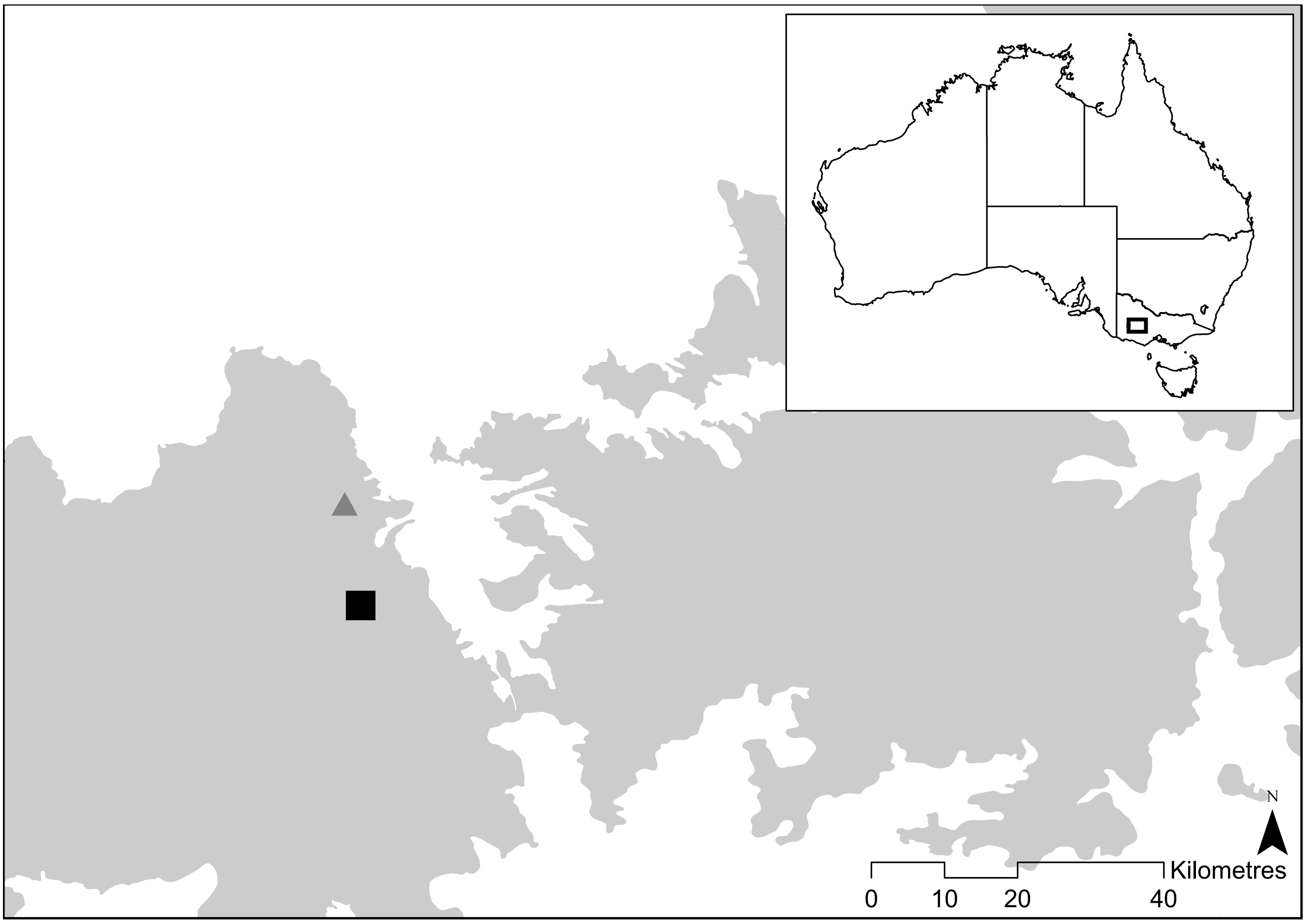
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Perennial herb with multiple clonal shoots (ramets) growing to 15 cm in height (Churchill 1985). Ramets form a clump with brown, erect or ascending stems covered in scale-like leaf sheaths. Leaves are linear and spiky, 10-16 mm long and 0.5 mm wide, tapering from a persistent sheath. Inflorescence is terminal with 4-12 white flowers on scapes held together in ovoid heads surrounded by sharp involucral bracts (Churchill 1985). It is the only species of the *Borya* genus found in south-eastern Australia.

Distribution

Borya mirabilis is known from a very restricted distribution in the Wonderland Range in the Victorian Midlands bioregion of central-western Victoria (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Environment, Land, Water and Planning 2020). A translocation 20 km away was initially successful but all plants had died by 2019 (Silcock *et al.* 2019). *Borya mirabilis* is considered severely fragmented as it occurs in a single isolated subpopulation and recolonisation following possible extinction cannot occur (IUCN 2019).



Current (black square) and translocated (grey triangle; now extinct) distribution of *Borya mirabilis* in the Victorian Midlands bioregion (shaded grey) of Victoria (AVH 2020; DAWE 2012; DELWP 2020; Silcock *et al.* 2019).

Population estimate and trends

Borya mirabilis was first collected in 1924 and was considered extinct until it was relocated in 1983 in the Wonderland Range (Kahout and Coates 2010). The species is currently known from a single subpopulation of four plants with three genetically distinct individuals (N Reiter pers.comm. 2020). For clonal species, population abundance is measured by the number of distinct reproductive units (i.e. ramets; IUCN 2019). The species declined from >200 ramets in 2003 to 70 over 1200 m^2 in 2015 (Reiter *et al.* 2015), equating to a population reduction of 65%. Sixteen plants were introduced to Mt Difficult in 2004 (Silcock *et al.* 2019). Twelve plants established with clonal reproduction, increasing to 504 ramets in 2012, but all were dead by 2019 (N Reiter pers.comm. 2020).

Time-series monitoring data was collected every three months from 1999-2000. Monitoring was undertaken regularly between 2007 and 2015, and revealed an overall decline in population health due to a number of threats simultaneously affecting the entire population (one location; Coates *et al.* 2002). Surveys have been conducted throughout similar habitat in the region, although the area and habitat is remote, indicating additional subpopulations may exist. There are unsubstantiated reports of additional subpopulations elsewhere in the Gariwerd (Grampians) region.

Borya mirabilis monitoring data, 2003-2019 (Reiter *et al.* 2015; N Reiter unpublished data).

Subpopulation (tenure)	Number of mature individuals (ramets)	Trend
1 Wonderland Range (national park)	2003: 7 (>200) 2007: 5 (70) 2015: 3 (70) 2019: 3 (not counted)	Decreasing
2 (T) Mt Difficult (national park)	2004: 12T (200) 2012: 12T (504) 2017: 12T (47) 2019: 0T (0)	Presumed extinct

Translocated individuals/subpopulation (T).

Habitat and ecology

Borya mirabilis occurs in low open shrubland on ferruginous terraced sandstone outcrops with a slope of ~15° facing north-east (Kahout and Coates 2010). Soils are typically dry in summer, becoming moist in cooler months via seepage combined with impeded drainage (Kahout and Coates 2010). The seepage results in an accumulation of fine sandy loam soil, which is rare in rocky environments (Kahout and Coates 2010). Associated species include *Grevillea aquifolium, Kunzea parvifolia, Calytrix tetragona, Melaleuca decussata, Dodonaea viscosa, Lepidosperma viscosa, Gonocarpos mezianus, Phyllanthus hirtellus, Leptospermum scoparium* and *Rytidosperma setaceum* (Kahout and Coates 2010). Other annual herbs appear in spring (Kahout and Coates 2010).

Borya mirabilis is xeromorphic; plants desiccate after spring flowering and regenerate in cool, wet weather at the end of summer to early autumn (Gaff and Churchill 1976). Plants can also re-sprout following fire. *Borya mirabilis* has an arbuscular mycorrhizal association that forms inside its root nodules (Reiter *et al.* 2013).

Borya mirabilis flowers bear nectar and are probably pollinated by flies and ants (Reiter *et al.* 2015). Seed production is very rare. Only a single seed has been produced via hand pollination, which did not germinate under controlled conditions (Reiter *et al.* 2015). The extremely low fecundity is probably caused by inviable pollen, low genetic diversity and unevenly maturing ovules (Reiter *et al.* 2015). Clonal reproduction appears to be the only form of viable reproduction (Reiter *et al.* 2015). Generation length is not precisely known, but given plants (colonies) can live for many decades, it is estimated to be at least 20 years.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km² (0.002 km²) Increasing	Medium High
Area of occupancy (actual) Trend	4 km² (0.002 km²) Increasing	Medium High
No. of mature individuals Trend	70 ramets Decreasing	Medium High
No. of locations (key threat) Trend	1 (all threats) Decreasing	Medium High
No. of subpopulations Trend	1 Decreasing	Medium High
Generation length	>20 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	EN: >50% reduction observed within 3 generations (65% from 2003-2015); causes may not have ceased, are not well-understood, and may not be reversible; based on direct observation.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed in EOO, AOO, quality of habitat, number of locations/subpopulations, number of mature individuals.
C1+2a(ii)	CR: <250 mature individuals, continuing decline of >25% in 1 generation observed; and 100% of individuals in one subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Inappropriate disturbance regimes *Ongoing*	Whole	Rapid	High	*Borya mirabilis* habitat is naturally prone to erosion, which has been exacerbated in recent years due to fire, prolonged drought and sporadic heavy rainfall, leaving the plants on small patches of soil (Kahout and Coates 2010). This is exacerbated by digging from rabbits, echidnas and other foraging animals.
Introduced pathogens *Ongoing*	Whole	Rapid	High	*Borya mirabilis* is moderately susceptible to phytophthora and the pathogen is present among the wild population (Reiter *et al.* 2004). Phytophthora causes chlorosis, browning, reduced vigour and eventual death. The death of the *ex situ* collection and one wild colony has been attributed to phytophthora (N Reiter pers.comm. 2019).
Low genetic diversity *Ongoing*	Whole	Rapid	High	Three genetically distinct individuals of *B. mirabilis* are currently known. Reproduction is thought to be exclusively clonal (Reiter *et al.* 2015). Low genetic diversity limits the capacity of this species to adapt to environmental change.
Competition *Ongoing*	Whole	Rapid	High	Competition with native vegetation post-fire may cause declines of *B. mirabilis*, particularly where exclosures are installed to prevent herbivore disturbance. Two cages at the translocation site had dense *Thryptomene* sp. and *Melaleuca* sp. regrowth to 1 m high, which may have outcompeted *B. mirabilis* (N Reiter pers.comm. 2020).
Vertebrate disturbance (feral and native) *Ongoing*	Whole	Slow	Medium	The restricted, unstable habitat of *B. mirabilis* renders it vulnerable to digging and trampling by rabbits, goats, deer and possibly macropods. Subsequent erosion damages plants and causes soil drying (Coates *et al.* 2002). Goats and rabbits were common at the translocation site in 2019 and may have contributed to plant death (N Reiter pers. comm. 2020).
Stochastic events *Future*	Whole	Very rapid	Medium	Given the small population size, restricted distribution and limited genetic diversity, this species is extremely vulnerable to stochastic events and has low capacity to adapt to environmental change (Reiter *et al.* 2013).
Climate change *Future*	Whole	Slow	Low	Climatic drying may exacerbate the effects of erosion and increase the possibility of stochastic events, as well as potentially exacerbating the impacts of phytophthora.

Current management

- Recovery actions have been identified in the recovery plan (Kahout and Coates 2010).
- The species is protected and included in the management plan for Grampians National Park (Parks Victoria 2003).
- Research into the effect of phytophthora, tissue culture, pollination, mycorrhizal associations and genetics of the species has been undertaken (Reiter *et al.* 2004, 2013, 2015; Reiter 2008).
- Cuttings were collected in 2019 and some successfully propagated *ex situ* (N Reiter pers.comm. 2020).
- Measures to reduce erosion and disturbance have been implemented.
- A management strategy for phytophthora in Grampians National Park has been implemented (Gallon *et al.* 2017).
- Extensive aerial and on-ground searches have been undertaken.
- Lack of funding has limited regular monitoring and maintenance of both subpopulations since 2014, leading to extinction of the translocated subpopulation. Regular monitoring and management of the extant subpopulation must be re-implemented to detect and manage issues that arise including with goat and rabbit pressure.

Conservation objectives

- Monitor and maintain wild population on an annual basis.
- Detect more subpopulations through targeted surveys. If additional subpopulations are located, attempt hand pollination as an opportunity to mix genes.
- Establish *ex situ* subpopulation representing maximum range of genetic diversity.
- Establish self-sustaining translocated subpopulations to spread risk of species extinction.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in suitable habitat to locate additional subpopulations.	High
	Monitor population to determine response to recovery actions and threats; limited to once per year to reduce risk of disease spread (N Reiter pers.comm. 2019).	High
Genetic diversity/reproduction	Investigate if seeds are the product of sexual recombination or apomixes (Reiter *et al.* 2015).	Medium
	Use nuclear and organelle probes to compare the genome of *B. mirabilis* with other extant *Borya* spp. (Reiter *et al*. 2015).	Medium
	Further artificial pollination attempts are likely to be unsuccessful in producing viable seed (Reiter *et al*. 2015). However, if additional genotypes are located this should be undertaken in an attempt to produce viable seed.	
Mycorrhizal fungi	Precisely determine the structure and identity of the fungi inside the root nodules of *B. mirabilis* via DNA analysis (Reiter *et al.* 2013). If the fungi species is the same as present in mycorrhizae of other, non-endangered taxa in the region, their roots can be used to inoculate roots of *B. mirabilis* in *ex situ* or translocated subpopulations to aid establishment (Reiter *et al.* 2013).	Medium

Management actions required

Theme	Specific actions	Priority
Introduced pathogens	Apply phosphonate spray to wild population where phytophthora is present.	High
	Maintain basic hygiene measures including fencing to exclude human foot traffic and providing footbaths on walking tracks.	High
	Augment wild population with additional individuals to reduce risk of extinction.	High
Ex situ conservation/translocations	Establish *ex situ* collection in Royal Botanic Gardens Victoria using tissue culture methods developed on *B. nitida* (Reiter 2009). Ensure collection includes maximum range of genetic diversity possible (Reiter *et al.* 2015).	High
	Establish translocated subpopulations in disease-free areas of suitable habitat. The species naturally occurs on a single sandstone outcrop and could be translocated to other peaks and sandstone outcrops within the vicinity of the wild subpopulation.	High
	Ensure all translocated subpopulations contain maximum range of genetic diversity present in wild population and are regularly monitored and managed (Reiter *et al.* 2015).	High
Habitat degradation (erosion)	Maintain soil stabilisation measures to prevent erosion with caging/ fencing and exclusion of vertebrate pests and foot traffic, especially after fires. Monitor subpopulation to ensure that vegetation in cages does not smother *B. mirabilis*.	High

Experts consulted

Noushka Reiter and Neville Walsh.

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Caladenia amoena D.L.Jones [ORCHIDACEAE]
Charming spider-orchid

Caladenia amoena flower and hairy leaf (image: Colin and Mischa Rowan).

Overview

Caladenia amoena is known from fewer than 50 individuals that occur over three locations. The species has undergone a rapid decline due to habitat loss and degradation, and much of its habitat remains unprotected. Recent research into germination requirements provides a promising opportunity for species recovery via *ex situ* propagation and subsequent translocation into secure tenure. However, two previous translocation attempts have failed to establish self-sustaining populations and future climate projections are unfavourable for emergence and flowering of the species.

Conservation status

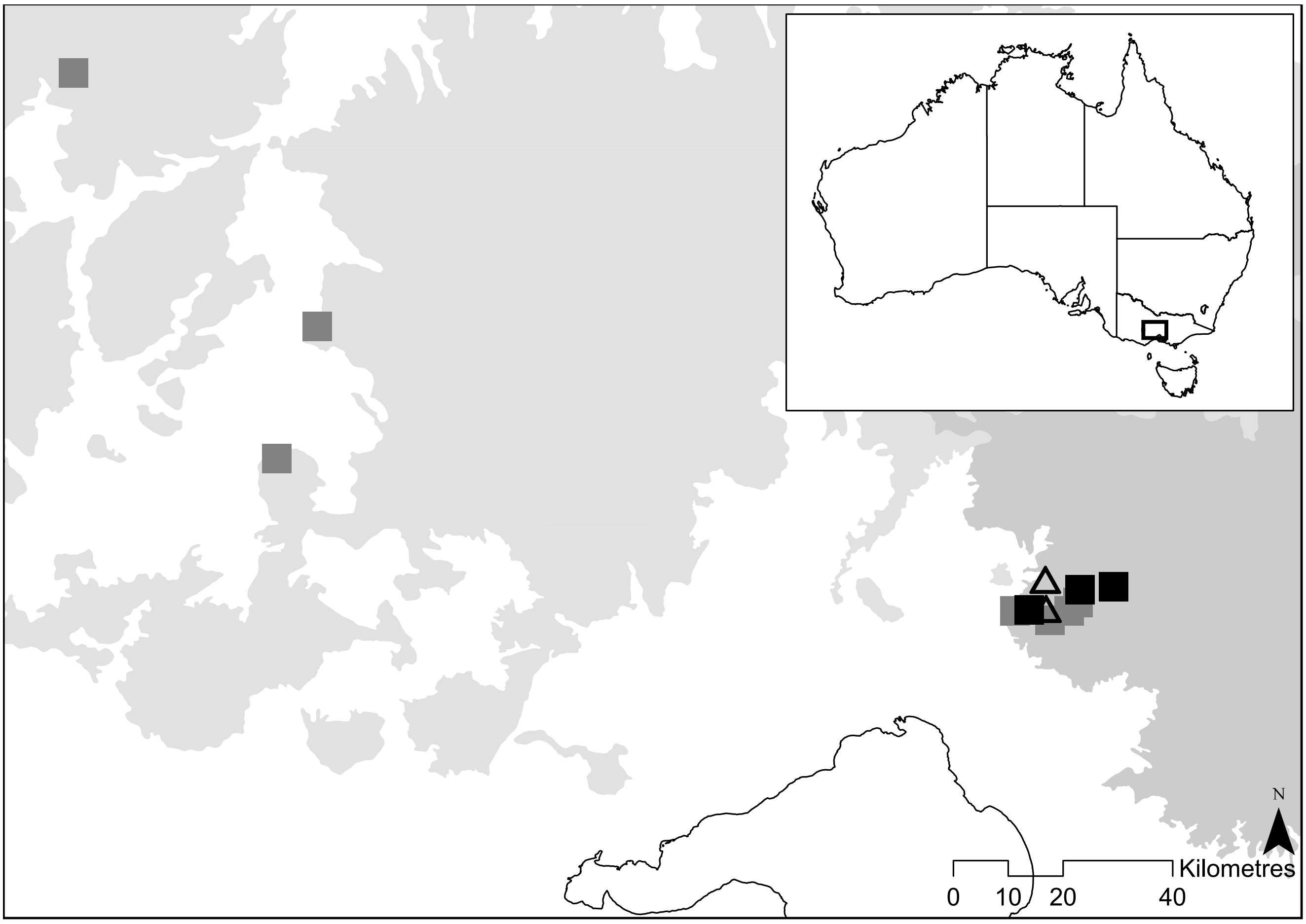
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Deciduous and hirsute terrestrial herb to 12 cm forming a spherical, subterranean tuber that is protected by a tough, fibrous tunic (Todd 2000). Leaves are lanceolate and densely hairy, 3-8 mm wide and 7-9 mm long with purple blotches at the base (Jones 1994). Bears a single (or rarely two) flower(s) 12-14 mm across with a yellow-cream perianth with red stripes (Jones 1994). It is similar to *C. concinna* and *C. toxochila* but differs in floral morphology and has a distinct distribution (Jones 1994).

Distribution

Caladenia amoena is known from a very restricted distribution near Melbourne; at Plenty Gorge Parklands, Boomers and Wattle Glen in the Victorian Midlands bioregion (Department of Agriculture, Water and the Environment 2012; Department of Environment, Land, Water and Planning 2020). Three collections from the Ballarat-Melbourne region in the 1930s and five collections from the Greensborough-Plenty-Hurstbridge areas from 1996-1998 indicate the species was once more widespread in central Victoria (Australasian Virtual Herbarium 2020).



Current (black squares) and historic (grey squares) distribution of *Caladenia amoena* in the South Eastern Highlands (shaded dark grey) and Victorian Midlands bioregions (shaded light grey) of Victoria (AVH 2020; DAWE 2012; DELWP 2020). The western-most extant subpopulation has been augmented, and an introduction has been established with propagated plants and individuals transplanted from Hurstbridge (hollow triangles; Janissen *et al.* 2021).

Population estimate and trends

Caladenia amoena is currently known from <50 mature individuals in three subpopulations. There are six mature individuals at Plenty Gorge Parklands, 26 at Hurstbridge, and a single individual at Boomers Reserve (C Beardsall pers.comm. 2019). In 2000, the species was known from two sites with 45 mature individuals (Todd 2000). One subpopulation was cleared shortly after it was documented (Jones 1994), and time-series monitoring data indicates ongoing declines at all extant subpopulations. Targeted searches have been undertaken at historical collection sites but the species has not been relocated here (Todd 2000).

The Plenty Gorge Parklands subpopulation was augmented with a small number of propagated plants in 2010, but only two emerged in 2019 (Janissen *et al.* 2021). More than 30 plants from the Hurstbridge site were transplanted to Yarrambat north of Plenty Gorge in 2004, but only nine survived in 2019. More than 90 propagated plants were planted at the same site in 2007. Despite some early success, only seven plants remained in 2019 (Janiessen *et al.* 2021).

Caladenia amoena monitoring data, 2000-2019 (G French and C Beardsall unpublished data; Janissen *et al.* 2021; Todd 2000).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Plenty Gorge Parklands (unreserved public land)	2000: 16 2005: 14 2007: 17 2008: 17 2010: 20 (19T) 2019: 6 (2T)	Decreasing
2 Hurstbridge (private property)	2000: 40 2005: 100 2019: 26	Decreasing
3 Boomers Reserve (conservation reserve)	2019: 1	Unknown
4a (T) Yarrambat – transplanted from Hurstbridge (conservation reserve)	2004: 35T 2005: 37T 2019: 9T	Decreasing
4b* (T) Yarrambat – introduction	2007: 95T 2010: 106T 2015: 28T 2019: 7T	Decreasing

Translocated individuals/subpopulation (T). *Includes two plantings.

Habitat and ecology

Caladenia amoena grows on ridges and sheltered slopes in dry grassy eucalypt woodlands in shallow clay loams derived from Silurian siltstone (Jones 1994; Todd 2000). Plants emerge annually in early autumn with a single leaf following soaking rains (Todd 2000). Flowering commences in late August, continuing for several weeks depending on climate and pollination (Todd 2000). The pollination of *C. amoena* is not documented, although may occur via pseudocopulation like other species in the genus (Todd 2000). Fruit develop over 5-8 weeks, releasing thousands of wind-dispersed seed by late October (Todd 2000). *Caladenia amoena* becomes dormant over summer as temperatures increase and soils become dry (Todd 2000). The longevity of *C. amoena* is not known, although could be up to 17 years (Carr 1999).

Caladenia amoena occurs in habitat with generally low fuel loads and infrequent fires (Todd 2000). Hot summer fires occur in the region that coincide with its period of dormancy (Todd 2000). The optimal time for fires for *C. amoena* is late summer or early autumn, after seed dispersal but prior to shoot growth (Todd 2000). Despite apparent fluctuations in population counts due to differences in emergence and flowering between years, extreme fluctuations (IUCN 2019) are considered unlikely as at least some individuals would persist as non-flowering tubers beneath the soil.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	7 km^2 (<1km^2) Decreasing	Medium Medium
Area of occupancy (actual) Trend	7 km^2 (<1km^2) Decreasing	Medium High
No. of mature individuals Trend	<50 Decreasing	Medium High
No. of locations (key threat) Trend	3 (all threats) Decreasing	Medium High
No. of subpopulations Trend	3 Decreasing	Medium High
Generation length	5-10 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented; and continuing decline observed in AOO, EOO, area/quality of habitat, number of locations/subpopulations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture and urban expansion has resulted in the decline and severe fragmentation of available habitat for the species (Todd 2000).
Herbivore grazing and trampling (feral and native) *Suspended*	Majority	Slow	Medium	*Caladenia amoena* is vulnerable to defoliation by rabbits while eastern grey kangaroos are in high numbers and have damaged *C. amoena* in Plenty Gorge Parklands. Most subpopulations are now fenced.
Invasive weeds *Suspended*	Whole	Slow	Medium	All subpopulations of *C. amoena* are small and invasive weeds are present, which increase competition and alter fuel loads. This may have substantial impacts on recruitment and overall population abundance (Duncan *et al*. 2005; 2010), however current management is apparently successful against annual weeds (Todd 2000)
Climate change *Ongoing*	Whole	Rapid	High	Emergence and flowering both declined with increasing maximum temperature between 2008 and 2019, and flowering was positively correlated with rainfall (Janissen *et al.* 2021). Climate change predicts increased temperature and decreased rainfall, which will reduce the growing season for the species and result in lower rates of emergence, flowering and recruitment.
Inappropriate fire regimes *Ongoing*	Whole	Negligible	Negligible	Although fires that occur in late autumn, winter and spring may burn plants before seed-set, the species generally occurs in areas with low fuels loads and infrequent fires (Todd 2000).
Human disturbance *Future*	Majority	Slow	Low	*Caladenia amoena* is potentially vulnerable to disturbance by mountain bike riders and foot-traffic as it occurs in close proximity to urbans areas on land not managed for conservation (Todd 2000).
Illegal collection *Future*	Whole	Slow	Low	Although there is no direct evidence of illegal collection, *C. amoena* occurs close to urban areas and may be targeted by orchid enthusiasts.
Stochastic events *Future*	Whole	Rapid	Medium	Given the small population and restricted distribution, *C. amoena* is vulnerable to stochastic events such as successive wildfires, future land management activities or prolonged drought.

Current management

- The species occurs in Plenty Gorge Parklands, which is partly managed for conservation.
- Fine-scale habitat management has been undertaken at all sites to increase seedling establishment (Wright *et al.* 2009).
- Three translocations have occurred: a small augmentation of propagated plants at Plenty Gorge Parklands, plants transplanted from Hurstbridge to Yarrambat, and introduction of propagated plants to Yarrambat. Despite early success, all translocated subpopulations declined to low numbers by 2019 (Janissen *et al.* 2021; Smith *et al.* 2005; Wright *et al.* 2009).
- An *ex situ* subpopulation was established and used for translocation, although these did not survive (N Reiter pers. comm. 2019).
- Research into the germination requirements and seed viability have been undertaken to optimise the symbiotic germination of the species (N Reiter pers.comm. 2019).

Conservation objectives

- Monitor and maintain known subpopulations.
- Increase understanding of the species' biology to inform management actions.
- Increase number of individuals and self-sustaining subpopulations in the wild via threat reduction and translocation.
- Establish *ex situ* subpopulation representing maximum range of genetic diversity for future translocation programs.

Information required

Theme	Specific actions	Priority
Population surveys	Identify and survey potential habitat for additional subpopulations during spring.	High
	Undertake regular monitoring to determine response to species to management actions and threats.	High
Life history and ecology	Undertake research to better understand the life history, ecology and germination requirements of the species including, disturbance ecology (fire, herbivory), pollination, seed production and viability, and habitat suitability for translocations.	High
Pollination ecology	Undertake research to identify pollinator(s) and their distribution throughout the habitat of *C. amoena*. Incorporate understanding of pollinators in selection of potential translocation sties.	High
Habitat requirements	Identify suitable habitat for future translocations into secure tenure.	High
	Undertake research to understand the microsite conditions required by plants for survival and successful recruitment to inform management of translocated sites.	High

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Establish *ex situ* collection for conservation and future translocation programs. Ensure collection represents maximum range of genetic diversity possible.	High
	Collect seed from all remaining individuals for conservation storage and propagation.	High
	Propagate large numbers of individuals for translocation into suitable sites.	High
Habitat protection	Protect habitat at Plenty Gorge and Wattle Glen in appropriate conservation agreements.	High
Invasive weeds	Control invasive weeds within known subpopulations and at identified translocation sites.	High

Theme	Specific actions	Priority
Vertebrate pests	Manage vertebrate pests to reduce grazing pressure. Maintain exclusion fencing/caging to reduce grazing pressure while individuals are aboveground and flowering.	High High
Extension and awareness	Raise awareness of species with relevant stakeholders in attempts to locate additional subpopulations.	Medium

Experts consulted

Noushka Reiter, Meg Cullen, Cam Beardsall, Garry French, Brendan Janissen and the *Caladenia amoena* Recovery Team.

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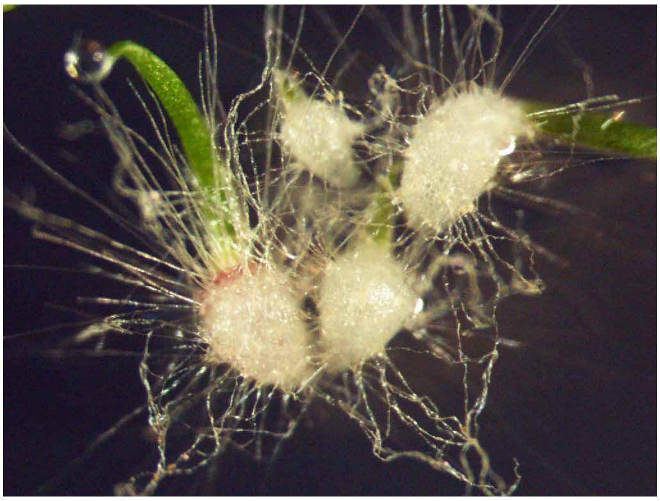
Caladenia busselliana Hopper & A.P.Brown [ORCHIDACEAE]
Bussell's spider-orchid



Flowers of one of the last remaining wild *Caladenia busselliana* plants (left) and green leaf (photosynthetic) stage of symbiotic *ex situ* germination (right; images: Belinda Davis).

Overview

Caladenia busselliana is known from three small subpopulations within a heavily fragmented and urbanising landscape. Although the subpopulations are protected in reserves they are declining due to invasive weeds, habitat disturbance (Hopper and Brown 2001), illegal collection and lack of recruitment. Further research is needed to understand the life history, mycorrhizal associations, pollination and limitations to recruitment. Recovery will involve continued habitat protection, monitoring and heavy investment from orchid specialists in research and translocation.

Conservation status

Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Critically Endangered

Brief description

Terrestrial ground-orchid occurring singly or in loose clumps (Paten *et al.* 2008). Bears a single, linear, erect and hairy leaf that often has irregular red-purple blotches towards the base. Inflorescence 20-30 cm tall with 1-3 creamy-yellow flowers 5-8 cm across with a 3-lobed labellum occasionally with pink-red radiating stripes and calli in four rows. Flowers are similar to *C. viridescens* and *C. paludosa*, but are paler-yellow with an entirely yellow labellum that is broader and longer, and with narrower sepal clubs (Hoffman and Brown 1998; Hopper and Brown 2001). The taxon is part of a complex and is difficult to distinguish based on genetic markers investigated to date, but has a distinct distribution (H Zimmer pers.comm. 2020).

Distribution

Caladenia busselliana is currently known from a very narrow geographic range between Vasse and Yallingup in the Swan Coastal Plain bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).

Current black polygon; encompasses extant subpopulations and historic (grey square) distribution of *Caladenia busselliana* in the Swan Coastal Plain bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020).

Population estimate and trends

Caladenia busselliana is currently known from four subpopulations comprising <50 individuals (DBCA 2020). The species was first recorded in 1954 at an orchid show from an unknown location (Patten *et al.* 2008). Surveys in 1990 found more than 100 plants in three subpopulations (Patten *et al.* 2008), but the largest of these is now presumed extinct. Monitoring at the two other subpopulations from 1991-2019 indicates the total number of flowering mature individuals has fluctuated between 2 and 63 plants, but has declined overall (Patten *et al.* 2008; DBCA 2020). An additional subpopulation of one individual was located in 2014, and another in 2019 that contained 3 individuals (DBCA 2020). One subpopulation was augmented with 140 seedlings in 2020, although it is too early to determine survivorship (T Llorens pers.comm. 2020). Targeted surveys have been conducted across the range of the species and it is unlikely additional subpopulations exist.

Habitat and ecology

Caladenia busselliana occurs on the margins of winter-wet swamps in grey, sandy loams with scattered limestone over clays (Paten *et al.* 2008). Associated species include *Eucalyptus marginata*, *E. calophylla, Xanthorrhoea preissii, Acacia pulchella, Hibbertia hypericoides, Hypocalymma robusta, Mesomelaena tetragona, Patersonia umbrosa* var. *xanthina, Agonis flexuosa, Anigozanthos manglesii* and *A. viridis* (Paten *et al.* 2008). The species also occurs alongside several other *Caladenia* spp. including *C. paludosa, C. procera, C. viridescens, C. flava* and *C. latifolia*, and hybrids with *C. viridescens* have been observed (Department of the Environment 2013).

Caladenia busselliana emerges from a dormant tuber following soaking autumn rains (Paten *et al.* 2008). Flowering occurs from mid-September to November, but depends on environmental conditions and may not occur every year (Paten *et al.* 2008). If flowers are pollinated, a capsule with up to 34 000 seeds will develop over 4-6 weeks (B Davis pers.comm. 2020). Seed germination and seedling establishment depends on mycorrhizal fungi associations (B Davis pers.comm. 2020). Over summer, the plants persist dormant underground (Paten *et al.* 2008). *Caladenia busselliana* reaches maturity at 2-3 years, and is probably long-lived, as other species in the genus survive for 20 to 40+ years (B Davis pers.comm. 2020). Generation length is estimated as >10 years. Despite apparent fluctuations due to differences in emergence and flowering between years, extreme fluctuations (IUCN 2019) are unlikely as at least some individuals persist as non-flowering tubers beneath the soil.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	13 km^2 Decreasing	High High
Area of occupancy (actual) Trend	12 km^2 (0.1 km^2) Decreasing	High High
No. of mature individuals Trend	<50 Decreasing	High High
No. of locations (key threat) Trend	4 (lack of recruitment) Decreasing	High High
No. of subpopulations Trend	4 Decreasing	High High
Generation length	>10 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for urbanisation and agriculture has resulted in the decline and severe fragmentation of available habitat for the species. All subpopulations are in Crown reserves or on private property that are not vested for conservation purposes, and urbanisation and associated impacts are increasing in the region.
Lack of recruitment *Ongoing*	Whole	Rapid	High	The population is declining and only minimal recruitment is occurring at all sites. This may be due to lack of pollinators, herbivory of both seed capsules and recruiting plants, an absence/patchy distribution of mycorrhizal fungi, soil compaction around parent plants due to trampling and climatic changes (Paten *et al.* 2008). As these threats can possibly be managed at the subpopulation scale, the species occurs at four locations.

Human activity *Ongoing*	Whole	Rapid	High	Although most subpopulations occur in reserves, the region is rapidly urbanising and bushland is subject to associated threats including weed invasion, recreational impacts and heavy visitation. Rubbish dumping has occurred at one site, but vehicle access is now prevented. One subpopulation is highly visited by orchid enthusiasts and this has caused serious damage to plants and their habitat. Plants have been illegally taken from one subpopulation.
Infrastructure maintenance *Ongoing*	Majority	Rapid	Medium	Part of one subpopulation occurs on a road verge and is vulnerable to infrastructure maintenance including grading, chemical spraying, drainage channel construction and slashing. Another subpopulation is adjacent to a powerline and telecommunications line that are regularly maintained.
Invasive weeds *Ongoing*	Whole	Slow	Medium	Invasive weeds are present at all subpopulations and increase competition and alter fuel loads and thus fire regimes. Invasive weed control has been undertaken and needs to be continued.
Grazing *Ongoing*	Majority	Slow	Medium	Quendas are known to disturb plants when digging for tubers. Rabbits may also disturb habitat and cause plant mortality via defoliation and burrow construction. Some subpopulations have been fenced to exclude grazing/foraging.
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	Many ground orchids flower more profusely after fire and may become outcompeted by other vegetation with a lack of fire, but fires that occur within the first 2 years of recruitment or when plants are actively-growing can kill plants. The optimum timing for fire is between December and March while *C. busselliana* is dormant.
Introduced pathogens *Ongoing*	Whole	Slow	Low	Some species in the habitat are vulnerable to phytophthora *Phytophthora cinnamomi* and marri canker *Quambalaria coyrecup*, which can cause a decline in habitat condition, with potential impacts on *C. busselliana* and its pollinators (A Webb, B Davis pers.comm. 2020).

Current management

- Recovery actions have been identified (Patten *et al.* 2008), including fencing, weed control, seed collection, and research into mycorrhizal fungi, pollinators, germination requirements and fire ecology.
- Seed and mycorrhizal strains have been collected from wild individuals and are held in long-term storage at the Western Australian Seed Centre at Kings Park. Seed has been collected from 11 individuals over all extant subpopulations and from one unknown location, with germination success ranging from 70% to 95% where testing has been performed. Multiple mycorrhizal isolates have been collected from four wild plants across three subpopulations and from one nursery plant. Testing for fungal efficacy has shown isolates promote between 20% and >80% germination (B Davis pers.comm. 2020).
- A germination protocol has been established for *C. busselliana* and an *ex situ* collection of approximately 100 plants has been propagated at the Kings Park Science Laboratory to create a seed and fungal orchard for conservation purposes and to provide additional plants to augment wild populations (B Davis pers.comm. 2020).
- One subpopulation was augmented with 140 seedlings in 2020, another 400 dormant plants will be translocated in summer 2020, with additional plantings to follow in winter 2021 (B Davis pers.comm. 2020).

Conservation objectives

- Monitor and maintain known subpopulations.
- Increase habitat quality at all sites in an attempt to promote and sustain natural recruitment.
- Increase the number of mature individuals and subpopulations in the wild via augmentation of existing subpopulations and introduction to secure tenure.
- Protect additional suitable habitat in appropriate conservation agreements.

Information required

Theme	Specific actions	Priority
Taxonomy	Undertake further studies with target sequence capture to define species complexes within this clade and obtain insights into the role of hybridisation in this group, and to increase understanding of species delimitation.	High
Population surveys	Monitor known subpopulations to better understand threats and response to ongoing recovery actions.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Lack of recruitment	Undertake research to better understand the mechanisms that limit recruitment, and management actions that can be implemented to increase recruitment.	High
Inappropriate fire regimes	Undertake research to better understand the disturbance ecology of the species, particularly in relation to fire. Determine a suitable fire regime for the species to increase the number of mature individuals.	High

Management actions required

Theme	Specific actions	Priority
Habitat quality	Maintain invasive weed control and herbivore exclusion fences to reduce grazing impacts. Increase habitat quality for pollinators.	High High
Ex situ conservation/translocations	Maintain and expand *ex situ* collection ensuring maximum range of genetic diversity possible is represented. Implement translocations into suitable habitat on secure tenure, including ongoing augmentation of existing subpopulations.	High High
Inappropriate fire regimes	Implement appropriate fire regime to maximise the number of mature individuals and reproductive capacity.	High
Habitat protection	Protect known habitat of species in appropriate conservation agreements.	High

Experts consulted

Andrew Webb, Ben Lullfitz, Natasha Moore, Belinda Davis and Tanya Llorens.

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Caladenia luteola Hopper & A.P.Brown [ORCHIDACEAE]
Lemon spider-orchid


Caladenia luteola flower (left) and habit (right; images: Jeremy Storey).

Overview

Caladenia luteola occurs in the heavily modified Avon Wheatbelt region of south-western Western Australia. The three known subpopulations have been declining for decades due to poor habitat condition, salinity and invasive weeds. Recovery efforts depend on ongoing monitoring, habitat protection and restoration, and establishment of an *ex situ* collection for future translocation.

Conservation status

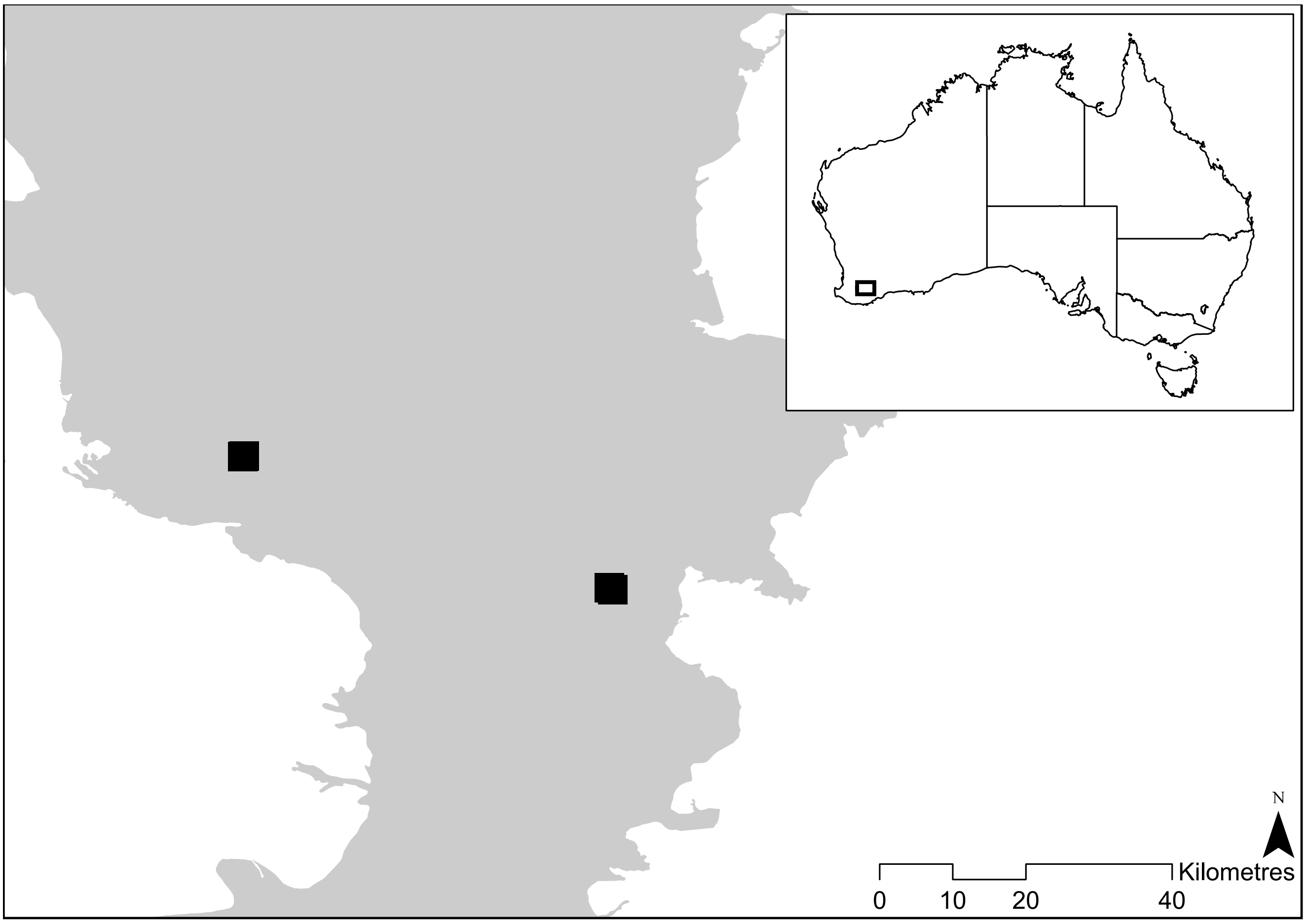
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Herbaceous perennial geophyte occurring singly or in clumps (Hopper and Brown 2001). Each plant has a single linear leaf 8-20 cm long and 3-5 mm wide with red-purple blotches at the base. Inflorescence 15-30 cm tall with 1-2 yellow-cream flowers 6-9 cm across with maroon-brown stripes. Labellum obscurely 3-lobed with entire margins and calli in 6-11 pairs. *Caladenia luteola* is similar to *C. caesarea, C. elegans* and *C. xantha*, but is distinguished by its paler-yellow-cream flowers, stiff obliquely descending lateral sepal apices, later flowering season and larger flowers (Hopper and Brown 2001).

Distribution

Caladenia luteola is known from a very narrow range near Woodanilling and Katanning in the Avon Wheatbelt bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution (black squares) of *Caladenia luteola* in the Avon Wheatbelt bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020). Note the two eastern subpopulations occur close together.

Population estimate and trends

Caladenia luteola is currently known from three subpopulations with 127 mature individuals (DBCA 2020). When the species was first collected at Woodanilling in 1985, it was known from >50 mature individuals (AVH 2020; Department of Parks and Wildlife 2016). Surveys from 2012-2015 located an additional subpopulation, while extending a known subpopulation with 32 individuals (DPW 2016). Both subpopulations at Woodanilling declined to zero plants by 2019, and the only mature individuals persist at Katanning. Monitoring, including repeated transects since 2011, has been conducted at the known sites. Subsequent targeted surveys have failed to locate additional subpopulations, although the plants may re-emerge at Woodanilling.

Caladenia luteola monitoring data, 1985-2019 (DBCA 2020; DPW 2016).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Woodanilling (unmanaged road reserve)	1985: 50 2011: 6 2013: 1 2014: 0 2019: 0	Decreasing
6 Katanning (unmanaged water reserve and adjacent private property)	2009: 50 2011: 216 2012: 213* 2014: 179 2015: 70 2016: 233 2017: 22 2018: 68 2019: 127	Fluctuating depending on seasonal rainfall
7 Woodanilling (private property)	2014: 1 2016: 25 2017: 0 2018: 3 2019: 0	Decreasing

* From 2012 includes additional plants recorded on adjacent private property (32 plants in 2012).

Habitat and ecology

Caladenia luteola occurs in sand and sandy clays amongst dense herbs in open woodland of *Eucalyptus wandoo*, *E. longicornis, Allocasuarina huegeliana* and *Acacia acuminata* (DPW 2016). Flowering occurs from September to early October and fruits mature by late November (DPW 2016). On rare occasions *C. luteola* can hybridise with *C. caesarea* subsp. *caesarea* (Hopper and Brown 2001). Less flowering occurs in years of poor rainfall (DPW 2016). The species can reproduce in the absence of disturbance and mycorrhizal fungi are required for seed germination (Swarts *et al.* 2010). Generation length is not precisely known, but other species in the genus may live to up to 40 years (see *C. busselliana* profile). Seedbank dynamics of the species are unknown, although *C. luteola* is a relatively long-lived perennial whose plants can survive disturbance such as fire, and therefore extreme fluctuations are not likely.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	26 km^2 Decreasing	High High
Area of occupancy (actual) Trend	8 km^2 (0.01 km^2) Decreasing	High High
No. of mature individuals Trend	127 Decreasing	High High
No. of locations (key threat) Trend	3 (lack of recruitment) Decreasing	High High
No. of subpopulations Trend	3 Decreasing	High High
Generation length	>10 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, number of mature individuals.
C2a(ii)	CR: <250 mature individuals; continuing decline observed and projected; and 90-100% (98%) of mature individuals in one subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing, mainly for agriculture, has resulted in the decline and severe fragmentation of the species. The three subpopulations of *C. luteola* occur in tiny remnants in two general areas separated by 47 km of heavily cleared land.
Lack of recruitment *Ongoing*	Whole	Rapid	High	Recruitment is minimal at two of three subpopulations and low fruit set has been observed. A long-term trend of declining rainfall is suspected to contribute to this threat (DPW 2016).
Altered hydrology *Ongoing*	Minority	Rapid	Medium	The Woodanilling reserve subpopulation occurs in habitat that is becoming increasingly saline, and on creeklines subject to inundation and therefore exposed to saline run-off (DPW 2016). Changes to groundwater levels are a potential future threat to the other two subpopulations.
Infrastructure maintenance *Ongoing*	Majority	Rapid	Medium	Two sites are vulnerable to road maintenance activities, especially road widening and drainage maintenance (DPW 2016).
Grazing (feral and native) *Ongoing*	Minority	Slow	Low	Grazing by rabbits and macropods has been observed at one subpopulation (DPW 2016).
Invasive weeds *Ongoing*	Minority	Slow	Low	Invasive weeds are currently restricted to creeks and margins of Woodanilling Reserve and are considered a future threat at the other two subpopulations (Threatened Species Scientific Committee 2018).
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	Fires that occur during the active growing and reproductive period of the species (winter-spring) may limit recruitment and kill plants. Disturbance is not required for flowering to occur (DPW 2016).
Climate change *Ongoing*	Whole	Slow	Low	Flowering occurs at lower rates in years where rainfall is poor (DPW 2016). Given the trend of climatic drying in the region (Hope *et al.* 2015), flowering rates and therefore recruitment may continue to decline.

Current management

- Recovery actions have been identified (DPW 2016; TSSC 2018).
- The species is not protected in conservation reserves.
- Seed has been collected from two wild individuals at the Woodanilling road reserve and is held in long term storage at the Western Australian Seed Centre and the Millennium Seed Bank. No mycorrhizal strains are currently held in the collection. The germinability of the stored seed is unknown.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Establish an *ex situ* conservation collection to support future translocation efforts.
- Increase the number of mature individuals and subpopulations in the wild by improving habitat quality and implementing translocations (augmentation and introductions).

Information required

Theme	Specific actions	Priority
Taxonomy	Undertake further genetic analysis of the *C. caesarea-C. luteola* species complex.	High
Population surveys	Monitor response of species to threats and recovery actions.	High
Ex situ conservation/translocations	Identify methods to successfully propagate the species *ex situ*, including seed germination trials, isolating mychorrizal fungi and pollinator studies.	High
Altered hydrology	Undertake research to better understand the potential impacts of salinity on the species, including the role of changes to groundwater levels.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Establish *ex situ* collection representing maximum range of genetic diversity possible.	High
	Undertake translocations (if feasible) by augmenting wild subpopulations and introducing species to suitable habitat on secure tenure.	High
Habitat protection and restoration	Protect known sites and potential habitat in appropriate conservation agreements.	High
	Undertake weed control and manage fire to protect the species and maintain habitat condition.	High
Infrastructure maintenance	Protect subpopulation near roadside from road maintenance activities via extension and awareness, marking the area, or fencing.	High

Experts consulted

Andrew Brown, Belinda Davis and Tanya Llorens.

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Caladenia pumila R.S.Rogers [ORCHIDACEAE]
Dwarf spider-orchid

Caladenia pumila flowering (image: Neil Anderton).

Overview

Caladenia pumila is known from two individuals in the heavily cleared landscape southwest of Melbourne. It was previously 'locally common' but not seen between 1926 and 2009 when it was relocated. There is no natural recruitment occurring within the population despite intensive ongoing management. *Ex situ* conservation at the Royal Botanic Gardens Victoria has been successful, with approximately 100 seedlings and 11 mature individuals propagated from seed with a long-term view to translocation.

Conservation status

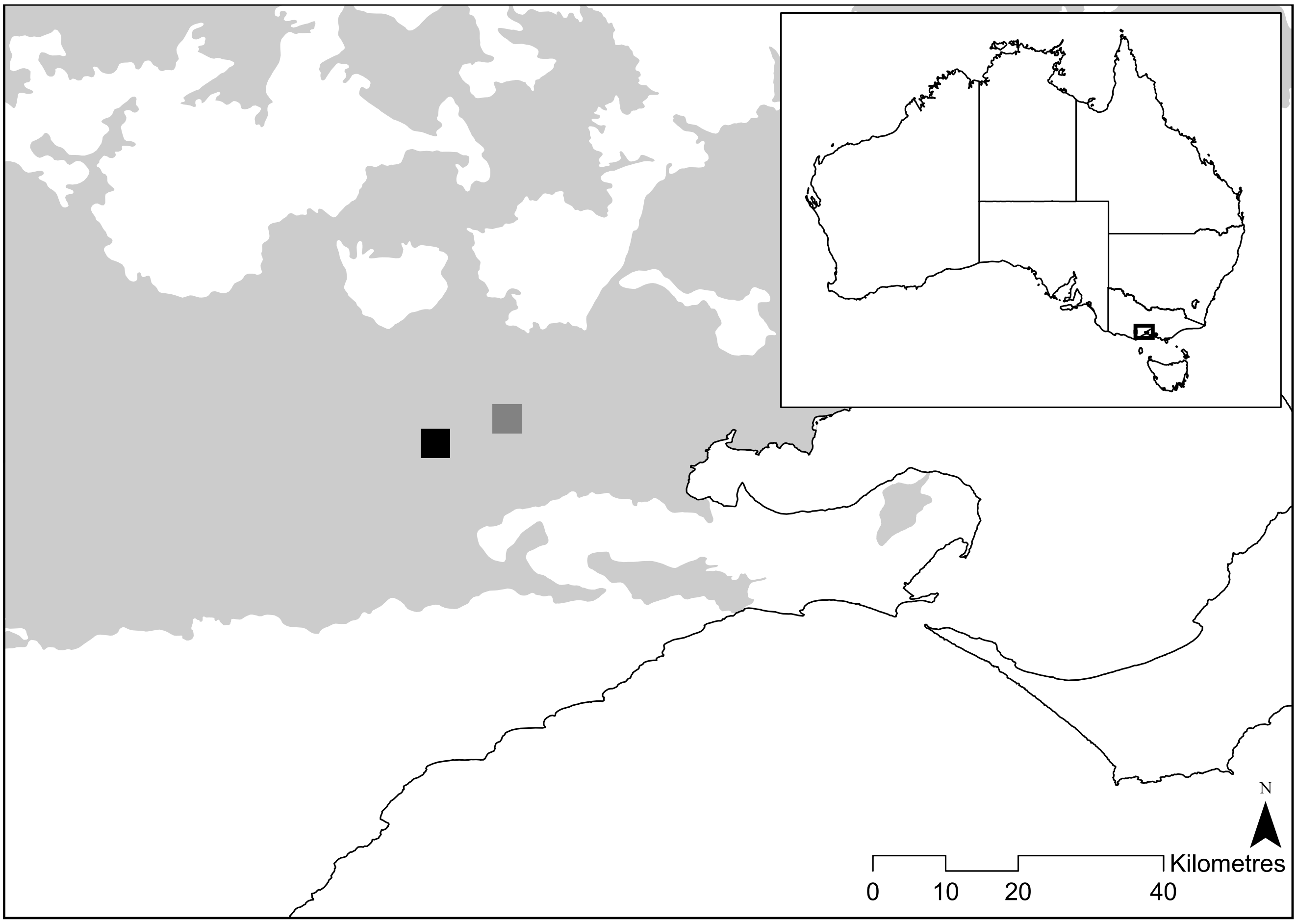
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Critically Endangered

Brief description

Deciduous, perennial geophyte 10-15 cm tall, with a single, lanceolate, fleshy, hairy, basal leaf 6-8 cm long and 5-15 mm wide (Rogers 1922; Entwisle 1994). Bears a single flower 50-60 mm across, with white petals and a pink labellum. Sepals and petals to 40 mm long with a broad base and deflexed tips. Petals taper to a short tail and sepals taper to an indistinct green club. Dorsal sepal erect, lateral sepals spreading. Labellum 17 mm long and 8 mm wide, margins entire except a few irregular teeth at the base of the mid-lobe, upper surface with 4-6 rows of short, widely-spaced callii (Rogers 1922; Entwisle 1994). *Caladenia pumila* is distinguished from other *Caladenia* species by its short stature, single white-pink flower, nearly entire labellum margins on half of the labellum and short sepal clubs (Rogers 1922; Entwisle 1994). However, clubbing is variable and sometimes absent, as in all propagated individuals perhaps due to inbreeding (N Reiter pers.comm. 2020).

Distribution

Caladenia pumila is only known from the Bannockburn area ca. 25 km northwest of Geelong in the Southern Volcanic Plain bioregion (Australasian Virtual Herbarium 2020; Deparment of Agriculture, Water and the Environment 2012; Department of Environment, Land, Water and Planning 2020).



Current (black square) and historic (grey square) distribution of *Caladenia pumila* near Bannockburn in the Southern Volcanic Plain bioregion (shaded grey) of Victoria (AVH 2020; DAWE 2012; DELWP 2020).

Population estimate and trends

*Caladenia pumila i*s currently known from two mature individuals. Once 'locally common' in the Bannockburn region, *C. pumila* was not seen after 1926 until it was relocated in a nearby reserve in 2009 by community members (Duncan 2015). Despite searching, the species has not been detected at Bannockburn or other suitable habitat. Although further searching is warranted given the species can persist undetected as a tuber for successive years, it is unlikely additional large subpopulations of the species persist (Duncan 2015).

Habitat and ecology

Caladenia pumila occurs in open, grassy, herb-rich woodlands on moist flats and hillslopes in grey sandy loam soils (Backhouse 2011). Associated species include *Acacia paradoxa, Arthropodium strictum, Chamaescilla corymbosa, Chrysocephalum apiculatum, Dillwynia hispida, Diuris chryseopsis, Drosera aberrans, Glycine latrobeana, Goodenia geniculata, Kennedia protrata, Microleana stipoides, Pimelea humilis, Stackhousia momhyna, Themeda triandra* and *Wurmbea dioica* (Duncan 2015).

Caladenia pumila emerges annually from a spherical, subterranean tuber covered in a tough, fibrous sheath. After a period of dormancy in summer, the basal leaf emerges in winter following soaking autumn rains. During the growing season, the tuber is replaced by a 'daughter' tuber and flowers appear from September. The pollination strategy of *C. pumila* is unknown and could be either food-rewarding, food-deceptive or sexually-deceptive, as *Caladenia* spp. are known to have multiple pollination strategies (e.g. Stoutamire 1983; Phillips and Peakall 2018; Reiter *et al.* 2018a, 2019). Seed production depends on the presence of pollinators, receptiveness of the stigma to pollen and climate.

Pollinated flowers mature into a capsule over 5-8 weeks, each containing thousands of microscopic wind-dispersed seeds (Duncan 2015). Mycorrhizal fungi (*Serendipita* OTUA) are essential for growth and seed germination in *C. pumila* (Reiter *et al.* 2020).

The longevity of *C. pumila* under ideal conditions is not known, but *C. hastata* can survive for 17 years (Carr 1999) and *C. rosella* plants at least 30 years (C Beardsell pers.comm. 2014). Strong flowering responses after fire have been observed in several *Caladenia* spp., although fires must occur after seed dispersal but prior to new shoot growth (i.e. summer to early autumn). Lack of disturbance especially fire and poor rainfall can cause prolonged dormancy that is associated with premature plant death (Coates and Duncan 2008). Seedbank dynamics of the species are unknown, although *C. pumila* is a relatively long-lived perennial that can survive disturbance such as fire, and therefore extreme fluctuations are not likely.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (<0.0001 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.0001 km^2) Decreasing	High High
No. of locations (key threat) Trend	1 (lack of recruitment) Decreasing	High High
No. of subpopulations Trend	1 Decreasing	High High
No. of mature individuals Trend	2 Decreasing	High High
Generation length	10 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; continuing decline observed and projected in AOO, EOO, quality of habitat, number of locations and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss and fragmentation *Past*	n/a	n/a	n/a	Extensive land clearing for urbanisation and agriculture has occurred throughout the habitat of *C. pumila*. The species occurs within the Critically Endangered Natural Temperate Grassland and Grassy Eucalypt Woodland of the Victorian Volcanic Plain ecosystem, of which <5% remains. The species is severely fragmented as most habitat remnants are small (<10 ha), with ongoing degradation and impaired ecosystem function (Threatened Species Scientific Committee 2008).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Herbivory/ soil disturbance *Suspended*	Whole	Rapid	Medium	Rabbits, hares, echidnas, macropods and possums have been observed browsing/digging near *C. pumila*, and are known to impact other species in the genus. Known individuals and habitat have been caged and fenced, but any additional plants may be browsed or disturbed before they are detected and fenced. Invertebrate eggs have been observed on *C. pumila* capsules, but their impact is unknown (N Anderton pers.comm. in Duncan 2015).
Lack of recruitment *Ongoing*	Whole	Very rapid	High	Since the species was relocated in 2009, no recruitment has been observed despite intensive management (Duncan 2015). No seed drop has occurred since 2009 due to irregular flowering and seed collection for propagation (N Reiter pers.comm. 2020). Seed is mostly sterile, with germination trials showing viability of 0.1% (N Reiter pers.comm. 2020).
Poor genetic diversity *Ongoing*	Whole	Rapid	High	Given there are only two extant individuals known, *C. pumila* probably has a severely reduced genetic base. The species only produces one flower per year and only one of the two individuals flowered from 2011-2013 (Duncan 2015). As of 2015, only six seedpods had been produced (Duncan 2015) and most seed is sterile (N Reiter pers.comm. 2020). Poor genetic diversity can decrease resilience to environmental change.
Invasive weeds/ vegetation change *Ongoing*	Whole	Slow	Medium	*Caladenia pumila* inhabits open areas where encroachment by native vegetation, particularly hedge wattle *Acacia paradoxa* is occurring (Duncan 2015). This pioneer species has potential to alter the open vegetation structure of the area, which can cause declines in grassland orchids (Todd 2000). The habitat of the species is also vulnerable to invasion by perennial grasses that may increase competition, and alter fuel loads and thus fire regimes (Todd 2000).
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	As with other species in the genus, fires in late spring to autumn during the growing season are likely to have negative population effects (Todd 2000). Successive fires during this time can limit reproduction and may cause plant death, while the absence of fire may contribute to lack of recruitment (Coates and Duncan 2009; Duncan 2015; Todd 2000). Local knowledge indicates there have been no fires at the site since at least 1950 (N Anderton pers.comm. 2020).
Illegal collection *Future*	Whole	Very rapid	Medium	*Caladenia pumila* is a very rare, charismatic species, and is vulnerable to illegal collection by orchid enthusiasts (Duncan 2015), especially as the location is well-documented. Individuals that have not yet been detected by threatened species managers are also vulnerable to collection.
Recreational activities *Suspended and future*	Whole	Rapid	Medium	The reserve where *C. pumila* occurs is close to suburbia and used regularly by bushwalkers, campers, trail bike riders and 4WD vehicles (Duncan 2015). The habitat has been fenced, but incursions are possible in the future.

Current management

- A Recovery Team of government and non-government partners was established in 2011. Recovery actions have been identified in an action statement (Duncan 2015) and implemented, including monitoring three times per annum, a sign erected to deter illegal collection, and stakeholder engagement to raise awareness of the species.
- An *ex situ* conservation program commenced in 2009 at the Royal Botanic Gardens Victoria; both flowers were cross-pollinated by hand in 2009 and 2010, seed from wild plants was collected (2009-2014), germination techniques have been identified including isolation of mychorrhizal fungi (2009) and propagation is ongoing, with 11 individuals successfully propagated by 2013.
- Measures to protect the extant plants and improve habitat quality have been implemented, including caging to prevent herbivory (2009) and fencing of the broader area to reduce grazing pressure and risk of damage by recreation (2010). The fenced area will be doubled in 2021 to approximately two hectares. Manual removal of hedge wattle to maintain the open grassland vegetation commenced in 2011. Controlled grazing under a browsing management plan occurs within exclosures while the plants are dormant to reduce biomass/competition of native vegetation. Hand cutting of vegetation is ongoing. Rabbit control is ongoing throughout the reserve (Duncan 2015). Biomass density is assessed annually (N Anderton pers.comm. 2020).

Conservation objectives

- Maintain current management activities and adapt in accordance with latest research.
- Increase the number of mature individuals and subpopulations in the wild via further survey (detect additional individuals), augmentation of known subpopulation and translocation to other secure tenure to reduce extinction risk.
- Increase knowledge of species' biology and ecology to inform management requirements.
- Secure additional suitable habitat in conservation agreements.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the seed production and viability of the species.	High
	Undertake research to determine the role of vegetation competition, disturbance and herbivory on the longevity of the species.	High
	Determine limitations to recruitment in the naturally occurring subpopulation. Determine micro-habitat requirements of the species for successful seed germination, growth and reproduction.	High
	Identify pollination mechanism and pollinator(s) of the species, along with their presence at any potential translocation site and their ecological requirements.	High
Ex situ conservation/translocations	Identify sites of suitable habitat with secure tenure that have other *Caladenia* spp. present that share *Serendipita* OTUA (Reiter *et al.* 2020) and the pollinator present for establishing translocated populations (Reiter *et al.* 2018b).	High
	Identify fine-scale habitat requirements in preparation for translocation.	High
Population surveys	Monitor response of subpopulations to threats and management actions.	High
	Undertake targeted surveys in other suitable habitat to locate additional subpopulations, particularly after disturbance.	Medium

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Maintain propagation program ensuring maximum range of genetic diversity possible is captured, with view to implement translocations (augmentation, introductions). Develop and implement translocation plan. Reinforce wild subpopulations with propagated individuals to increase population abundance, and implement translocations to secure suitable habitat.	High High High
Habitat protection	Protect habitat of the species on private land in appropriate conservation agreements.	High
Habitat quality	Develop and implement fire management strategy for the species. Maintain management of invasive weeds and vertebrate pests nearby individuals of *C. pumila*, and also in wider areas of suitable habitat where individuals may persist as dormant plants. Continue micro-habitat management in accordance with current research (e.g. hand-cutting dense vegetation, watering during drought).	High High High
Recreational activities	Divert recreational activities from areas of the reserve where known and potential habitat for *C. pumila* occurs.	High
Illegal collection	Install camera surveillance and a locked gate to deter illegal collection.	High
Extension and awareness	Maintain engagement with relevant landholders that are custodians of the species. Raise awareness with other stakeholders in the area in an attempt to locate additional subpopulations.	Medium

Experts consulted

Noushka Reiter and Neil Anderton.

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Calochilus richiae Nicholls [ORCHIDACEAE]
Bald-tip beard orchid

Calochilus richiae flower (image: Jeff Jeanes, State Botanical Collection, Royal Botanic Gardens Victoria).

Overview

Calochilus richiae is one of Australia's rarest orchids, known from a single, declining population of <10 mature individuals. Recovery actions have been implemented including fencing to exclude herbivores, *ex situ* propagation and hand-watering during dry periods. The population remains vulnerable to grazing and illegal collection by orchid enthusiasts, and further *in situ* recovery options are limited.

Conservation status

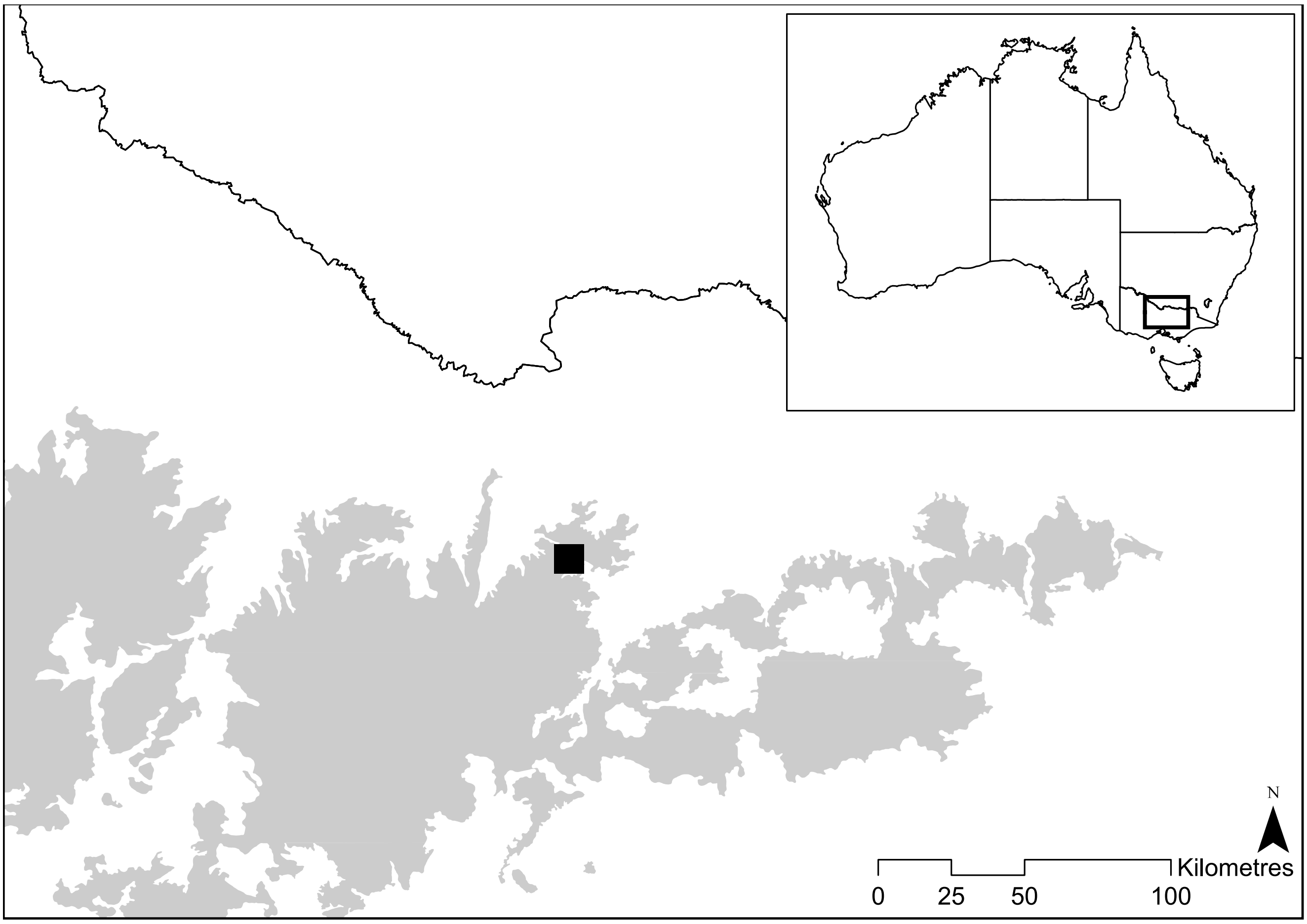
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare and Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Terrestrial, perennial herb with a single, dark-green leaf emerging annually from a subterranean tuber. Inflorescence to 35 cm with up to five yellow-green flowers with red-brown stripes on an open raceme. Labellum ovate, covered with short purple calli on the basal two-thirds and a glabrous, curved apex (Entwisle 1994). There is low genetic divergence and unclear species delimitation to closely-related taxa including *C. robertsonii* and *C. platychilus*, however it is morphologically distinct due to labellum calli (H Zimmer pers.comm. 2020).

Distribution

Calochilus richiae is known from a single site near Rushworth in north-central Victoria in the Victorian Midlands bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Environment, Land, Water and Planning 2020). There is no evidence that the species was formerly more widespread, and it is not considered severely fragmented (IUCN 2019).



Current distribution (black square) of *Calochilus richiae* in the Victorian Midlands bioregion (shaded grey) of Victoria (AVH 2020; DAWE 2012; DELWP 2020).

Population estimate and trends

Calochilus richiae was first collected in 1928 but not seen again until 1968 when the currently known subpopulation was relocated (AVH 2020; DELWP 2020; Duncan 2010). Twenty-three individuals were present in 1980, which declined rapidly to six in 1988 and only four individuals have been seen since 1988 (Duncan 2010). Some targeted surveys have been undertaken and additional subpopulations have not been located.

Calochilus richiae monitoring data, 1968-2010 (Duncan 2010).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Rushworth (conservation reserve)	1968: present 1980: 23 1981: 21 1984: 12 1988: 6 1995: 6 1996: 1 1998: 4 2000: 4	Decreasing

Habitat and ecology

Calochilus richiae occurs in dry heathy forest on shallow stony clay loams over Devonian sandstone and interbedded siltstone (Duncan 2010). The habitat is dominated by *Eucalyptus macrorhyncha* and *E. polyanthemus* with a shrubby understorey of *Acacia pycnantha, A. paradoxa, Leucopogon virgatus, Daviesia ulicifolia, Dianella revoluta, Grevillea alpina, Brachyloma daphnoides, Cassinia sifton* and *Xanthorrhoea australis*. The sparese ground layer is dominated by *Rytidosperma pallidum* (Duncan 2010).

Little is known of the species biology and ecology. *Calochilus richiae* is a deciduous geophyte that emerges annually from late spring, typically after soaking rains (Duncan 2010). Flowering is brief and occurs in October. Pollination is via sexual deception of male scollid wasps (Duncan 2010). Fruits develop over 5-8 weeks with each capsule containing thousands of wind-dispersed seeds (Duncan 2010).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (<0.01 km^2) Decreasing	Medium High
Area of occupancy (actual) Trend	4 km^2 (0.01 km^2) Decreasing	Medium High
No. of mature individuals Trend	<10 Decreasing	Medium High
No. of locations (key threat) Trend	1 (all threats) Decreasing	Medium High
No. of subpopulations Trend	1 Decreasing	Medium High
Generation length	Unknown	n/a
Extreme fluctuations	Not documented	Medium
Severely fragmented	No	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; 1 location; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations and number of mature individuals.
C2a(i,ii)	CR: <250 mature individuals, continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Extractive industry *Past*	n/a	n/a	n/a	Gold mining was present in the habitat of this species for many years (Duncan 2010).
Timber harvesting *Past*	n/a	n/a	n/a	The only known subpopulation occurs in former state forest (now a conservation reserve) where timber harvesting caused habitat change and disturbance (Duncan 2010).
Herbivore grazing (native) *Suspended*	Whole	Rapid	Medium	*Calochilus richiae* is vulnerable to grazing by macropods. In 1989, six of the 11 maturing seed capsules were eaten, and in 2004, two of four plants were defoliated (Duncan 2010). The subpopulation is now fenced.
Illegal collection and human trampling *Ongoing*	Whole	Rapid	High	There is anecdotal evidence that ~12 individuals were collected in the early 1980s. During one season, a local enthusiast removed all flowering stems to discourage collection. The location is well-known by orchid enthusiasts, who threaten the population with illegal collection and trampling (Duncan 2010).
Invasive weeds *Ongoing*	Whole	Negligible	Negligible	Invasive weeds are not prevalent in this habitat and are considered a minor threat to the species (Duncan 2010).
Climate change *Future*	Whole	Slow	Medium	Prolonged drought is thought to be causing premature abortion of flowers and overall lower recruitment (Duncan 2010).
Stochastic events *Future*	Whole	Very rapid	Medium	The restricted range and small population size render *C. richiae* vulnerable to stochastic events.

Current management

- Recovery actions have been identified in the recovery plan (Duncan 2010).
- The species protected within a conservation reserve.
- By 2003, the site was fenced, seed was collected and a permanent monitoring transect had been established (Duncan 2010). Seed successfully germinated under laboratory conditions however establishment in soil has been unsuccessful.
- No translocations have been undertaken.

Conservation objectives

- Monitor and maintain known subpopulation.
- Reduce collective impact of threats through intensive site management.
- Detect more subpopulations through targeted surveys.
- Establish an *ex situ* collection to facilitate research and translocation.
- Increase the number of mature individuals and subpopulations in the wild via translocation (augmentation and introductions).

Information required

Theme	Specific actions	Priority
Taxonomy	Undertaken further genetic studies to define relationship to closely related species including C. *robertsonii* and *C. platychilus*.	High
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations.	High
	Maintain regular monitoring to assess population response to management activities and threats.	High
Germination requirements/seed viability	Undertake trials to determine seed viability, germination cues and requirements for successful establishment in controlled and natural conditions.	High
Habitat requirements	Undertake research to identify habitat requirements, including possible micro-site preferences in preparation for future translocation efforts and intensive site management.	High
	Identify areas of suitable habitat for translocation to secure tenure.	High
Illegal collection	Investigate additional options to decrease illegal collection.	High

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Establish *ex situ* subpopulation as a conservation collection, with maximum range of genetic diversity.	High
	Propagate large numbers of individuals for translocation including augmentation of wild subpopulation and into other areas of suitable habitat.	High
Climate change/stochastic events	Hand water plants during flowering/ fruiting season if weather is persistently dry.	High
	Establish *ex situ* conservation collection as an insurance population for future augmentation of wild subpopulations or reintroduction if extant sites become extinct.	High
Grazing/herbivory	Maintain exclusion fence to reduce herbivory.	High
	Investigate other options (i.e. culling, caging) to reduce the impacts of herbivory.	Medium
Invasive weeds	Control invasive weeds in extant population and in potential translocation sites.	Low

Experts consulted

Neville Walsh, Gary Backhouse and Jeff Jeanes.

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Commersonia erythrogyna C.F.Wilkins [MALVACEAE] Trigwell's rulingia

Commersonia erythrogyna flowers (left), fruits and leaves (right), at Kings Park and Botanic Garden (images: Russell Cumming).

Overview

Commersonia erythrogyna (formerly *Rulingia* sp. Trigwell Bridge) is known from a single wild population on a rocky ridge amongst cleared farmland, but no plants have been seen here since 2012. Five translocations have been undertaken but none have successfully established. Mechanisms of decline are not well-understood but probably relate to lack of high-intensity fires to stimulate germination and a declining rainfall trend.

Conservation status

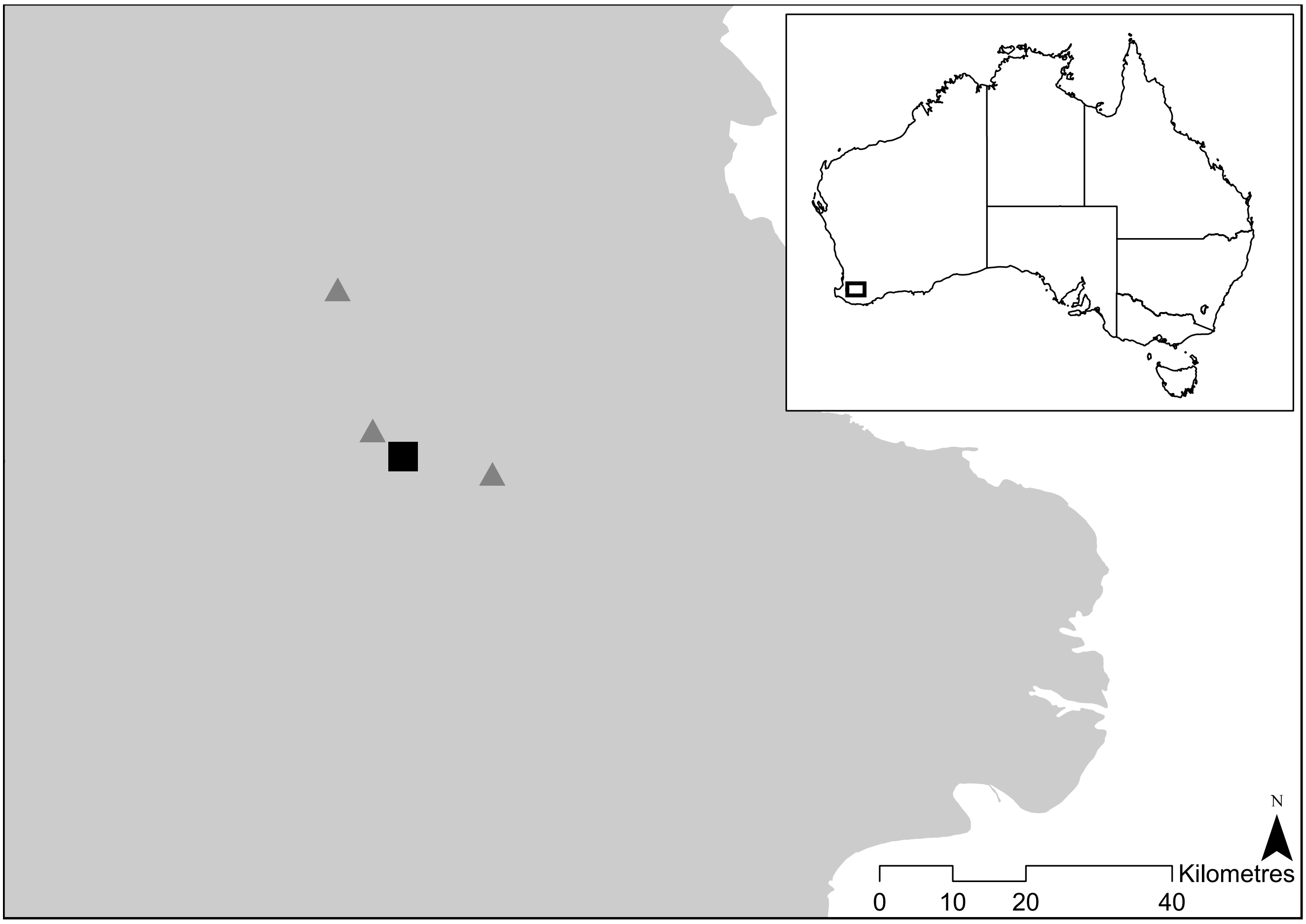
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect, spreading shrub to 3 m with star-shaped hairs covering the branches and leaves (Wilkins and Whitlock 2011). Narrow, deciduous stipules arise from the base of the petioles with the upper stipules often divided into lobes. Inflorescence terminal, 7.5-11.5 mm long with 3-7 white flowers with dark red anthers. Flower buds are strongly ribbed, petals have a broad base that extends to a narrow ligule and are equal or shorter in length than the sepals. Fruit white-brown, ellipsoid, 9.5-12.8 mm long and 6-8 mm wide. *Commersonia erythrogyna* is distinguished by the pink-red ovary hairs and glabrous inner calyx and petal ligule (Wilkins and Whitlock 2011).

Distribution

Commersonia erythrogyna is known from a very restricted distribution near Booyup (Boyup Brook) within the Jarrah Forest bioregion of south-western Western Australia (Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020). No plants have been observed since 2012, but the species may persist in the soil seedbank. Five translocations have been undertaken nearby, but only two plants survive.



Current distribution (black square) of *Commersonia erythrogyna* in the Jarrah Forest bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020). Five translocated subpopulations were established but have been unsuccessful (three are displayed as grey triangles; Silcock *et al.* 2019).

Population estimate and trends

Commersonia erythrogyna is known from a single subpopulation in remnant woodland surrounded by farmland (Wilkins and Whitlock 2011). Since the species was first collected in 1989, fewer than four wild plants have been known (Australasian Virtual Herbarium 2020; DBCA 2020). Two juvenile plants present in 1992 survived to maturity in 1995 (Stack and Brown 2003). The subpopulation declined thereafter and no plants have been seen since 2012, although the species may persist here in the soil seedbank. Targeted surveys have been conducted in similar habitat and no additional wild subpopulations have been located.

Five translocated subpopulations were established between 1997 and 2001 by planting *ex situ* propagated plants and conducting trial burns using buried seed (Stack and Brown 2003; Silcock *et al.* 2019). In 2003, these translocations were estimated to contain 130 mature individuals and 300 juveniles (Stack and Brown 2003). The health of all translocated subpopulations has declined and only two plants remain (A Webb pers.comm. 2018). Access to water appears to have been insufficient for plant survival, indicating the translocation sites were unsuitable.

Commersonia erythrogyna monitoring data, 1992-2018 (AVH 2020; DBCA 2020). Five translocated subpopulations were established, but only two plants remain across all sites (Silcock *et al*. 2019).

Subpopulation (tenure)	Number of mature individuals (juveniles) [dead]	Trend
1 Booyup (Boyup Brook) (private property)	1989: 3 [1] 1992: 2 (2) 1995: 4 1998: 4 2001: 3 2002: 2 2007-2012: 1 2014-2018: 0	Decreasing

Habitat and ecology

The single wild subpopulation is found on a lateritic ridge supporting low open jarrah *Eucalyptus marginata* and marri *Corymbia calophylla* woodland, with plants growing in small fissures in the rock (Wilkins and Whitlock 2011). This may not be the preferred habitat for the species, as it may have survived here due to respite from grazing (Stack and Brown 2003). Associated species include *Banksia grandis, Xanthorrhoea preissii, Macrozamia riedlei, Billardiera heterophylla* and *Acacia pulchella*. Translocations into more fertile, laterite-rich soils in less exposed areas have shown poor survival, possibly because plants had limited moisture access compared with the plants growing in rock fissures.

Commersonia erythrogyna flowers between August and October (Wilkins and Whitlock 2011). Individuals grown in cultivation are vigorous and can reach reproductive maturity within 1 year (Stack and Brown 2003). Observations of the wild population found that 60% of flowers produced fruit with 5000 seeds per plant (Stack and Brown 2003). Seed remains viable in the soil for at least 7 years, so extreme fluctuations are not likely. Germination is maximised after high intensity fires (>50°C and >10 minutes duration), but is not influenced by smoke (Stack and Brown 2003).

Ringneck parrots *Barnardius zonarius* have been observed consuming the fruit of *C. erythrogyna* and the foliage is palatable to domestic stock and rabbits (Stack and Brown 2003). This species does not appear to be susceptible to *Phytophthora cinnamomi* (Stack and Brown 2003).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	4 km^2 Decreasing	Low Medium
Area of occupancy (actual) Trend	4 km^2 (0.001 km^2) Decreasing	Low Medium
No. of mature individuals Trend	0 Decreasing	High High
No. of locations (key threat) Trend	1 (lack of recruitment) Decreasing	Low Medium
No. of subpopulations Trend	1 Decreasing	Low Medium
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed and projected in EOO, AOO, quality of habitat, number of locations/subpopulations and number of mature individuals.
C2a(i,ii)	CR: <250 mature individuals; continuing decline observed and projected; <50 mature individuals in each subpopulation; and 100% of mature individuals in one subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Habitat has been greatly reduced and severely fragmented by land clearing for agriculture. The only known wild subpopulation occurred on a rocky outcrop amongst cleared farmland.
Lack of recruitment *Ongoing*	Whole	Rapid	High	The only known wild subpopulation has disappeared with no observed recruitment since 1992, although the species may persist here in the seedbank. Recruitment has occurred in translocated subpopulations and is maximised with high-intensity fires, although subpopulations are still declining simultaneously despite management.
Inappropriate fire regimes *Ongoing*	Whole	Rapid	High	Occasional high intensity fires are required to germinate soil-stored seed. A lack of high intensity fires would result in low recruitment. The area around the single wild subpopulation has low fuel load and exposed rock, and has not had an intense fire for >50 years.
Climate change *Ongoing*	Whole	Rapid	High	Declines have occurred at all subpopulations despite management. Decline may be associated with a decreasing rainfall trend (Hope *et al.* 2015). Juvenile plants have poor survivorship in hot, dry summer conditions.
Grazing and herbivory *Ongoing*	Majority	Slow	Medium	The remaining wild individuals were known only from a rocky outcrop where grazing may have been limited. These plants were caged immediately after they were located. Grazing by rabbits and sheep is a threat at translocations that are not fenced or caged. Ringneck parrots damage the plants while feeding on the fruit.
Invasive weeds *Ongoing*	Minority	Slow	Low	Weeds are not a major threat in the rocky habitat of the wild subpopulation, but may threaten translocations on more fertile soil.
Genetic diversity *Ongoing*	Whole	Unknown	Unknown	Translocated subpopulations are derived from two wild individuals that are now dead, representing an extremely limited gene pool. Impacts of this are unknown.
Stochastic events *Ongoing*	Whole	Rapid	Medium	Given the very restricted distribution and small population size, this species is vulnerable to stochastic events including successive wildfires and prolonged drought.

Current management

- Recovery actions are identified in a recovery plan (Stack and Brown 2003).
- The only known wild subpopulation does not occur in a conservation reserve.
- Five translocated subpopulations have been established on private property, conservation reserves and nature reserves from individuals propagated via tissue culture, cuttings and grafting. Although the subpopulations have produced viable seed, they are not considered self-sustaining as only two individuals remain (Stack and Brown 2003).
- Burning trials have been undertaken to determine the effect of fire on germination. A recruitment burn was conducted at one translocation site in 2017.

- The Western Australian Seed Centre holds 19 237 seeds in storage that were collected from wild and translocated plants in 1994 and 1998, as well as 43 042 seeds collected in 2003 from an unknown source. The collection includes 8846 seeds collected from up to four wild plants in 1994 and 1998. Germination trials indicate seed germinability ranges from 39% to 96%.
- The species forms part of the living collection at Kings Park and Botanic Gardens, with 30 plants from three clones (12 plants in the Conservation Garden and 18 in the nursery collection). Kings Park Science have several genotypes in tissue culture and cryogenic storage.

Conservation objectives

- Monitor and maintain translocated and historic subpopulations.
- Protect habitat of known subpopulation in appropriate conservation agreements. Increase area of potential habitat in appropriate conservation agreements.
- Trial translocation in higher rainfall habitats to determine the role of climatic drying in long-term habitat suitability.
- Increase the number of mature individuals and subpopulations in the wild via intensive site management and translocations (augmentation and introduction).

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations, particularly after fire.	High
	Monitor known subpopulations to determine response to management actions and threats.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Undertake research to better understand the most suitable fire regime for the species.	High
Ex situ conservation/translocations	Identify suitable habitat in higher rainfall areas for future translocation trials.	High
	Identify mechanisms of decline in translocated subpopulations.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect potential and historical habitat for future translocations. Continue to monitor and manage translocated subpopulations including protection from grazing.	High
Lack of recruitment	Conduct trials within suitable habitat to determine requirements for germination and long-term survival considering fire regimes, competition, grazing and other disturbances.	High
Ex situ conservation/translocations	Establish and maintain genetic diversity of *ex situ* collections to support ongoing translocation efforts.	High
	In the event of recruitment in the natural subpopulation, or the discovery of other natural subpopulations, collect seed for *ex situ* conservation.	High
		High
	Trial hand watering of juveniles to increase survivorship.	High
	Conduct translocations in suitable habitat in higher rainfall areas.	High
Extension and awareness	Raise awareness of the species with relevant stakeholders in attempts to locate additional subpopulations.	Medium

Experts consulted

Andrew Webb, Natasha Oke, Andrew Crawford and Tanya Llorens.

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Daviesia bursarioides Crisp [FABACEAE]
Three Springs daviesia

Daviesia bursarioides flowers (image: Andrew Crawford).

Overview

Daviesia bursarioides is restricted to several small subpopulations that mostly occur along roadsides in the heavily cleared Avon Wheatbelt region of Western Australia. The species relies on disturbance including fire for recruitment, but this is difficult to implement. A translocation has been undertaken, but in the absence of recruitment all subpopulations are declining as mature individuals senesce.

Conservation status

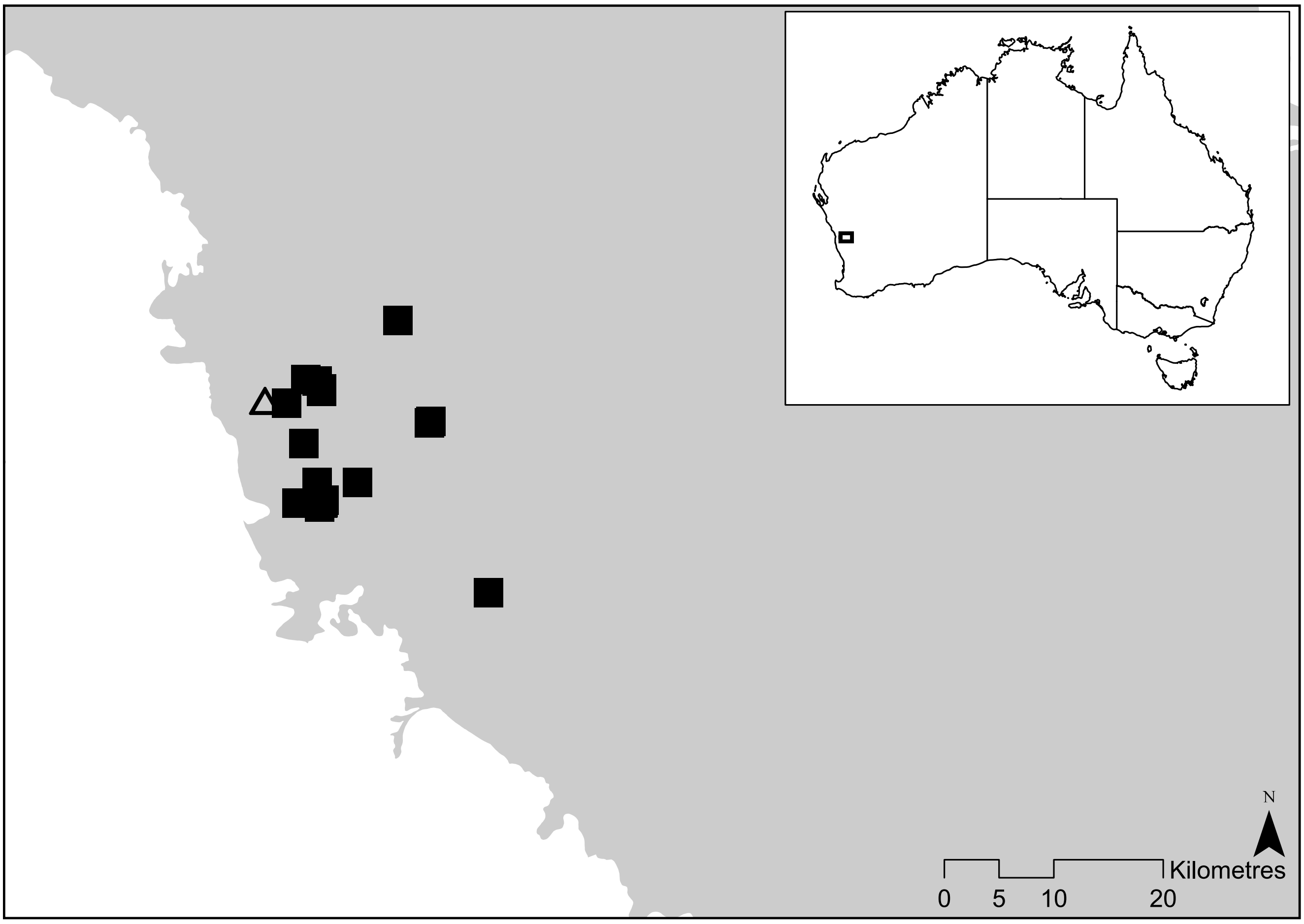
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Straggly shrub to 2 m with blue-green spine-tipped branchlets that diverge from the stem at 45° angles (Crisp 1995). The leaves are distinctive among *Daviesia* species, being scattered and small, obovate, up to 20 mm long and 2.5 mm wide (Patrick and Brown 2001). Inflorescence is a raceme with 4-8 yellow flowers with maroon centres. Fruit is a compressed and leathery pod 10-14 mm long (Crisp 1995). *Daviesia bursarioides* cannot be confused with any other species in the genus (Crisp 1995).

Distribution

Daviesia bursarioides is known from a very restricted distribution in the Three Springs area, 300 km south-east of Geraldton in the Avon Wheatbelt bioregion in south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution (black squares) of *Daviesia bursarioides* in the Avon Wheatbelt bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020). One subpopulation has been augmented with translocated individuals since 1998 (hollow triangle).

Population estimate and trends

Daviesia bursarioides was first collected in 1932 from between Moora and Mingenew and it is probable the species is naturally restricted to this region (Stack *et al.* 2014). Additional collections were made in 1958, 1972 and 1973 (AVH 2020; DBCA 2020). After re-survey in 1978 only three individuals in one subpopulation were located. Four additional subpopulations were located between 1993 and 1995, with three occurring on road verges and another on private property (Stack *et al.* 2004). A sixth subpopulation was located in a nature reserve in 1997 (Stack *et al.* 2004). The species is currently known from six subpopulations with 44 mature individuals. One subpopulation has been augmented and 36 of the translocated plants survive (Silcock *et al.* 2019).

Ongoing declines are projected given the prevalence of threats to subpopulations and lack of recruitment. Eight plants were removed from Subpopulation 3 in 2019 for planned road maintenance. Some targeted surveys have been undertaken but more are needed given the species' response to disturbance.

Daviesia bursarioides monitoring data, 1978-2019 (DBCA 2020; Stack *et al.* 2014).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Three Springs south (road reserve/ private property)	1978: 3 1984: 12 1994: 19 1999: 9 2000: 12 2006: 6 (1) 2011: 5 2016: 1	Decreasing
2 Three Springs (road reserve)	1993: 4 1994: 5 (6) 1997: 5 (6) 2000: 4 2002: 2 2006: 1 (8) 2011: 8 2016: 0 (3)	Decreasing
3 Three Springs north (Main Roads road reserve)	1993: 5 1994: 5 (12) 2000: 15 2006: 9 (4) 2011: 17 2016: 14 (2) 2019: 9 2019: 1	Decreasing
4 Three Springs north (Main Roads road reserve)	1994: 9 (3) 2000: 11 2002: 5 2006: 2 2011: 1 (1) 2016: 1	Decreasing
5 Three Springs southwest (private property)	1995: 60 2001: ~35 2006: 36 (8) 2011: 41 (1) 2016: 39 (3)	Decreasing
6 Three Springs (nature reserve)	1997: 4 1998: 15 (192T) 2000: 14 (330T) 2006: 5 + 114T including seedlings 2011: 3 (T not counted) 2012: 4 + 52T 2016: 2 + 36T	Decreasing

Translocated individuals/subpopulation (T).

Habitat and ecology

Daviesia bursarioides occurs on rises and slopes in gravelly red-brown sandy loams over laterite amongst open shrubby heath. Associated species include *Eucalyptus gittinsii, Allocasuarina campestris, Santalum* sp., *Olearia* sp., *Grevillea* sp., *Acacia* sp., and *Hakea* sp. (Stack *et al.* 2004). Flowering occurs between July and September (Stack *et al.* 2004) and pollination is assumed to be by bees (Schwarten 1995). A high proportion of ovules abort, although this is apparent in other *Daviesia* spp. (Schwarten 1995). The quantity of seeds stored in the topsoil is thought to be low, as the majority are moved to depth by ants or consumed by other invertebrates. Experimentally buried seeds retained 100% viability after 6 months but declined to 65% within 12 months (Schwarten 1995). Translocated plants produce seed within 3 years, and longevity is thought to be >15-20 years (L Monks pers.comm. 2020).

Daviesia bursarioides is probably a disturbance opportunist. Plants were observed to be more vigorous in recently disturbed areas (e.g. a disused gravel pit) than in adjacent remnant vegetation (Stack et al. 2004). Competition for light and water limits growth and seed production when under a dense canopy (Schwarten 1995). Fire commonly stimulates seed germination for other legumes, but the specific response of *D. bursarioides* is unknown (Crisp 1985). Seeds have physical dormancy that must be broken before germination can occur. Heat from fire may be the major mechanism for triggering germination, as smoke treatments were found to decrease germination of *D. bursarioides* seed (Schwarten 1995). Seed scarification during mechanical disturbance is also likely to stimulate seed germination as seedlings appear after roadworks and fence construction (Stack *et al.* 2004).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	74 km^2 Decreasing	Medium High
Area of occupancy (actual) Trend	20 km^2 (<1 km^2) Decreasing	Medium High
No. of locations (key threat) Trend	6 (lack of recruitment) Decreasing	Medium High
No. of subpopulations Trend	6 Decreasing	Medium High
No. of mature individuals Trend	44 Decreasing	Medium High
Generation length	4-6 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented; and continuing decline observed and projected in EOO, AOO, area, extent and quality of habitat, number of locations/subpopulations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Land clearing *Past*	n/a	n/a	n/a	Land clearing, predominantly for agriculture, has resulted in the decline and severe fragmentation of available habitat. This may also have reduced the abundance of suitable pollinators.
Lack of appropriate disturbance *Suspended*	Whole	Rapid	High	*Daviesia bursarioides* responds positively to some level of disturbance. Lack of recruitment observed across all subpopulations is likely due to lack of appropriate disturbance. However, inappropriate disturbance can kill mature individuals.
Infrastructure maintenance *Ongoing*	Majority	Slow	Medium	The majority of subpopulations occur on roadside reserves or private property. These are threatened by activities associated with the maintenance of roads, fences and firebreaks including mowing, herbicide spraying, grading, drain construction and gravel extraction (Threatened Species Scientific Committee 2015). While some plants have been destroyed in past roadworks, all roadside subpopulations are now marked and Shire staff are aware of them.
Grazing *Ongoing*	Majority	Slow	Medium	Grazing by macropods and domestic stock can cause death of juvenile plants that are not yet spiny (TSSC 2015). A subpopulation on private property has been fenced although future management is uncertain. Macropods grazed heavily upon translocated individuals in 1999 and 2000, although this may vary according to the availability of alternative browse.
Invasive weeds *Ongoing*	Majority	Slow	Low	Roadside populations occur in very narrow (3-4 m wide) reserves adjacent to cleared farmland providing an ongoing source of invasive weed seeds that can increase competition and alter fuel loads. However, current weed levels in the harsh habitat are low.
Introduced pathogens *Future*	Whole	Unknown	Unknown	Preliminary research indicates *D. bursarioides* is highly susceptible to phytophthora *Phytophthora cinnamomi* dieback. However, the pathogen has not been confirmed within the dry habitat of the species.

Current management

- Recovery actions have been identified (Stack *et al.* 2004; TSSC 2015).
- One subpopulation is protected within a nature reserve.
- Relevant stakeholders have been engaged and made aware of the location of the plants. All roadside subpopulations are marked with threatened flora markers.
- The subpopulation on private property has been fenced to exclude stock.
- The Western Australian Seed Centre holds 5130 seeds collected between 1996 and 2014 from Subpopulations 1, 2, 3, 5 and 6. Testing conducted on six of the 23 seed collections indicated that seed germinability ranged from 50-100%.
- A translocation of approximately 600 juveniles was undertaken to the nature reserve from 1998-2000 and 36 plants remain. Other individuals planted at Kings Park and Botanic Gardens have died.
- Monitoring is ongoing at known subpopulations.

Conservation objectives

- Detect more subpopulations through targeted surveys.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Increase the habitat quality for both *D. bursarioides* and potential pollinators within the vicinity of known subpopulations.
- Maintain and increase connectivity between known subpopulations.
- Increase the number of mature individuals and subpopulations in the wild via translocation (augmentation and introductions to secure tenure).

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations.	High
	Monitor subpopulations in response to management actions and threats.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate disturbance regimes	Undertake research to better understand the disturbance requirements of the species (both mechanical and fire).	High
	Determine suitable methods to increase the population abundance via disturbance, probably fire.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known and potential habitat in appropriate conservation agreements.	High
Inappropriate disturbance regimes	Implement appropriate disturbance at subpopulations following sufficient seed set (Stack *et al.* 2004) to stimulate germination and limit competition from taller canopy species. Mechanical disturbance can be used in hot weather when fire may not be suitable.	High
Ex situ conservation/translocations	Maintain and expand *ex situ* seed collections to represent maximum range of genetic diversity.	High
	Continue propagation to support ongoing translocation efforts.	High
	Continue to implement translocation project, ensuring juvenile plants receive adequate water and protection from herbivory, and ideally implement a recruitment burn at the translocated subpopulation.	High
Invasive weeds	Manage invasive weeds at all subpopulations to reduce competition, especially following disturbance.	Medium
Habitat quality	Increase connectivity between subpopulations in attempts to increase pollination.	Medium

Experts consulted

Leonie Monks, Andrew Crawford and Tanya Llorens.

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Daviesia cunderdin Crisp & G.Chandler [FABACEAE]
Cunderdin daviesia



Daviesia cunderdin in roadside remnant (top left) and flowering branch (bottom, images: J and F Hort for Bert Hort), and flowers (top right, image: Andrew Brown).

Overview

Daviesia cunderdin has only ever been known from a single population and only two individuals remain. The Kwongan habitat of the species has been extensively cleared for agriculture and the population occurs on a very narrow road verge. Population declines have been ongoing since the species was identified, but the high seed germinability and ongoing translocation provide promise of recovery. Additional self-sustaining subpopulations need to be established on secure tenure, with ongoing weed, pest and fire management.

Conservation status

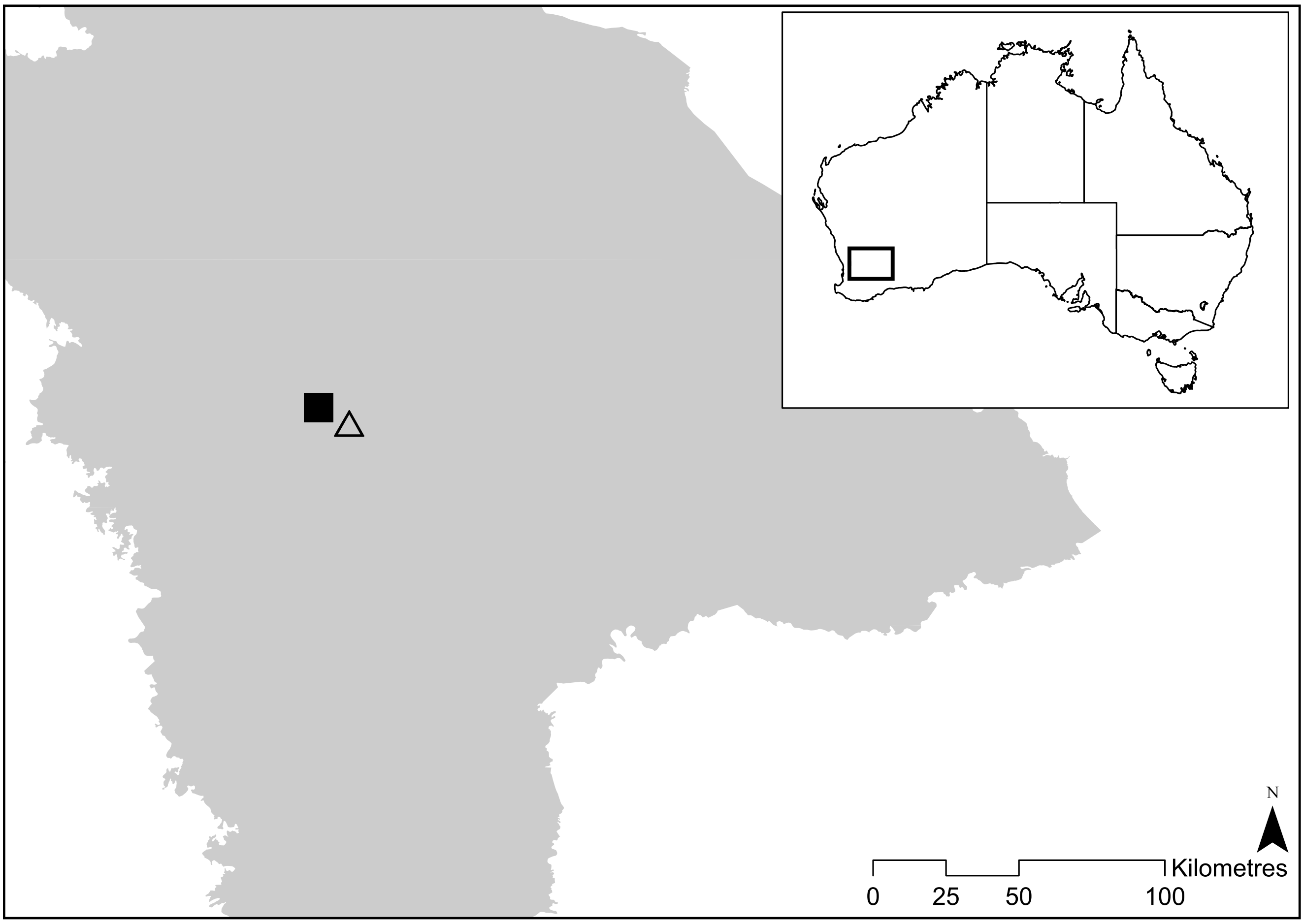
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect, compact to open, divaricate shrub, 1.5 m wide and 1.2-1.6 m high. Branchlets prominently ribbed and at 45° with a pedestal at each node. Phyllodes dull green, rigid and flat, elliptical to ovate, 10-20 mm long and 4-9 mm wide, with an acuminate apex 3-4 mm long and three node-like thickenings at the base. Inflorescences axillary, solitary or rarely paired, of a single red-orange flower with a dark centre and two whorls of five stamens (Crisp and Chandler 1997). *Daviesia cunderdin* is closely related to *D. cardiophylla, D. eurylobos* and *D. umbonata*, but has larger red flowers, a standard 12-15 mm long that remains partly folded at anthesis and bears a pair of basal deltoid appendages. The other species have yellow-red flowers with a smaller standard (<10 mm long) that fully opens. The phyllodes of *D. cunderdin* are rounded rather than cordate in *D. cardiophylla*, cuneate like *D. umbonata*, or adaxially concave in *D. eurylobos (*Crisp and Chandler 1997).

Distribution

Daviesia cunderdin is only known from its type locality north of Cunderdin in the Avon Wheatbelt bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020). A translocated subpopulation has been established nearby, but recruitment has not yet occurred (Silcock *et al.* 2019).



Current distribution (black square) of *Daviesia cunderdin* in the Avon Wheatbelt bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020). A translocated subpopulation has been established (hollow triangle) but recruitment has not yet occurred (Silock *et al.* 2019).

Population estimate and trends

Daviesia cunderdin was only known from five to six individuals along a single road verge when it was described by Crisp and Chandler (1997). Despite searching throughout suitable habitat, no additional subpopulations have been located (Department of Environment and Conservation 2009). Continuing decline has been observed as mature individuals senesce in the absence of recruitment (DEC 2009). Two individuals remain.

A translocation was undertaken in 2004, followed by four subsequent plantings (Silcock *et al.* 2019). Of the 306 young plants derived from seeds and cuttings, 51 were alive and reproductively mature in 2019 (L Monks pers.comm. 2020). However, as recruitment has not been observed the subpopulation is not considered self-sustaining and was not included in the IUCN assessments.

Daviesia cunderdin monitoring data, 1991-2007 (DBCA 2020; DEC 2009; Crisp and Chandler 1997; L Monks unpublished data).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Cunderdin north (road reserve)	1991: 14 1993: 5-6 1997: 6 [7] 1999: 5 (3) 2000: 4 (8) [3] 2003: 5 (7) [3] 2005: 11 2006: 9 [3] 2018: 2	Decreasing
2 (T) Cunderdin northeast (private property)	2004: 102T 2007: 30 [105] T 2015: 51 [189] T 2019: 51 [255] T	Decreasing

Translocated individuals/subpopulation (T); numbers of dead plants are shown within square brackets.

Habitat and ecology

Daviesia cunderdin occurs in lateritic sandy clays in Kwongan vegetation dominated by *Allocasuarina campestris, Eucalyptus loxophleba* and *E. salmonophloia*. Other associated species include *Acacia acuminata, A. volubilis, Dianella revoluta, Banksia fraseri, Gastrolobium spinosum, Grevillea hookeriana* and *Leptospermum erubescens* (DEC 2009).

Flowering is typically between May and June but can occur earlier in the year following sufficient rainfall. Flowers are probably pollinated by insects including bees and wasps (DEC 2009). Immature and dehisced fruit have been observed in August and October, respectively. Seeds have a small appendage (elaisome) to facilitate dispersal by ants (DEC 2009).

Thirty-three to 67% of seed germinate under controlled conditions, and seedlings can become reproductively mature within 3 years (DEC 2009). Plants live for at least 15 years (L Monks pers.comm. 2020). Fire is required to stimulate germination of soil-stored seed, however high mortality (>90%) was observed following controlled burns in 1998 and 2000. This is possibly a response to unfavourable conditions (although the plants were watered) or selection against inbred seed, given the very small population size (DEC 2009).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.01 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.01 km^2) Decreasing	High High
No. of locations (key threat) Trend	1 (lack of recruitment) Decreasing	High High
No. of subpopulations Trend	1 Decreasing	High High
No. of mature individuals Trend	2 Decreasing	High High
Generation length	10 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	CR: >80% reduction observed within 3 generations (85% from 1991-2018); causes have not ceased, are not understood and may not be reversible; based on direct observation.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; continuing decline projected in AOO, EOO and number of locations; and continuing decline observed in quality of habitat and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	The habitat of *D. cunderdin* has undergone a significant past decline due to agriculture, with <6% of bushland remaining in the Central Wheatbelt (Wheatbelt NRM 2015). Remaining habitat is severely fragmented, with 94% of habitat patches <10 ha (WNRM 2015). The naturally occurring subpopulation of *D. cunderdin* occurs in a very small patch of degraded vegetation along a road verge.
Lack of recruitment *Ongoing*	Whole	Rapid	High	Despite high seed germination, survivorship of recruits is <10% even with regular watering. Recruitment has been very limited in the natural subpopulation of *D. cunderdin*. Lack of fire has probably contributed to the small population size, as fire is required to stimulate seed germination (DEC 2009).
Inappropriate fire regimes *Ongoing*	Whole	Rapid	High	Fire kills mature individuals of *D. cunderdin*, but is required to stimulate germination of soil-stored seed (DEC. 2009). Fires that occur before seedlings mature and contribute to the seedbank will cause population declines. In the absence of fire, mature individuals senesce and are not replaced, also causing population declines.
Drought *Ongoing*	Whole	Rapid	High	Mortality of seedlings is heightened during summer and especially drought periods, with up to 90% mortality observed despite mulching, weeding and watering every 1-2 weeks (DEC 2009).
Road maintenance activities *Ongoing*	Whole	Rapid	High	*Daviesia cunderdin* occurs on a narrow road verge (<5 m wide) that is vulnerable to road maintenance activities including grading, drainage channel construction, herbicide drift/spraying, firebreak and fence maintenance. Herbicide spraying occurred near the subpopulation from 1994-1997 (DEC 2009).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Vertebrate pests (rabbits) *Future*	Whole	Slow	Medium	Rabbits have been recorded within the natural subpopulation and seedlings are vulnerable to herbivory until they develop spiny branchlets at ca. 12 months. Root disturbance due to rabbit burrowing has also been observed. Rabbit control commenced in 2008 and requires ongoing maintenance (DEC 2009). The translocated subpopulation is fenced, with occasional rabbit control carried out as necessary (L Monks pers. comm. 2020).
Invasive weeds *Ongoing*	Whole	Slow	Medium	Invasive weeds were abundant within the narrow road verge when the species was first recorded (DEC 2009). Invasive weed control has since been undertaken and requires ongoing maintenance. Invasive weeds increase competition and alter fuel loads and thus fire regimes.
Introduced pathogens *Future*	Whole	Unknown	Unknown	A high proportion of *Daviesia* spp. have a moderate to high susceptibility to phytophthora *Phytophthora cinnamomi* dieback (Cahill et al. 2008). The susceptibility of *D. cunderdin* has not been established. The species does not co-occur with phytophthora, which is confined to the 400 mm rainfall isohyet (D Coates pers.comm. 2020).

Current management

- Recovery actions have been identified (DEC 2009) and implemented, including measures to address invasive weeds, roadside threats, rabbit control and stakeholder engagement.
- A translocation proposal was developed and undertaken in 2004, with four additional plantings in later years. Fifty-one individuals were reproductively mature at this private property site in 2019.
- Controlled burns were undertaken in 1998 and 2000, which stimulated seed germination around the base of dead individuals. More than 90% of germinants died (DEC 2009).
- Germination trials have been undertaken by the DBCA Threatened Flora Seed Centre with 33-67% germination success. Propagation trials of cuttings undertaken by the Botanic Gardens and Parks Authority had a 20-60% success rate. The strike rates for cuttings derived from young plants grown *ex situ* from seed were significantly higher (DEC 2009).
- Monitoring of control burn trials has informed a fire management strategy with return intervals of ca. 10 years (DEC 2009). This management strategy is currently unfeasible in the narrow, weedy roadside habitat of the wild subpopulation (L Monks pers.comm. 2020).
- The translocated subpopulation is fenced and rabbit control occurs when necessary.

Conservation objectives

- Monitor and maintain known subpopulations.
- Increase the area of suitable habitat for the species in conservation reserves. Establish translocated subpopulations in these reserves.
- Initiate recruitment in both subpopulations.
- Increase the number of self-sustaining subpopulations and individuals in the wild.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and fire ecology. The length of time soil-stored seed can remain viable is of particular relevance.	High
	Identify reasons and management strategies for high mortality of seedlings following fire.	High
Ex situ conservation/translocations	Identify sites of suitable habitat with secure tenure for establishing translocated subpopulations.	High
Population surveys	Monitor response of subpopulations to threats and management actions.	High
	Undertake targeted surveys in other suitable habitat to locate additional subpopulations, particularly after fire.	Medium
Introduced pathogens	Establish the susceptibility of *D. cunderdin* to phytophthora dieback.	Low

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Continue to collect and germinate seed for *ex situ* conservation, and propagate cuttings. Ensure maximum range of genetic diversity possible is represented in the collection.	High
	Continue to reinforce translocated subpopulation with propagated individuals to increase abundance.	High
	Undertake additional translocations into secure tenure.	High
Lack of recruitment/ inappropriate fire regimes	Implement and maintain a fire management strategy to promote recruitment at all subpopulations.	High
	Hand water seedlings post-germination.	High
Habitat protection	Identify areas of additional suitable habitat and protect under appropriate conservation covenants.	High
Herbivory/ vertebrate pests	Maintain fence and rabbit control at translocated subpopulation.	High
	Reduce grazing pressure at wild subpopulation via fencing or other suitable methods, particularly after disturbance.	Medium
Invasive weeds	Continue invasive weed management at both subpopulations, particularly after fire.	Medium
Extension and awareness	Maintain engagement with landholders that are custodians of the species. Raise awareness with other stakeholders in an attempt to locate additional subpopulations.	Medium
Introduced pathogens	If found to be susceptible to phytophthora, implement management actions to abate dieback.	Low

Experts consulted

Leonie Monks and David Coates.

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Epilobium brunnescens susp. *beaugleholei* K.R.West & P.H.Raven [ONAGRACEAE]

Bog willow-herb

Epilobium brunnescens subsp. *beaugleholei* plant (top left), flower (right) and Daniel Ohlsen undertaking surveys (bottom left; images: Andre Messina, State Botanical Collection, Royal Botanic Gardens Victoria).

Overview

There are three subspecies of *Epilobium brunnescens: E. brunnescens* subsp. *brunnescens* and *E. brunnescens* subsp. *minutiflorum* are endemic to, and widespread, in New Zealand. *Epilobium brunnescens* subsp. *beaugleholei* is restricted to a single site in the Snowy Range of Australia. The population is small and has very specific habitat requirements. Although time-series monitoring is not available, a marked decline has occurred over the past four decades. The reason for decline is not well-understood and this taxon, which presumably evolved in isolation since Gondwana diverged 180 million years ago, is now extremely vulnerable to extinction.

Conservation status

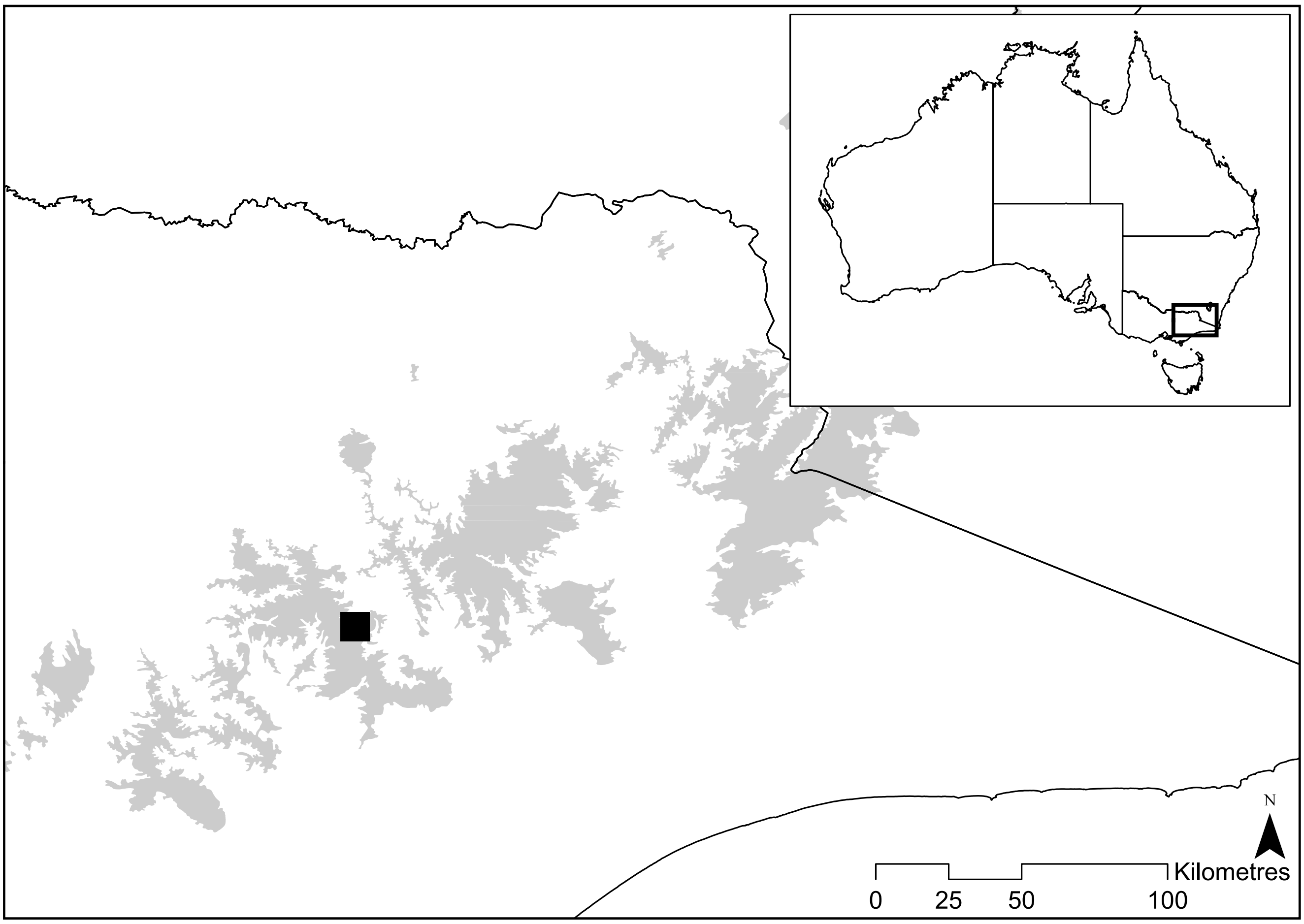
Environment Protection and Biodiversity Conservation Act 1999	Vulnerable
Flora and Fauna Guarantee Act 2016	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Prostrate perennial forb that forms mats (West and Raven 1977). Leaves are opposite, slightly glossy, have entire margins or a few shallow teeth, and are elliptic to ovate, 3-14 mm long and 2-7 mm wide. White flowers to 8 mm wide have four petals to 4 mm long, and are borne on stalks to 7 cm long. Fruit is a narrow, cylindrical capsule, 18-24 mm long with small dark seeds attached to long silky hairs (West and Raven 1977). This subspecies is distinguished from other *Epilobium* sp. that occur nearby, which have variously toothed leaf margins, rather than mostly entire (Walsh and Entwisle 1996), have pink flowers and are mostly erect or sub-erect (N Walsh pers.comm. 2020). The two other subspecies of *E. brunnescens* are native to New Zealand, where they are widespread.

Distribution

Epilobium brunnescens subsp. *beaugleholei* is known from a single site at Conglomerate Creek Falls in the Snowy Range in Alpine National Park near Licola, in the Victorian Alps bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012). Targeted searches of suitable habitat have failed to locate additional sites. The subspecies is considered severely fragmented (IUCN 2019).



Current distribution of *Epilobium brunnescens* subsp. *beaugleholei* (black square) in the Victorian Alps bioregion (shaded grey) of Victoria (AVH 2020; DAWE 2012).

Population estimate and trends

Epilobium brunnescens subsp. *beaugleholei* was first collected in 1973 and described in 1977 (AVH 2020; West and Raven 1977). There are no time-series monitoring data, but observations suggest a substantial recent decline in abundance. In 1983, 50 plants over 900 m^2 of habitat were recorded, and in 2001 there were only three patches totalling 1 m^2 over an area of 12 m^2 (Carter and Walsh 2006). A similar area of occupancy was estimated in 2020, although some small (ca. 10 cm^2) moss clumps containing *E. brunnescens* subsp. *beaugleholei* were recently dislodged from the rock face (A Messina pers.comm. 2020). Population dynamics and seasonal fluctuations are poorly understood, and the species is considered at extreme risk of extinction (Carter and Walsh 2006; N Walsh pers.comm. 2020).

Habitat and ecology

Epilobium bunnnescens subsp. *beaugleholei* grows on moist cliff faces and rocks at 1320 m above sea level amongst bryophyte moss mats that remain moist due to a perennial sub-alpine waterfall (N Walsh pers.comm. 2016). The long nodal roots of *E. brunnescens* subsp. *beaugleholei* permeate this mossy substrate, which grows with scarce soil and sunlight. Little is known of the ecology and biology of the taxon, however it depends on moisture to grow, flower and set seed (West and Raven 1977). Generation length is unknown.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (<0.001 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (<0.001 km^2) Decreasing	High High
No. of mature individuals Trend	<50 Decreasing	High Medium
No. of locations (key threat) Trend	1 (climate change) Decreasing	High High
No. of subpopulations Trend	1 Stable	High High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline projected in AOO, EOO and number of locations; and continuing decline observed in quality of habitat and number of mature individuals.
C2a(i,ii)	CR: <250 mature individuals; continuing decline observed and projected; <50 mature individuals in each subpopulation; and 90-100% (100%) of individuals in one subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Climate change *Ongoing (?) and future*	Whole	Unknown	Unknown	*Epilobium brunnescens* subsp. *beaugleholei* is dependent on the microclimate generated by a waterfall that provides a constant source of moisture (Carter and Walsh 2006). With climate change, many habitats at high altitudes are predicted to become drier and unsuitable, while the species has little capacity to 'move' (Grose *et al.* 2015). Declines in abundance since the 1980s may reflect changes in climate but further evidence is required.
Stochastic events (rock falls) *Future*	Whole	Very rapid	Medium	The population grows on rocks and cliff faces in a very restricted area, and is vulnerable to disturbances such as rock falls (Carter and Walsh 2006). Numerous small clumps containing the species were dislodged from the rock face in 2020. This is probably a natural occurrence after heavy rainfall but highlights the vulnerability of the species to such events (A Messina pers.comm. 2020).
Human activities (recreation/ illegal collection) *Future*	Whole	Rapid	Medium	The population is vulnerable to human visitation impacts such as trampling and illegal collection (Carter and Walsh 2006). However, the site is relatively inaccessible and no impacts have been documented to date (N Walsh pers.comm. 2020).

Current management

- Recovery actions have been identified (Carter and Walsh 2006; Threatened Species Scientific Committee 2016).
- The single subpopulation is protected in national park that is managed for conservation.
- Fencing is not feasible at the site due to very steep topography, and site visitation is low (N Walsh pers.comm. 2020).
- Targeted surveys have been undertaken in potential habitat but no systematic population monitoring has occurred.
- Effective propagation techniques have been identified (West and Raven 1977), and plants have been grown in cultivation at the Melbourne Botanic Gardens.

Conservation objectives

- Monitor and maintain known subpopulation.
- Establish *ex situ* subpopulation for seed collection and future translocations.
- Better understand the biology and ecology of the species, along with the drivers of population declines to inform threat management.

Information required

Theme	Specific actions	Priority
Population surveys	Implement and maintain monitoring program to discern population trends and response to management actions.	High
Life history and ecology	Undertake research to better understand the biology, ecology and threats to the species including conservation genetics, seed production and viability, germination requirements and specific habitat requirements.	High
Ex situ conservation/translocations	Investigate the feasibility of translocations via augmentation and introduction to other areas of suitable habitat on secure tenure.	High

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Collect and store seed representing the maximum range of genetic diversity possible.	High
	Maintain and expand *ex situ* population via seed/cutting propagation.	High
	Reinforce wild population with propagated individuals to increase abundance.	Medium
Habitat protection	Install and maintain conservation signage around the taxon's habitat.	Medium
Extension and awareness	Maintain engagement with relevant landholders that are custodians of the species.	Medium
	Raise awareness with other stakeholders in the area in an attempt to locate additional subpopulations.	Medium

Experts consulted

Andre Messina and Neville Walsh.

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Eremophila pinnatifida (Chinnock) [SCROPHULARIACEAE]
Pinnate-leafed eremophila


Eremophila pinnatifida flower and leaves, and habit near Dalwallinu (images: Steve and Allison Pearson).

Overview

Eremophila pinnatifida occurs in six subpopulations in south-western Western Australia and only two of these contain mature plants. All subpopulations occur in degraded and fragmented habitat. Disturbance appears to be important for recruitment and the species may persist in the seedbank at some locations.

Conservation status

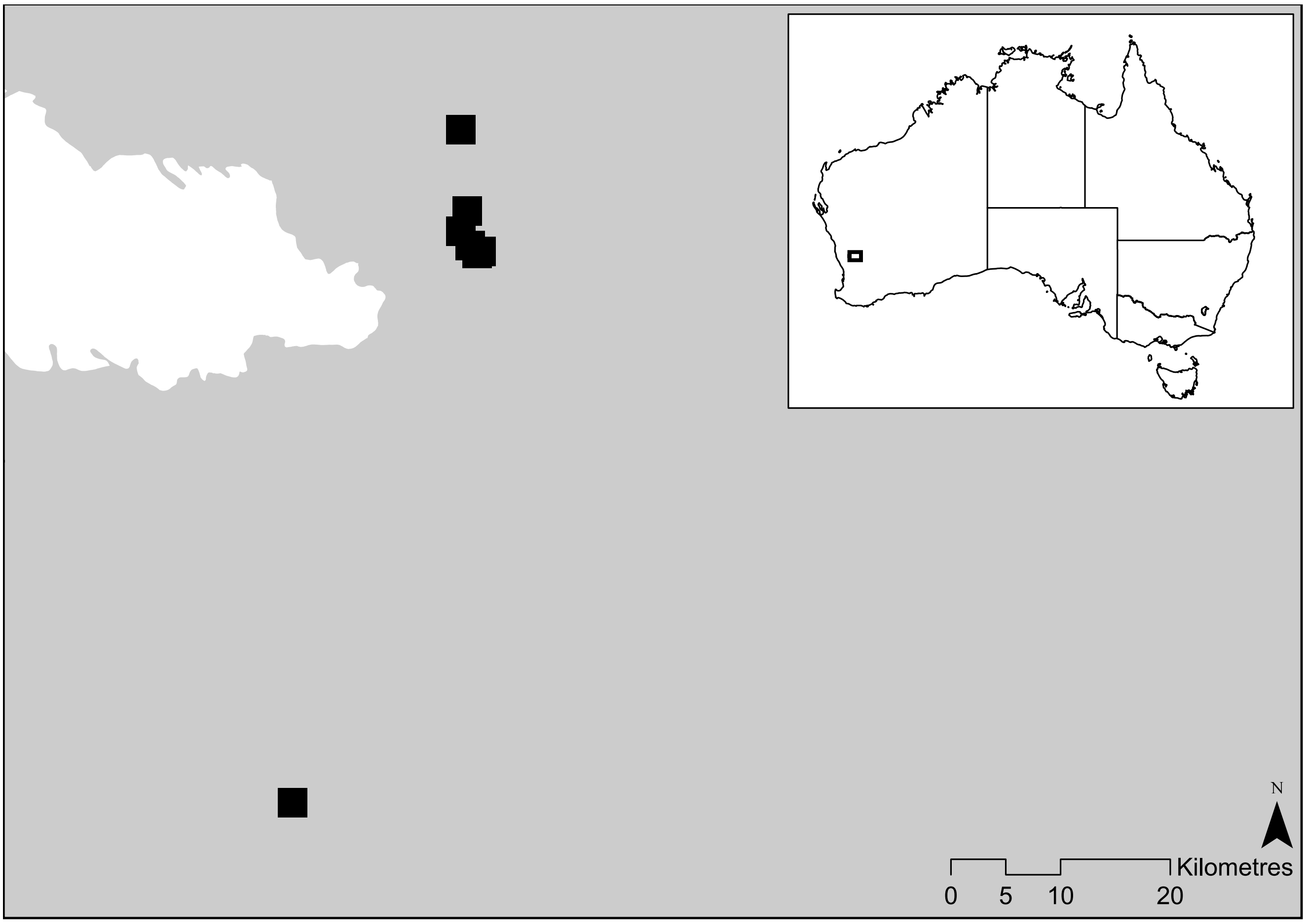
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Spreading, aromatic shrub to 1 m with densely hairy branchlets (Chinnock 2007). Leaves are hairy, erect with deeply lobed margins 5-9 mm long and 3-5 mm wide, and in whorls of three. Tubular flowers are 18-25 mm long, hairy and pale purple outside with purple spots over white inside. Fruit is woody, broadly ovate and contains pale yellow-brown seeds 2.5 mm long and 0.7 mm wide. *Eremophila pinnatifida* is allied to *E. ternifolia*, but differs by its pinnate leaves and prominent pubescence of the vegetative parts (Chinnock 2007). It has larger flowers and more prominently lobed leaves than the closely-related *E. koobabbiensis* (Stack and Brown 2002).

Distribution

Eremophila pinnatifida is known from a scattered distribution near Dalwallinu and Wongan Katta (Wongan Hills) in the Avon Wheatbelt bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution (black squares) of *Eremophila pinnatifida* in the Avon Wheatbelt bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020). Only two subpopulations contain mature individuals, but the species may persist in the seedbank at the other subpopulations.

Population estimate and trends

Eremophila pinnatifida is currently known from 19 individuals in two subpopulations. When it was first recorded in 1990 the species was known from 35 individuals (Stack and Brown 2002). Additional subpopulations were located nearby and a total of 449 individuals were known in 2002 (Stack and Brown 2002). A disjunct subpopulation with a single individual was located near Wongan Katta (Wongan Hills) in 2007, and an additional subpopulation of 18 individuals was located in 2016 near Dalwallinu (AVH 2020; DBCA 2020).

Time-series monitoring from 1990 indicates the species is in decline at all sites. A population reduction of 93% occurred between 2006 and 2015, assuming the 18 previously-unrecorded mature individuals at Subpopulation 6 remained stable. Many targeted surveys have been undertaken in suitable habitat. The species may still persist in the seedbank at historical locations.

Eremophila pinnatifida monitoring data, 1990-2017 (DBCA 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 (shire reserve)	1990: 35 1997: 6 1998: 3 2000: 3 (367) 2001: 200 (170) 2002: 355 2003: 90 (200) 2006: >150 (>150) 2011: 9 2015: 0	Decreasing
2 (shire road verge)	1997: 2 1998: 3 2001: 2 2003: 1 2006: 0 2011: 0 2015: 0	Decreasing, possibly extinct
3 (Main Roads road verge)	1998: 16 1999: 16 2001: 14 2004: 13 2006: 10 2011: 4 2015: 0	Decreasing
4 (shire road verge)	2001: 78 2003: 85 2006: 96 2011: 6 2015: 0	Decreasing
5 (road verge)	2007: 1 2011: 1 2015: 1	Stable
6 (road verge)	2017: 18	Unknown

Habitat and ecology

Eremophila pinnatifida occurs in red-brown clay loams amongst tall open woodland and shrubland (Chinnock 2007). Associated species include *Eucalyptus salmonophloia, E. salubris, E. loxophleba, Santalum acuminatum, Templetonia sulcata, Eremophila drummondii, Acacia merrallii*, chenopods and perennial grasses (Stack and Brown 2002).

Plants flower from August to February with seed maturing between June and July (Collins 2009). The proportion of fruit bearing seed is low, with only four seeds per 100 fruits observed in one case (Stack and Brown 2002), however more recent results from cleaned collections indicate that this is variable and often higher (A Crawford pers.comm. 2020). Plants are thought to live for approximately 10 years (Stack and Brown 2002). Germination occurs after disturbance such as flooding and fire, and the species has declined in areas where disturbance has been absent for prolonged periods. Low seed viability may reflect low genetic diversity associated with the small population size (Chinnock 2007). Due to its persistent soil seedbank, which is unlikely to be exhausted by a single event, extreme fluctuations are unlikely (IUCN 2019).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	74 km^2 Decreasing	High High
Area of occupancy (actual) Trend	16 km^2 (0.01 km^2) Decreasing	High High
No. of mature individuals Trend	19 Decreasing	High High
No. of locations (key threat) Trend	6 (inappropriate disturbance) Decreasing	High High
No. of subpopulations Trend	6 Decreasing	High High
Generation length	3.5 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	CR: >80% reduction observed within 3 generations (93% from 2006-2015); causes have not ceased, are not understood and may not be reversible; based on direct observation.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented; and continuing decline observed and projected in AOO, area/extent and quality of habitat, number of locations/subpopulations, and number of mature individuals.
C2a(i,ii)	CR: <250 mature individuals; continuing decline observed and projected; <50 mature individuals in each subpopulation; and 90-100% (95%) of mature individuals in one subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing, predominantly for agriculture has resulted in the decline and fragmentation of available habitat. The species is considered severely fragmented as all subpopulations are very small, and isolated in narrow roadside strips surrounded by cleared land.
Inappropriate disturbance regimes *Ongoing*	Whole	Rapid	High	Some disturbance is required to maintain population abundance. A fire in 1998 at Subpopulation 1 stimulated germination of hundreds of plants but all died by 2015. Fire suppression is typical in the habitat of this species and this lack of disturbance is limiting recruitment resulting in population declines as mature plants senesce. As disturbance and fire can be managed at the subpopulation/ land tenure scale, the species occurs at six locations.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Lack of recruitment *Ongoing*	Whole	Rapid	High	Few seedlings have been observed and germination appears to depend on disturbance of soil-stored seed. Pollinators may be infrequent or absent due to habitat fragmentation and degradation, with implications for seed fertility and dispersal.
Infrastructure maintenance *Ongoing*	Majority	Rapid	Medium	Subpopulations occurring on road verges are vulnerable to road maintenance activities including grading, slashing, herbicide application and drainage construction. Water run-off from roads has caused soil erosion and root exposure of some individuals in roadside drainage lines, which have subsequently died. Several subpopulations previously known from roadsides have disappeared.
Invasive weeds *Ongoing*	Whole	Slow	Medium	All subpopulations are known from degraded and weedy habitat in road verges and road reserves with limited native vegetation. Wild oats (*Avena fatua*) are the dominant understorey species in the habitat of three subpopulations, inhibiting recruitment.
Genetic diversity *Ongoing*	Whole	Unknown	Unknown	The population is small and declining, and therefore vulnerable to loss of genetic diversity. Long-term impacts are unknown.
Housing development *Future*	Minority	Slow	Low	Proposals for housing developments have been considered near one subpopulation. If approved, the area where the species occurs will be set aside as a conservation reserve.

Current management

- Recovery actions have been identified (Stack and Brown 2002; Threatened Species Scientific Committee 2016).
- The species occurs in a Shire reserve.
- More than 6353 fruits containing an estimated 1973 germinable seeds were collected between 1997 and 2019 from Subpopulations 1, 3, 4 and 5, and are stored at the Western Australian Seed Centre.
- The species forms part of the living collection at Kings Park and Botanic Gardens, with 31 plants from four clones (seven plants in the Conservation Garden and 24 in the nursery collection). Kings Park Science have several genotypes in tissue culture and cryogenic storage.
- Engagement is ongoing to protect subpopulations from road maintenance activities and urban development.

Conservation objectives

- Monitor and maintain known subpopulations.
- Detect more subpopulations through targeted surveys, particularly after disturbance.
- Increase area of habitat and number of subpopulations under appropriate conservation agreements.
- Stimulate germination of soil-stored seed and maintain recruitment at known and historic subpopulations.
- Establish *ex situ* subpopulations to spread extinction risk and support translocation efforts.
- Increase the number of mature individuals and subpopulations in the wild via habitat management and translocation (augmentation, re-introduction, introduction to secure tenure).

Information required

Theme	Specific actions	Priority
Population surveys	Conduct targeted surveys in historic locations and other suitable habitat to locate additional subpopulations, especially after disturbance. Monitor subpopulations in response to management actions and threats.	High High
Inappropriate disturbance regimes	Determine the disturbance requirements of the species. Conduct trials within known habitat to determine requirements for germination and long-term survival considering fire regimes, competition, grazing and other disturbances such as flooding.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including soil seed bank dynamics, conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	Medium

Management actions required

Theme	Specific actions	Priority
Habitat protection	Maintain protections over subpopulation in Shire reserve. Protection of this site will also benefit *Haloragis platycarpa*. Protect other known habitat or potential habitat in appropriate conservation agreements.	High
Inappropriate disturbance regimes/ lack of recruitment	Implement disturbance trials in known or historic habitat in an attempt to stimulate recruitment.	High
Ex situ conservation/translocations	In the event of a recruitment event, collect seed from mature plants and propagate *ex situ*. Establish translocated subpopulation in suitable habitat on secure tenure representing maximum range of genetic diversity possible.	High High
Habitat quality	Conduct activities to improve habitat quality within vicinity of known subpopulations by addressing threats including erosion, invasive weed management and increasing habitat connectivity between patches via revegetation.	High

Experts consulted

Bree Phillips, Andrew Crawford and Tanya Llorens.

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Eremophila subangustifolia (A.P.Br. & T.M.Llorens) [SCROPHULARIACEAE]

Eremophila subangustifolia (clockwise from left) branch showing linear-subterete leaves, spreading habit of mature individuals, long flower pedicel and pale lilac flowers (images: Andrew Brown).

Overview

Eremophila subangustifolia was previously considered to sit within *E. microtheca*, but was described at species level in 2017. It is currently listed as *E.* sp. Narrow leaves (J.D. Start D12-150) federally. The two remaining subpopulations occur in a heavily cleared landscape in highly modified habitat. This short-lived disturbance opportunist undergoes natural fluctuations in abundance due to flooding, however one subpopulation has declined dramatically since 1992, apparently due to limited recruitment, habitat modification and grazing of seedlings.

Conservation status

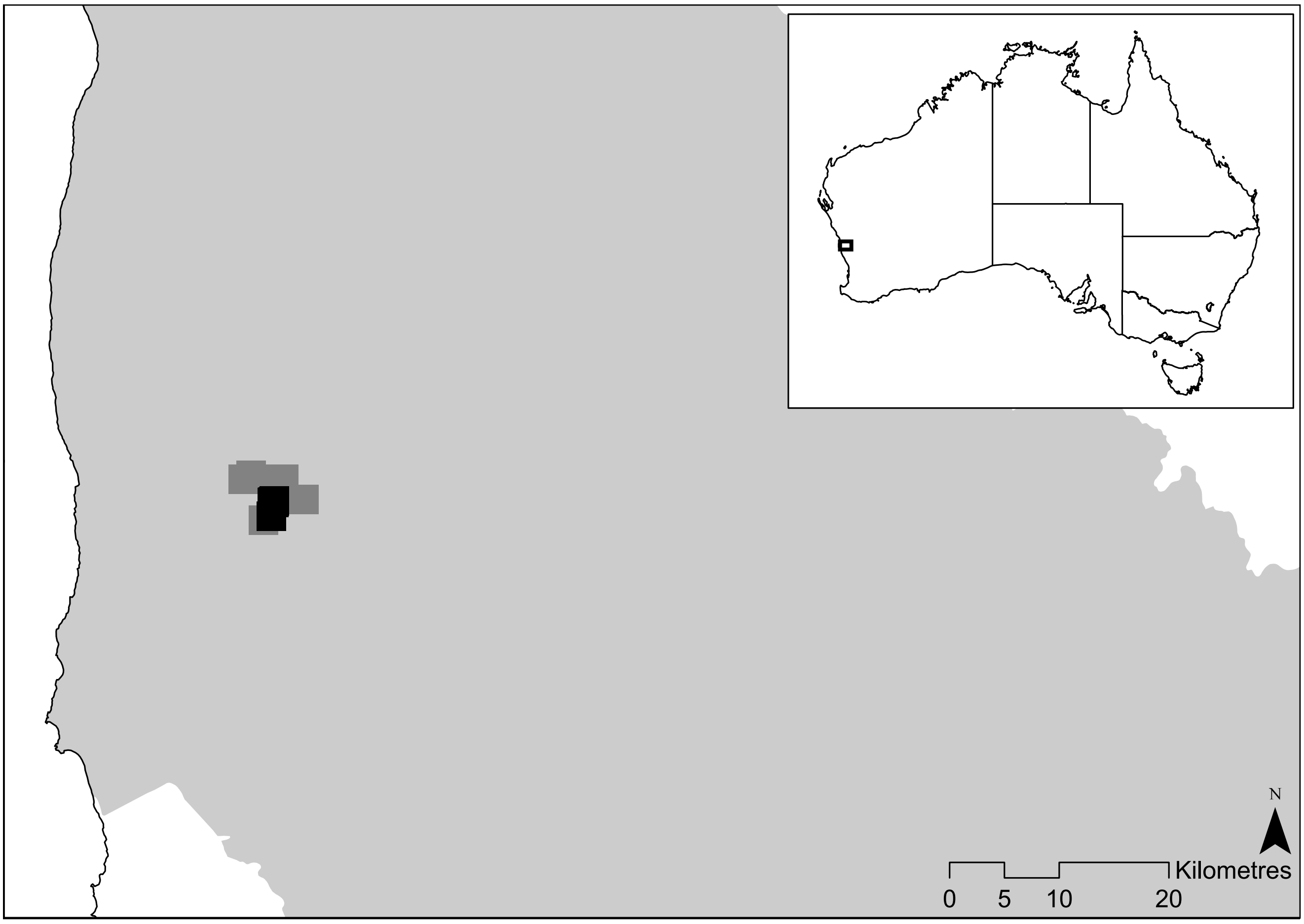
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect to spreading shrub 2.5 m tall and 4 m wide with many grey and hairy branches (Brown *et al.* 2018). Leaves are hairy, aromatic, 6-17 mm long and 0.5-1.0 mm wide, scattered along branches. Solitary pale-purple flowers 12-15 mm long and 8-12 mm wide emerge from leaf axils, forming dry, glabrous fruit (Brown *et al.* 2018). *Eremophila subangustifolia* was formerly known as the southern occurrence of *E. microtheca*, but molecular and morphological evidence resulted in its recognition as the subspecies *E. microtheca* subsp. narrow leaves (J.D.Start D12-150), later elevated to *E.* sp. Narrow leaves (J.D. Start D12-150). *Eremophila subangustifolia* is similar to *E. microtheca*, but has a larger, more spreading habit, longer narrower leaves, longer flower pedicels and larger flowers. It does not grow with or near other species in *E.* sect. *Australophilae* (Brown *et al.* 2018).

Distribution

Eremophila subangustifolia is known from a very restricted distribution near Eneabba in the Geraldton Sandplains bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current (black squares) and historical (grey squares) distribution of *Eremophila subangustifolia* in the Geraldton Sandplains bioregion (shaded grey) in Western Australia (AVH 2020; DAWE 2012; DBCA 2020).

Population estimate and trends

Eremophila subangustifolia is known from 81 individuals in two subpopulations (DBCA 2020). The narrowly separated subpopulations were probably part of a larger population prior to land clearing (Brown *et al.* 2018). Subpopulation 1 had between 20 and 65 plants recorded from 1985 and 1996. In 1999, a flood submerged the entire subpopulation and killed all plants, but the flood and subsequent roadworks to raise the height of the causeway stimulated germination from the soil seedbank, and the subpopulation appears to have recovered (DBCA 2020; T Llorens pers. comm. 2020). Subpopulation 2 has decreased from some 10 000 mature individuals in 1992, which had apparently germinated following land clearing but were heavily grazed, to 16 in 2014 (Brown *et al.* 2018). This decline appears to have been caused by a combination of a large flood in 1999 and grazing by stock, particularly of younger plants. Targeted surveys have been undertaken but no additional subpopulations have been located.

Eremophila subangustifolia monitoring data, 1985-2020 (DBCA 2020; Brown *et al.* 2018).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 (shire road reserve, nature reserve and private property)	1985: 42 1986: 26 1990: 20 1992: >20 1996: 20 1999: 0 [entire population submerged] 2001: 0 2003: 42 (30) 2013: 65 2015: >38 (partial survey) 2020: >31 (partial survey)	Stable (with fluctuations)
2 (private property)	1992: ca. 10 000 2003: 7 2014: 16	Decreasing

Habitat and ecology

Eremophila subangustifolia grows in slightly saline, pale brown sandy-clays on the margins of seasonally wet flats and lakes (Brown *et al.* 2018). Its habitat has been extensively modified through land clearing, roadworks and grazing. Associated species include *Acacia saligna, Casuarina obesa* and *Melaleuca rhaphiophylla* (Department of Parks and Wildlife 2016). Flowering mostly occurs from June to October (Brown *et al.* 2018). The species is thought to be relatively short-lived but generation length is unknown. Mortality due to flooding followed by mass germination appears to be part of the natural life cycle of this disturbance-opportunist. Due to its persistent soil seedbank, which is unlikely to be exhausted by a single event, extreme fluctuations are not likely for this species (IUCN 2019).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.48 km^2) Stable	High High
Area of occupancy (actual) Trend	4 km^2 (0.017 km^2) Stable	High High
No. of mature individuals Trend	81 Decreasing	High High
No. of locations (key threat) Trend	2 (lack of recruitment) Decreasing	High High
No. of subpopulations Trend	2 Decreasing	High High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(iii,iv,v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented; and continuing decline observed and projected in area/extent and quality of habitat, number of subpopulations/locations, and number of mature individuals.
C2a(i)	EN: <250 mature individuals; continuing decline observed and projected; and <250 mature individuals in each subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Habitat has been severely reduced and fragmented by land clearing for agriculture. The two remaining subpopulations may have once formed a single population, as each site is in an isolated area of remnant vegetation (DPW 2016). The species is considered severely fragmented as both subpopulations are very small and isolated by cleared land.
Lack of recruitment/ inappropriate disturbance regimes *Ongoing*	Whole	Rapid	High	Recruitment is limited at both subpopulations, apparently due to altered disturbance regimes (particularly flood characteristics due to changed hydrology) and post-germination threats (particularly sheep grazing). Plants are relatively short-lived and are thought to require periodic disturbance, primarily flooding and probably also fire, to stimulate germination of soil-stored seed (DPW 2016). The species is considered to occur at two locations as disturbance regimes and post-germination threats are managed at the subpopulation/ land tenure scale.
Grazing land management *Ongoing*	Majority	Rapid	Medium	The subpopulation on private property is subject to grazing and trampling by stock, which target young plants, and scrub rolling (DPW 2016). The subpopulation was fenced in the early 2000s, but by 2013 the fence was in disrepair, allowing stock to graze young plants and impact surrounding habitat.
Infrastructure maintenance *Ongoing and future*	Majority	Rapid	Medium	The roadside habitat is highly disturbed and subject to grazing, spraying, slashing, road widening and raising of the causeway (T Llorens pers.comm. 2020). Plants occurring along the property boundary may be affected by fence and road maintenance activities including slashing, herbicide spraying and drainage channel construction (DPW 2016).
Invasive weeds *Ongoing*	Whole	Slow	Medium	The habitat of both subpopulations comprises a high cover of introduced grasses (T Llorens pers.comm. 2020), resulting in increased competition and fuel loads.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Altered hydrology/ salinisation *Future*	Whole	Unknown	Unknown	Hydrology has been altered in the habitat of the species due to land clearing and causeway construction. Long-term impacts are unknown, but are likely to include rising watertables and secondary salinisation (T Llorens pers.comm. 2020).
Stochastic events *Future*	Whole	Rapid	Medium	Flooding caused a decline in Subpopulation 1 but numbers have since recovered; the other subpopulation has declined due to both flooding and agricultural practices (T Llorens pers.comm. 2020). As the species only persists in two small subzpopulations, it is vulnerable to stochastic events including future floods and prolonged drought.

Current management

- Recovery actions have been identified (DPW 2016; Threatened Species Scientific Committee 2018).
- Part of Subpopulation 1 is protected in a conservation reserve (DPW 2016).
- Approximately 11 156 fruits were collected from Subpopulation 1 between 1997 and 2017 and are stored for conservation and research purposes. The fruits are estimated to contain at least 9450 germinable seeds.
- Relevant stakeholders have been engaged to minimise damage to the subpopulations during road and fence maintenance.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Improve habitat quality at both subpopulations.
- Increase the number of mature individuals and subpopulations in the wild via stimulating recruitment of soil-stored seed (if possible) and translocations (augmentation, re/introductions).

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations, particularly after disturbance.	High
	Monitor response of subpopulations to recovery actions.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Ex situ conservation/translocations	Undertake research to determine appropriate propagation methods to inform/support future translocations.	High
Inappropriate disturbance regimes	Undertake research to better understand the disturbance requirements of the species.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known and potential habitat in appropriate conservation agreements, and rehabilitate and fence degraded habitat.	High
Inappropriate disturbance regimes/ lack of recruitment	Implement disturbance into known habitat in an attempt to stimulate recruitment and increase the number of subpopulations/individuals in the wild.	High
Ex situ conservation/translocations	Maintain and expand *ex situ* seed collections to represent maximum range of genetic diversity.	High
	Undertake translocations to secure tenure to increase the number of subpopulations in the wild.	High

Experts consulted

Andrew Crawford and Tanya Llorens.

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Eriocaulon aloefolium R.J.Davies [ERIOCAULACEAE]

Eriocaulon aloefolium in spring wetland habitat at Edgbaston Reserve, with pig damage in foreground (image: Rod Fensham).

Overview

Eriocaulon aloefolium is restricted to a single Great Artesian Basin spring wetland in semi-arid central Queensland. The small population is vulnerable to feral pig disturbance and monitoring indicates the number of individuals declined between 2013 and 2018. A translocated subpopulation has been established in artificial spring wetlands close by, and further monitoring will inform threats, population trends and management requirements.

Conservation status

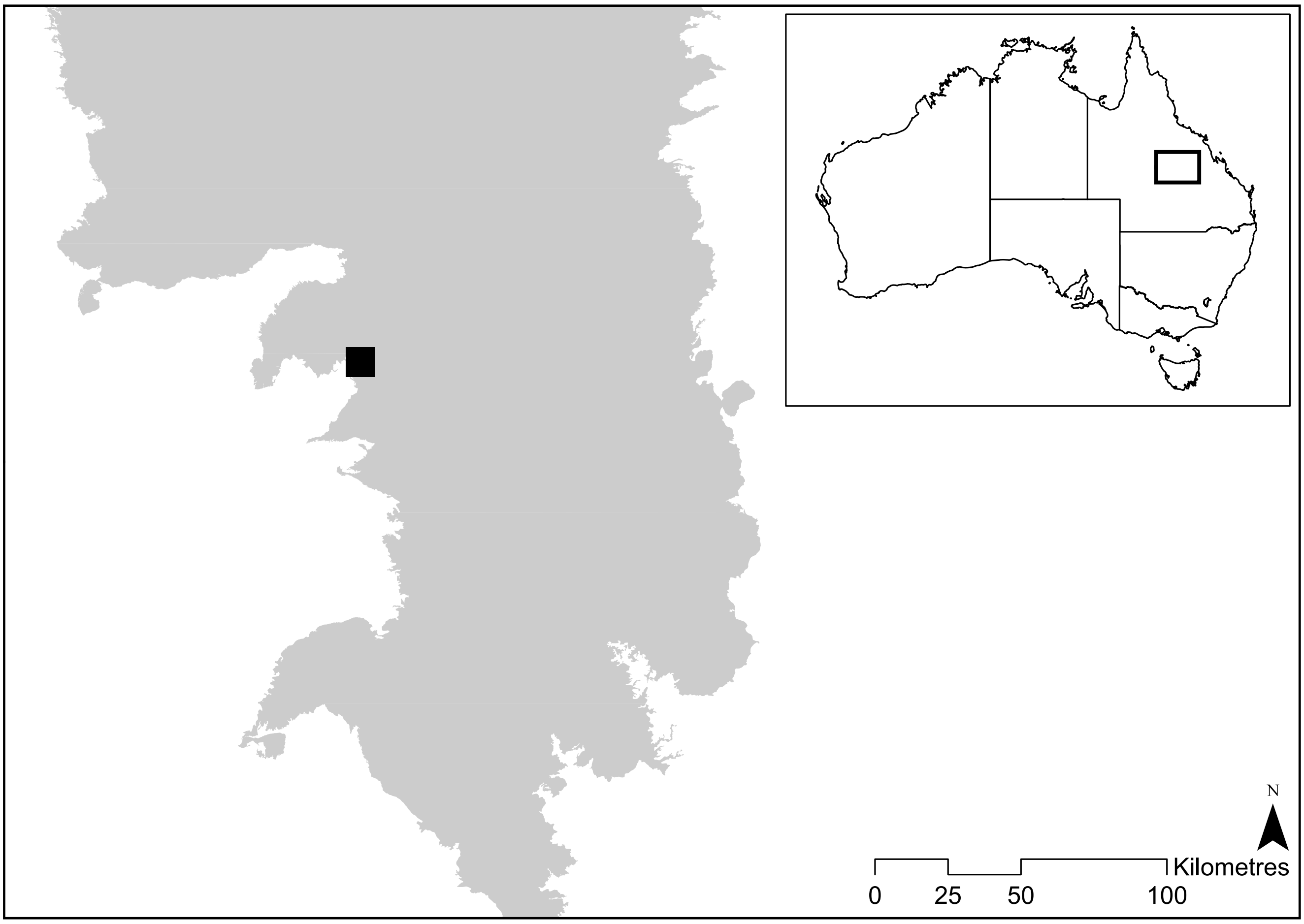
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Perennial tussock-forming herb 14-36 cm high (Davies *et al.* 2007). Leaves lanceolate, 40-94 (rarely 160) mm long, 10-19 mm wide at base, 0.8-1.6mm wide 1 mm from apex with 11-13 nerves and a fleshy broad, flat base. Peduncles 12.8-34.5 cm long with 7-8 ribs. Flowerheads are hemispherical, 9-12 mm long and 8-17 mm wide, with 1-3 rings of ≈270 female flowers alternating with 1-3 rings of ≈210 male flowers, appearing white due to long hairs. Seeds ellipsoid, 0.7-0.8 mm long and 0.5-0.6 mm wide, not smooth nor shiny, faintly reticulate (Davies *et al.* 2007). *Eriocaulon aloefolium* is unique in the *E. carsonii* complex by having significantly longer involucral bracts, floral bracts, sepal and petals, and significantly broader floral hairs (Davies *et al.* 2007).

Distribution

Eriocaulon aloefolium is known from a single Great Artesian Basin spring in the Barcaldine Supergroup north-east of Aramac in the Desert Uplands bioregion of Queensland (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012). All springs in the Barcaldine Supergroup have been surveyed, and unrecorded subpopulations are unlikely (Fensham *et al.* 2016). *Eriocaulon aloefolium* is considered severely fragmented due to its occurrence in an isolated oasis within a semi-arid landscape (IUCN 2019).



Current distribution of *Eriocaulon aloefolium* (black square) in the Desert Uplands bioregion (shaded grey) of Queensland (AVH 2020; DAWE 2012).

Population estimate and trends

Eriocaulon aloefolium typically forms clumps of 4-6 rosettes joined by short rhizomes, which are considered individuals for monitoring purposes. The species is restricted to a single subpopulation covering ca. 1500 m^2 (30 x 50 m area). The number of mature individuals has fluctuated since 2010, with 1274 clumps in 2010, 2588 clumps in 2013 and 1558 clumps in 2018 (P Foreman, R Fensham, J Silcock upublished data). However, the mean number of rosettes per clump was highest in 2010 (6.08) and lowest in 2018 (4.3), indicating an overall decline, although further monitoring is required to distinguish fluctuations from long-term trends. These fluctuations are not considered extreme as they do not vary by an order of magnitude (IUCN 2019).

Eriocaulon aloefolium monitoring data, 2010-2018 (P Foreman, R Fensham, J Silcock unpublished data).

Subpopulation (tenure)	Number of clumps (rosettes)	Trend
1 Edgbaston Reserve (private conservation reserve)	2010: 1274 clumps (7746) 2013: 2588 (12 883) 2018: 1588 (6699)	Decreasing (?)

Habitat and ecology

Eriocaulon aloefolium grows in a Great Artesian Basin spring wetland, in permanent shallow water alongside *Phragmites australis, Sporobolus pamelae, Myriophyllum artesium*, on the spring vent with *E. carsonii*, and on the spring tail with *Fimbristylis dichotoma, Cyperus laevigatus*, *Myriophyllum artesium* and *E. carsonii* (J Silcock pers. comm. 2020). The spring occurs on a scalded plain dotted with *Melaleuca bracteata* clumps (J Silcock pers.comm. 2020). *Eriocaulon aloefolium* appears to require variegated habitat including open areas adjacent to small pools (J Silcock pers.comm. 2020). Lifespan and thus generation length is unknown.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.002 km^2) Stable	High High
Area of occupancy (actual) Trend	4 km^2 (0.002 km^2) Stable	High High
No. of mature individuals Trend	1588 Decreasing	High Medium
No. of locations (key threat) Trend	1 (feral pigs) Stable	High High
No. of subpopulations Trend	1 Stable	High High
Generation length	Unknown	Low
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(iii,v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline projected in quality of habitat and number of mature individuals.
C2a(ii)	EN: <2500 mature individuals; continuing decline projected; and 90-100% (100%) of mature individuals in one subpopulation.
D2	VU: AOO <20 km^2; <5 locations; and plausible future threat.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Aquifer drawdown *Past*	n/a	n/a	n/a	Since colonisation, many springs in the Barcaldine Supergroup and across the GAB have become extinct, or have greatly reduced flow volume and wetland area due extraction of aquifer water through pastoral bores. Undocumented subpopulations of *E. aloefolium* may have existed in now-extinct or modified springs.
Feral herbivores (pigs) *Suspended*	Whole	Very rapid	High	Feral pigs can rapidly plough the soil of an entire spring; trampling vegetation, defoliating plants and exposing plant roots. *Eriocaulon aloefolium* is especially vulnerable to these impacts because it occurs in a single spring and its fleshy roots appear to be targeted. Impacts vary seasonally; from highly disturbed to virtually untouched, and *E. aloefolium* is able to recover from severe pig disturbance. The spring wetland was fenced in 2018 in response to escalating pig impacts, although ongoing maintenance will be necessary to prevent breaches. Periodic disturbance may also maintain open habitat for *E. aloefolium* to colonise. In the absence of disturbance, mat-forming *E. carsonii* or *P. australis* (which dominates the vent) may become more prevalent. Appropriate disturbance mechanisms and intervals are not well-understood and require further monitoring and research.
Future groundwater extraction *Future*	Whole	Rapid	Medium	Although many pastoral bores have been capped, future demands for groundwater for extractive industries may arise – as is the case for the nearby Doongmabulla springs. Future water extraction may reduce aquifer pressure and cause spring extinction.

Current management

- Recovery actions are identified in the GAB springs recovery plan (Fensham *et al.* 2010).
- Edgbaston Reserve is managed by Bush Heritage Australia for conservation of spring ecosystems and their dependent species, including *E. aloefolium*, which is continually monitored (P Kern pers.comm. 2020).
- Feral pigs are regularly controlled through a trapping and baiting program.
- A translocated subpopulation has been established from rhizomes/clumps of plants at artificial springs, which were created as habitat for an insurance population of the critically endangered red-finned blue-eye fish *Scaturiginichthys vermeilipinnis*.
- All springs in the Barcaldine Supergroup have been surveyed for threatened flora.
- Most bores in the area have been capped, and spring wetland area appears to be increasing in association with aquifer pressure (R Fensham, B Laffineur unpublished data). Continued monitoring will further inform these trends.

Conservation objectives

- Monitor and maintain known subpopulations (wild and translocated).
- Expand *ex situ* subpopulation for seed collection.
- Better understand the biology, ecology and population trends of the species to inform threat management.

Information required

Theme	Specific actions	Priority
Population surveys	Population monitoring every 3-5 years to determine population trends in response to threats and management actions, particularly fencing.	High
Life history and ecology	Undertake research to better understand the biology, ecology and threats to the species including conservation genetics, seed production and viability, germination requirements, specific habitat requirements and long-term response to disturbance.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Continue feral pig control as required and monitor fence for breaches. Ensure that sufficient open habitat for the species is maintained.	High
	Proposals that may affect aquifer pressure in the area need to be thoroughly assessed and not permitted where there are potential impacts on the spring ecosystems.	High
Ex situ conservation/translocations	Maintain translocated subpopulation in artificial spring wetland.	High
	Collect and store seed representing the maximum range of genetic diversity possible.	High

Experts consulted

Rod Fensham, Paul Foreman, Pippa Kern and Jen Silcock.

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Eucalyptus dalveenica T.L.Collins, R.L.Andrew & J.J.Bruhl [MYRTACEAE]
Dalveen blue box



Eucalyptus dalveenica fruit (top left), buds (bottom left; images: Tim Collins) and stand of trees on private property near Dalveen (right; image: John Neldner).

Overview

Eucalyptus dalveenica was previously included within *E. magnificata* but was described and assigned species status in 2019 after genetic, phytochemical and morphological analysis. It is restricted to a small patch of remnant vegetation across three private properties and a roadside reserve. Past decline has occurred due to its association with fertile soils, which have largely been converted to cropping land. Declines are continuing due to clearing and dieback from an unknown cause. The species has high recovery potential as there is recruitment occurring and seed is viable, but conservation agreements and restoration plantings are urgently needed.

Conservation status

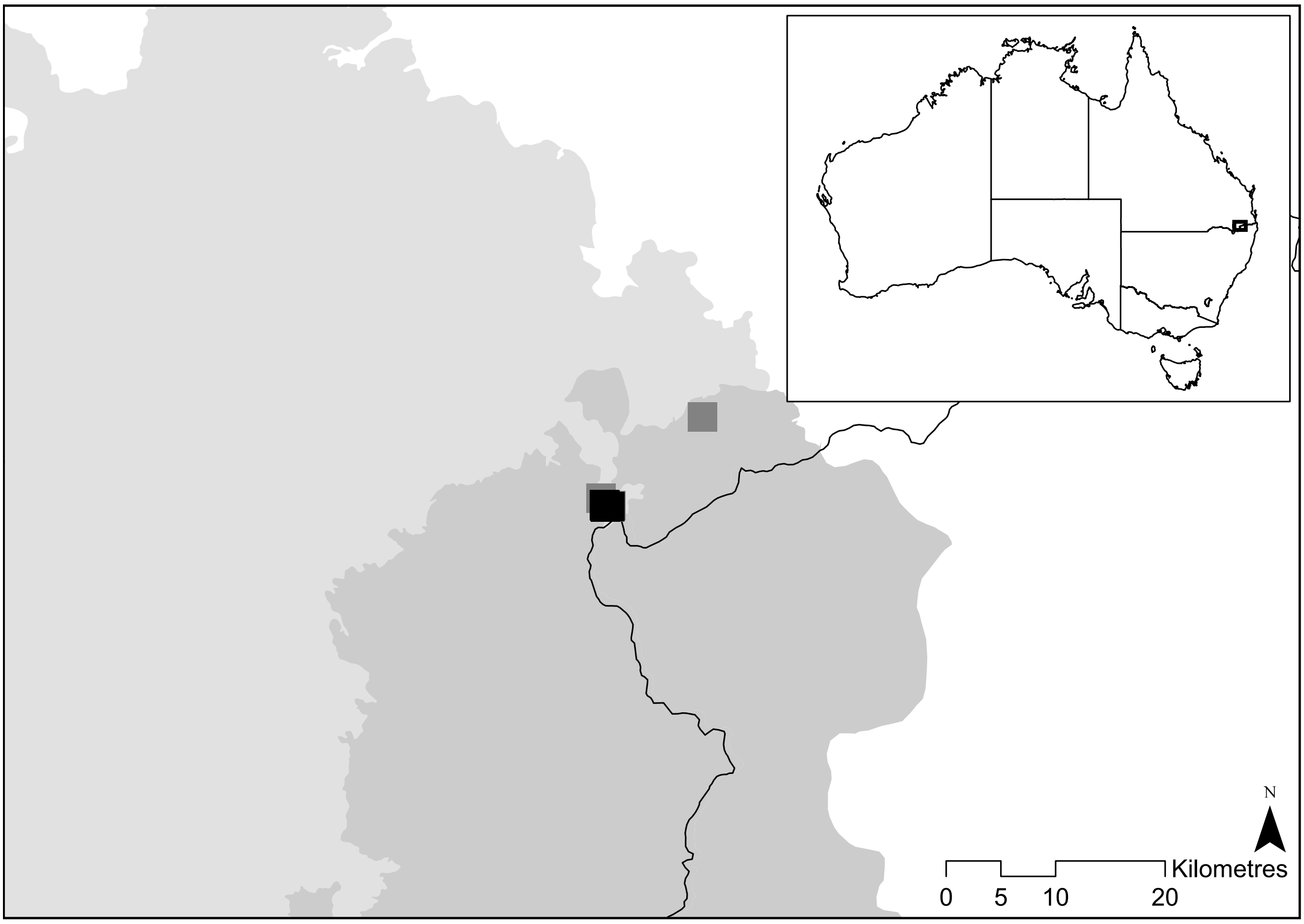
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992	Critically Endangered
IUCN Red List	Critically Endangered

Brief description

Tree to 15 m tall with light grey, flaky, 'box' bark that becomes smooth on branches <50 mm in diameter (Collins *et al.* 2019). Leaves slightly glossy, concolorous, broadly lanceolate, 10-15 cm long and 2.6-4.1 cm wide, with an acuminate apex and visible intramarginal veins. Inflorescence terminal or sometimes axillary, with up to 6 clusters of 7 flowers. Floral buds 9-12 mm long and 4-4.5 mm wide, calyptra hemispherical to conical. Fruit conical, 7-9.8 mm long and 6.2-7.8 mm wide with 3-4 valves and dark brown seeds (Collins *et al.* 2019). *Eucalyptus dalveenica* is distinguished from *E. baueriana* and *E. magnificata* by its acute seedling leaf apices, shorter bud pedicels and the mild, fruity aroma of its crushed leaves (Collins *et al.* 2019).

Distribution

Eucalyptus dalveenica is known from a very restricted distribution near the town of Dalveen bordering the Nandewar and New England Tablelands bioregions of southern Queensland (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment; Collins *et al.* 2019).



Current (black squares) and historic (grey squares) distribution of *Eucalyptus dalveenica*, which currently occurs on the boundary of the Nandewar (shaded light grey) and New England Tablelands (shaded dark grey) bioregions of southern Queensland (AVH 2020; Collins *et al.* 2019; DAWE 2012; Booth and Bourne 2020).

Population estimate and trends

Eucalyptus dalveenica was described in 2019 when it was known from <100 mature individuals (Collins *et al.* 2019). Approximately 220 mature individuals were counted in the first census in 2008, which increased to 244 in 2019 as juveniles matured (Booth and Bourne 2020). The single subpopulation is spread over three neighbouring properties and extends onto an adjacent road reserve. In 2020, another stand of *E. dalveenica* was confirmed on property nearby, although this remains unsurveyed (C Booth pers.comm. 2020).

A historical decline of >90% has been estimated based on the species' association with fertile soils that have been extensively cleared in the region (Fensham *et al.* 2020). A historical collection record at Cherry Gully cannot be relocated (Booth and Bourne 2020). Recent declines have been documented, with three previously unrecorded trees identified next to a fence in 2019, within a paddock that was largely cleared between 2012 and 2018 (Booth and Bourne 2020). The understorey of Subpopulation 1b was also cleared prior to property sale in 2019, which would have killed any juvenile plants (Booth and Bourne 2020).

Although some recruitment has been documented from 2008-2019, the security of the population is tenuous as it occurs almost exclusively on private land where clearing can rapidly occur under certain circumstances. Surveys of historical collection records and other accessible habitat in the area have failed to locate additional plants. However, more stands may be located in surveys of private property in the region.

Eucalyptus dalveenica monitoring data, 2008-2019 (Booth and Bourne 2020; Collins *et al.* 2019; Holmes and Holmes 2008; SRWC 2019).

Subpopulation (tenure)	Number of mature individuals (dead)*	Trend
1a Butler Lane (freehold)	2008: 120 2019: 168	Unknown
1b Granite Belt Drive – garden (freehold)	2008: 55 2019: 50	Unknown
1c Granite Belt Drive – remnant (freehold)	2008: 40 2019: 23	Unknown
1d Hamilton Road (freehold)	2019: 3	Unknown
1e Granite Belt Road (roadside reserve)	2008: 2 2015: 1 2019: 0 [1]	Presumed extinct

*Note: dead trees were present at subpopulations other than 1e in 2019 but were not counted (C Booth pers.comm. 2020). Juvenile plants are present but have not been counted at any subpopulation.

Habitat and ecology

Eucalyptus dalveenica occurs on fertile clay soils with impeded drainage in open woodlands with *E. moluccana* (Collins *et al.* 2019). The ecology of *E. dalveenica* is not well-documented. Well-developed buds have been observed in June, indicating flowering occurs in spring and early summer (Collins *et al.* 2019). The species may also reproduce clonally, as juvenile plants appear to grow from root suckers within 1 m (and sometimes further) from parent plants (T Collins pers.comm. 2019). Generation length is unknown, but is likely to be at least 70 years (Fensham *et al.* 2020).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.4 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.4 km^2) Decreasing	High High
No. of mature individuals Trend	244 (plus 1 unsurveyed stand) Decreasing	High High
No. of locations (key threat) Trend	1 (habitat loss) Decreasing	High High
No. of subpopulations Trend	1 Decreasing	Medium High
Generation length	>70 years	Low
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Inferred and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A4ce	CR: >80% reduction inferred within 3 generations (210 years); based on decline in AOO, EOO and habitat quality (see Booth and Bourne 2020; Fensham *et al.* 2020).
B1ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; continuing decline inferred and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(ii)	EN: <2500 mature individuals; continuing decline inferred and projected; and 90-100% (100%) of mature individuals in one subpopulation.
D	VU: <1000 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Infrastructure maintenance/ roadside threats *Past*	n/a	n/a	n/a	One stand of trees occurred along a road reserve where it was vulnerable to roadside threats, but is now presumed extinct.
Habitat loss *Past and ongoing*	Whole	Very rapid	High	Land clearing for agriculture has severely reduced and fragmented the available habitat of the species. All individuals occur in a restricted patch of (now fragmented) remnant vegetation isolated by cleared land. The understorey of Subpopulation 1b was removed in 2019, which may have caused losses of juvenile plants and reduced habitat quality. Approximately 3.6 ha directly next to a patch of remnant trees was cleared in recent years (Collins 2016). Some trees have been incorporated into garden beds surrounded by lawn areas, and are vulnerable to future clearing (Collins 2016). No stands occur on protected estate and clearing can occur under certain circumstances (Evans 2016). As all individuals can be rapidly affected by this threat, the species occurs at one location (IUCN 2019).
Dieback *Ongoing*	Majority	Slow	Medium	Dieback has been observed during both drought and non-drought periods. Moderate dieback was observed in 2015, a non-drought period (T Collins unpublished data) and high stress levels were observed during drought in 2019 in 17% (1a), 20% (1b) and 30% (1c) of plants (SRWC 2019).

Current management

- There is no recovery plan for this species.
- Research into the taxonomy (morphology, phytochemistry and molecular analysis), demography, seed viability and threats has been undertaken by Tim Collins (Collins 2016).
- Monitoring surveys have been commissioned by Queensland Murray-Darling Committee in 2008 (Holmes and Holmes 2008) and by the Stanthorpe Rare Wildflower Consortium in 2019 (SRWC 2019).
- Seed viability is high and propagation has been occurring with individuals planted in local gardens and the school at Dalveen.

Conservation objectives

- Establish conservation covenants over habitat of *E. dalveenica*.
- Ensure no further clearing of the species and its habitat.
- Increase the number of self-sustaining subpopulations in the wild via translocation to suitable habitat in secure tenure. As there are no suitable reserves in the region (C Booth pers.comm. 2020), land acquisition or conservation covenants are necessary.
- Involve local community in conservation of the species.
- Determine causes of dieback and implement management strategies to mitigate this threat.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake surveys to locate additional stands.	High
	Urgently survey the newly located stand on private property.	High
	Regularly monitor the population to better understand demographics, and response to threats and management actions.	High
Dieback	Undertake research to better understand the cause of dieback in the population.	High
Ex situ conservation/translocations	Liaise with local community groups to determine potential areas for translocations (revegetation) projects.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including the relative importance of asexual and sexual reproduction; pollination biology (including mating system), germination under natural conditions, habitat suitability for translocations and appropriate fire regimes.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect all individuals on freehold land under appropriate conservation agreements. If additional stands are located, ensure these are also protected.	High
Ex situ conservation/translocations	Collect and propagate seed (ideally alongside SRWC) in *ex situ* collection ensuring maximum range of genetic diversity possible is captured.	High
	Undertake conservation plantings into recipient sites with local community groups. Maintain plantings until established by weeding, watering, mulching etc.	High
Extension and awareness	Maintain engagement with landholders and conservation groups.	High
	Engage local community groups and landholders in conservation activities (e.g. *ex situ* plantings, re-vegetation projects especially around extant stands).	High
	Raise awareness of the species with local stakeholders and conservation groups in attempts to locate additional occurrences.	Medium

Experts consulted

Tim Collins, Rose Andrew, Jeremy Bruhl and Carol Booth.

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Eucalyptus imlayensis (Crisp & Brooker) [MYRTACEAE]
Imlay mallee, Mt Imlay mallee


Eucalyptus imlayensis growth habit (left; image: Brooker & Kleinig © Australian Plant Image Index, Australian National Botanic Gardens) and peeling bark (right; image: M Crisp © APII, ANBG).

Overview

Eucalyptus imlayensis occurs in a single population on the isolated peak of Balawan (Mount Imlay) in south-eastern New South Wales. The population is declining due to dieback from an unknown source. Establishing an insurance subpopulation is challenging given the low level of seed production, and all translocated individuals were killed in severe fires in 2020.

Conservation status

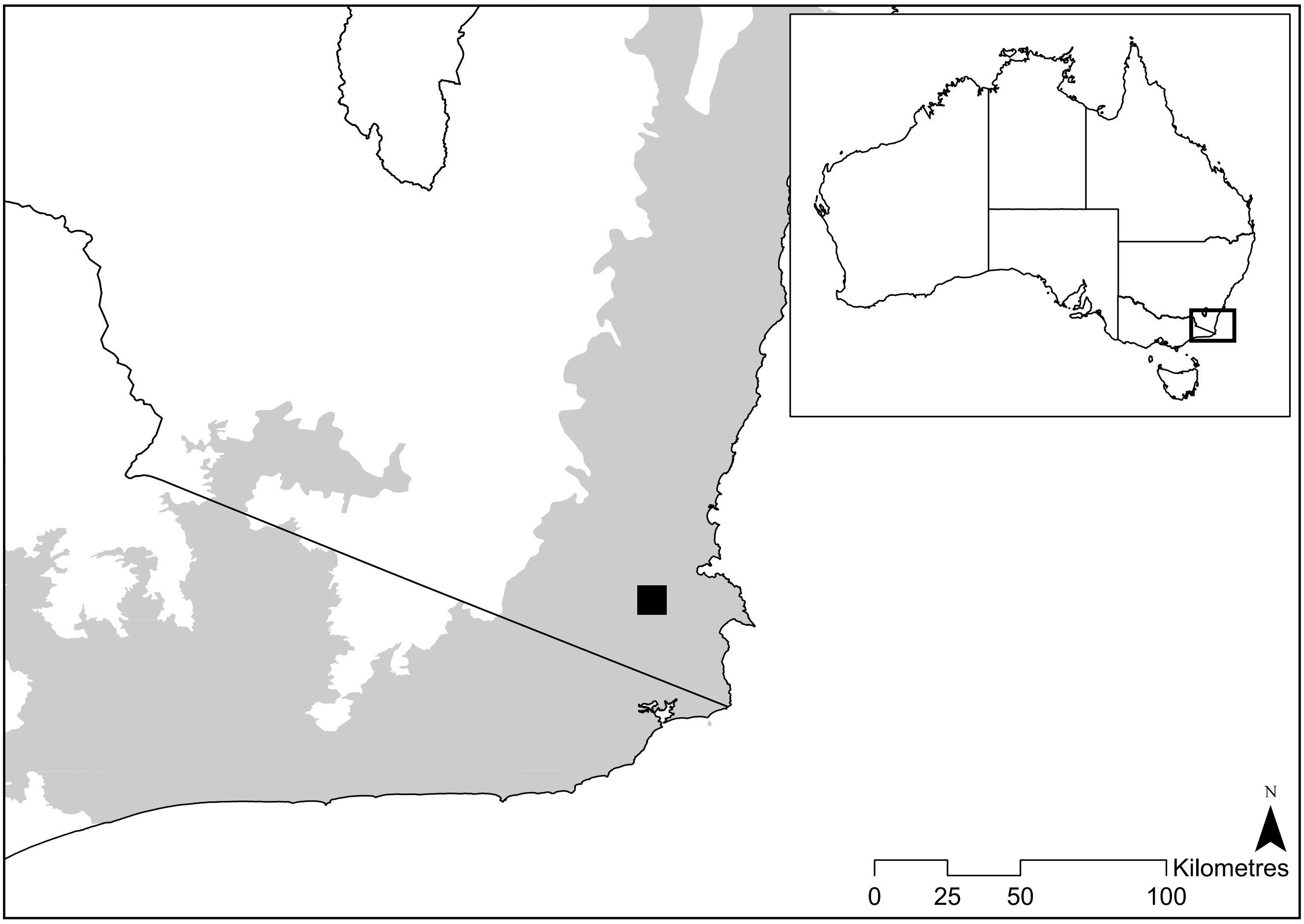
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List	Critically Endangered

Brief description

Mallee to 7 m tall forming a large lignotuber with a dense canopy (Crisp and Brooker 1980). Smooth green bark weathers to orange-brown to grey and sheds in ribbons. Leaves with strongly flattened petioles to 1.5 cm clustered towards ends of branchlets. Lamina thick, lanceolate and falcate, 10-15 cm long and 1.5-2 cm wide with few oil glands. Inflorescences axillary, with flower buds in groups of three on a short peduncle with conical to slightly beaked operculums. Fruit sessile with a prominent disc and exserted valves, and smooth dark grey seed. *Eucalyptus imlayensis* is similar to *E. subcrenulata* but has ascending discs on the fruit. It also differs from *E. baeuerlenii* by its narrower, wingless seedling leaves, larger fruits and abruptly acuminate operculum (Crisp and Brooker 1980).

Distribution

Eucalyptus imlayensis is known from the isolated peak of Balawan (Mt Imlay) near Eden in New South Wales, in the South East Corner bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012). The species is considered severely fragmented as it occurs in a single isolated population (IUCN 2019).



Current distribution (black square) of *Eucalyptus imlayensis* at Balawan (Mt Imlay) in the South East Corner bioregion (shaded grey) of southern New South Wales (AVH 2020; DAWE 2012).

Population estimate and trends

Eucalyptus imlayensis was first recorded in 1977 from a small population of 70 'individuals' (Crisp and Brooker 1980). Genetic analysis has since established *E. imlayensis* exists as a multi-stemmed clonal population comprising five genetically distinct individuals (James and McDougall 2007). For clonal species, population abundance is measured by the number of distinct reproductive units (i.e. stems; IUCN 2019). Currently, there are 80 stems over an area of approximately 1000 m^2, and this has been declining since regular monitoring began in 1998 (James and McDougall 2007). In March 2001, almost one-third of stems were estimated to have >50% crown death; by 2001, the mean proportion of dead branchlets on stems had increased significantly (James and McDougall 2007). This decline is continuing, with the death of an estimated 15% of clones since 2000 (K McDougall pers.comm. 2017). Assuming a constant rate of decline (15% over 20 years), a population reduction of >90% is projected within 100 years.

Other mountains in the region were searched before the species was described, but the habitat was unsuitable and other subpopulations were not located (Crisp and Brooker 1980).

Habitat and ecology

Eucalyptus imlayensis occurs on the eastern slopes of Balawan (Mt Imlay) at 850-870 m above sea level (Crisp and Brooker 1980). It grows on steep terrain amongst granite rocks and dense shrubland dominated by *Leptospernum scoparium* (AVH 2020). The habitat receives a large amount of orographic moisture (Crisp and Brooker 1980). Associated species include *Boronia imlayensis, Cassytha pubescens, Derwentia perfoliata, Dianella tasmanica, Doodia media, Lomandra longifolia, Melaleuca squarrosa, Oxylobium ellipticum* and *Prostanthera walteri* (AVH 2020).

Eucalyptus imlayensis is a relict species (Crisp and Brooker 1980) and may be adapted for survival in the single, small, isolated population. However, it is considered severely fragmented given that dispersal outside its isolated, or recolonisation following extinction, is unlikely (IUCN 2019). Reproduction is predominantly asexual with most stems arising from a small number of genetically distinct plants (James and McDougall 2007). Seedlings or juveniles have not been documented and germination is presumably a very rare event. Flowers appear annually during mid-summer, but have also been observed in May. However fruit production is rare, and capsules contain few seeds (James and McDougall 2007). The mechanisms for maintaining genetic diversity are not well-understood, but even occasional sexual reproduction in long-lived species can be sufficient for maintaining genetic diversity (James and McDougall 2007).

Wasp galls have been observed on leaves and may contribute to poor vigour, but are not considered a significant threat. Under controlled conditions, *E. imlayensis* was tolerant to *Phytophthora cinnamomi*, which occurs at the population (Liew and McDougall unpublished data). The entire population burnt severely in 2020 but most plants have regenerated from lignotubers, although there are no new mature stems and all translocated plants were killed (K McDougall pers. comm. 2020). *Eucalyptus imlayensis* is a long-lived tree. The very large lignotubers that are moulded around and between the quartzite rocks of Balawan (Mt Imlay) (Crisp and Brooker 1980), plus the large distance between clones (>10 m), indicates the species can probably live for hundreds of years (K McDougall pers.comm. 2020).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.001 km^2) Stable	High High
Area of occupancy (actual) Trend	4 km^2 (0.001 km^2) Decreasing	High High
No. of mature individuals Trend	80 Decreasing	High High
No. of locations (key threat) Trend	1 (dieback) Stable	High High
No. of subpopulations Trend	1 Stable	High High
Generation length	>100 years	Medium
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Observed and estimated	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A4ac	CR: >80% reduction projected in past and future (15% observed in past from 2000-2020 and 75% estimated in next 100 years); based on direct observation and decline in habitat quality.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; continuing decline observed and estimated in EOO, AOO, area/extent/quality of habitat, number of locations, and number of mature individuals.
C2a(ii)	CR: <250 mature individuals; continuing decline observed and estimated; 100% of mature individuals in one subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Infrastructure development *Past*	n/a	n/a	n/a	Two developments were proposed on Balawan (Mt Imlay) (possibly telecommunication towers), but were averted due to the documentation of the species (Crisp and Brooker 1980).
Dieback (cause unknown) *Ongoing*	Whole	Rapid	High	Fifteen percent of clones have died since 2000 from an unknown cause (K McDougall pers.comm. 2020). As all individuals in the population are affected by dieback, the species occurs at one location.
Lack of recruitment *Ongoing*	Whole	Rapid	High	Establishment from seed is probably a naturally rare event, with no seed observed over a 4 year period (James and McDougall 2007). In the absence of recruitment, the population will continue to decline due to dieback.
Insect damage *Ongoing*	Majority	Slow	Low	An unknown species of wasp occasionally causes galls on the leaves of most individuals, and may be contribute to poor health (James and McDougall 2007), but is not considered a major long-term threat (K McDougall pers.comm. 2020).
Competition with native vegetation *Ongoing*	Whole	Unknown	Unknown	Observed lack of recruitment and death of clones may be due to competition from dense native vegetation, but this hypothesis requires further evidence. After the 2020 fire, large numbers of *E. sieberi* (which is dominant upslope but was not present at the site previously) germinated within the *E. imlayensis* population; these seedlings will be removed, as their establishment would alter the local environment (K McDougall pers.comm. 2020).
Climate change *Ongoing*	Whole	Unknown	Unknown	Dieback may be associated with climatic drying due to climate change, which is projected to increase in severity in the future (Grose *et al.* 2015).
Limited genetic diversity *Ongoing*	Whole	Unknown	Unknown	The genetic structure of *E. imlayensis* is largely the product of asexual reproduction, with only five genetically distinct individuals (James and McDougall 2007).
Stochastic events *Future*	Whole	Very rapid	High	Given the very restricted geographic range and small population size, the species is vulnerable to stochastic events such as prolonged drought or repeated severe wildfires.
Disease Future	Whole	Slow	Low	*Phytophthora cinnamomi* is present at the site and may affect plants when under stress but is not currently considered a major threat (K. McDougall pers.comm. 2020).

Current management

- There is no national recovery plan for this species (K McDougall pers.comm. 2020). Recovery actions are identified in the conservation advice (Department of the Environment, Water, Heritage and the Arts 2008) and under the NSW Saving our Species strategy for the species (NSW Department of Planning, Industry and Environment 2020).
- The single subpopulation is protected in Mt Imlay National Park and monitoring is ongoing (NSW DPIE 2020).
- Research has been undertaken into the genetic variability within the subpopulation (James and McDougall 2007) and its susceptibility to phytophthora (Liew and McDougall unpublished data).
- The species has been propagated and translocated to nearby sites on Balawan (Mt Imlay) in a variety of microhabitats (NSW DPIE 2020), but all 37 surviving translocated plants were killed in the 2020 fire (K McDougall pers.comm. 2020).
- Seedlings of *Eucalyptus sieberi* that germinated post-fire will be removed (K McDougall pers.comm. 2020).

Conservation objectives

- Monitor and maintain population.
- Establish *ex situ* subpopulation with all genotypes represented.
- Identify causes of decline and manage these threats.
- Identify reproductive system and germination requirements.
- Increase the number of individuals in the wild via augmentation of natural subpopulation.

Information required

Theme	Specific actions	Priority
Population surveys	Monitor population to better understand demographics, and response to threats and management actions.	High
Life history and ecology	Investigate reproductive system and identify limitations to producing fertile seed, as sexual reproduction may be advantageous for maintaining genetic variability essential to the long-term viability of the species (James and McDougall 2007).	High
	Conduct trials to determine requirements for successful germination via seed.	High
Genetic diversity	Analyse genomes of plants further downslope in an attempt to identify additional genotypes.	High
Dieback	Establish cause of dieback, including possible effects of vegetation competition.	High
Ex situ conservation/translocations	Investigate potential sites for future translocations, if feasible.	High

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Establish and maintain *ex situ* subpopulation representing the maximum range of genetic diversity feasible, to support future translocation attempts.	High
Dieback	Implement and maintain disease hygiene measures at the site.	High

Experts consulted

Keith McDougall.

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Eucalyptus morrisbyi Brett [MYRTACEAE]
Morrisby's gum

Dieback of mature *Eucalyptus morrisbyi* trees in a fragmented agricultural landscape, with juveniles emerging following installation of an exclosure fence in 2017 (Image: Magali Wright).

Overview

Extensive land use change had occurred within the habitat of *Eucalyptus morrisbyi* by the early 1990s, when only 2000 mature individuals were known. Between 2011 and 2016 the species declined drastically to <50 mature individuals. Recent declines are thought to be symptomatic of climatic drying, exacerbated by several other threats especially possum browsing. Recovery actions have included banding adult trees, wildlife-proof fencing to encourage recruitment, seed-banking, translocations and weed control. Considerable regeneration of juveniles has occurred at Calverts Hill where exclosure fencing has been installed, however ongoing maintenance is required. The subpopulation at Risdon Hills is expected to become extinct in the near future. Assisted migration is considered in the long-term conservation planning strategy for this species due to severe declines and lower planting success rates within the known species range.

Conservation status

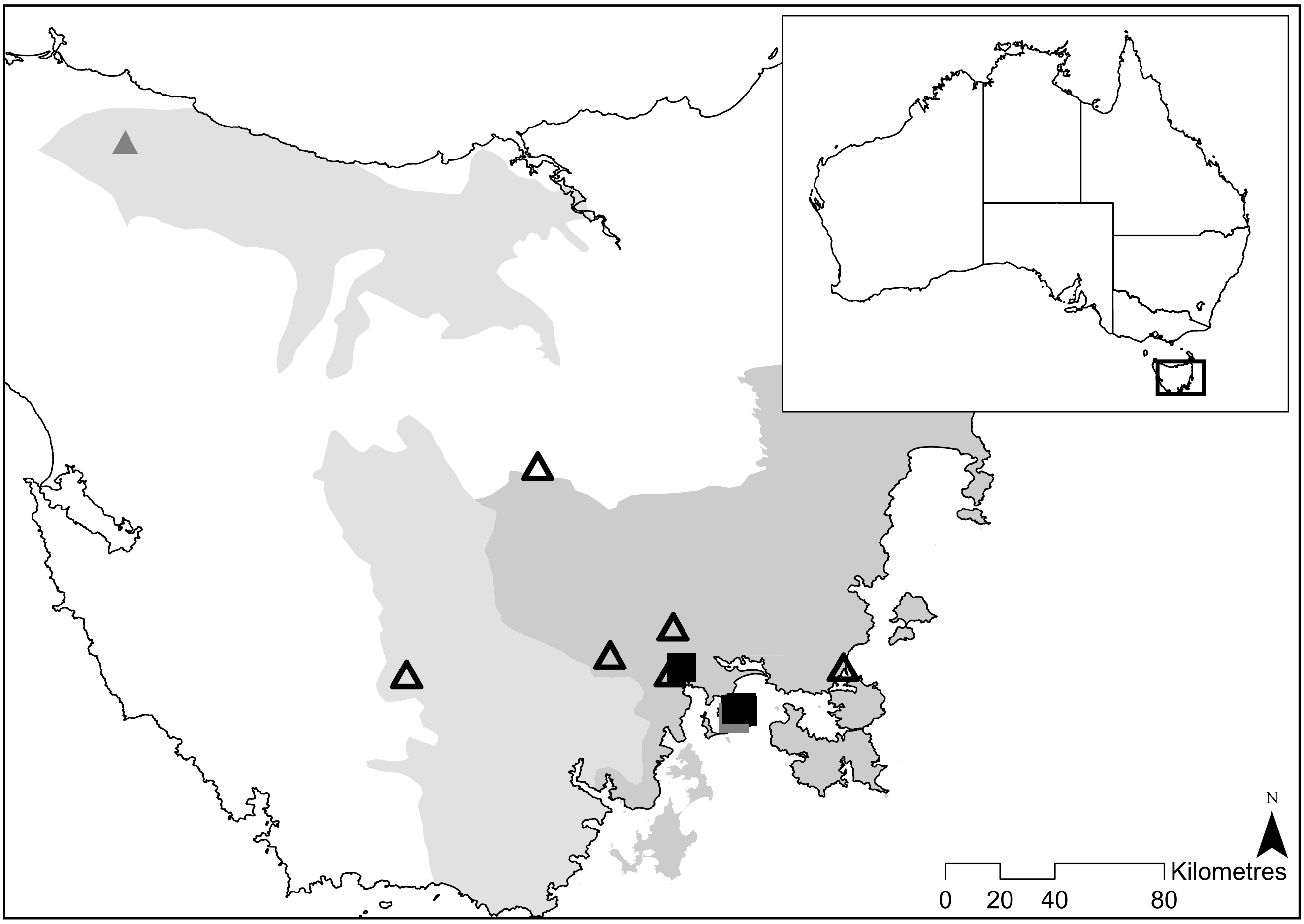
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Threatened Species Act 1995	Endangered
IUCN Red List	Critically Endangered

Brief description

Mallee (multi-stemmed tree with a lignotuberous base) or tree to 12 m with rough basal bark becoming smooth, brown, white-grey or pink-grey on the upper branches (Threatened Species Section 2006). Juvenile leaves are glaucous, opposite, unstalked, rounded, 2-3 cm long and 2-4 cm wide. Adult leaves alternate, 5-10 cm long and 1.5-4 cm wide. Flower buds are pointed and arise in clusters of three from the leaf axils. *Eucalyptus morrisbyi* is closely related to *E. gunnii, E. archeri, E. cordata and E. urnigera* (TSS 2006). It can be distinguished from *E. gunnii* and *E. archeri* by the more distinct bud/fruit pedicels and coastal distribution; from *E. cordata* by its smaller capsules that arise only in leaf axils; and from *E. urnigera* that has urceolate fruit (Centre for Australian National Biodiversity Research 2020; TSS 2006). *Eucalyptus morrisbyi* is known to hybridise with *E. viminalis*, and the hybrids are readily distinguished by their narrower and less glaucous juvenile leaves (TSS 2006).

Distribution

Eucalyptus morrisbyi is known from two subpopulations near Hobart, on the eastern side of the Derwent River in the Tasmanian South East bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012).



Current (black squares) and historic (grey square) distribution of *Eucalyptus morrisbyi* in the Tasmanian South East bioregion (shaded grey) near Hobart (AVH 2020; DAWE 2012). Several seed orchards have been established but are not considered self-sustaining subpopulations (hollow triangles) and one translocation has failed (grey triangle). Augmentation has occurred at the Calvert Hills subpopulation and the species has been introduced to the east of its range, but these are not yet considered self-sustaining (hollow triangles).

Population estimate and trends

Eucalyptus morrisbyi is currently known from two subpopulations with fewer than 50 mature individuals. In 1991, the species was known from <2000 mature individuals (Wiltshire *et al.* 1991). There were approximately 1950 mature individuals over five sites at Cremorne, with the majority occurring in Calvert Hills Nature Reserve, and small remnant stands in Honeywood Drive, Lumeah Point, South Arm Road and Cremorne Avenue (TSS 2020). An additional stand was present at Risdon Hills, which comprised <20 mature individuals by 1996 (*Eucalyptus morrisbyi* Working Group 2018). Between 2011 and 2016, the population declined by >90%, and by 2018 there were seven mature trees at Calverts Hill and the Risdon Hills subpopulation was reduced to weak regrowth from lignotubers (EMWG 2018). There are approximately 2400 juvenile plants at Calverts Hill Nature Reserve (EMWG 2018). Since establishment of wildlife proof fencing at this site in 2017 these juveniles have grown considerably, with some reaching over 4 m in height (EMWG unpublished data).

The area has been well-surveyed and additional stands are unlikely to be found. Although *E. morrisbyi* has a clonal growth habit and the number of genetically distinct individuals is much lower than original population counts indicate (Jones *et al.* 2005), stems are considered separate reproductive units and thus individuals in this assessment (IUCN 2019).

In the early 1990s many community plantings in the species' known range and four large seed orchards were established (Wright in prep). There was low survival of community plantings, however the seed orchard plantings have been relatively successful (Wright in prep). The seed orchards are not considered self-sustaining as they are planted outside the species natural range, and the trees are planted close together with no natural recruitment (EMWG 2018).

Eucalyptus morrisbyi monitoring data, 1988-2020 (TSS 2006; TSS 2020; Eucalyptus morrisbyi Working Group 2019, R Wiltshire pers.comm. 2020, M Wright pers.comm. 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1a Calverts Hill Nature Reserve (nature reserve)	1991: 1915 2013: 833 (529 with some living canopy) 2014: 604 (368 with some living canopy) 2017: 7 2018: 7 (2 400) 2019: 6 (2 400) 2020: 6 (>2 400) + 550T and hybrids	Decreasing
1b Lumeah Point (coastal reserve)	1991: 16 2020: 19 (52) + including hybrids	Increasing
1c Honeywood Drive (road reserve)	1991: 12* 2019: 8 2020: 5 (188) + many T	Decreasing
1d South Arm Road/ Delphis Drive (road reserve)	1991: 12* 2017: 6 +9T 2020: 0 (1) + many T and hybrids	Decreasing
1e Cremorne Avenue (road reserve)	1991: 5 2019: 5 + many T and hybrids 2020: 13 (42)	Stable
2 Risdon Hills (East Risdon State Reserve)	1996: <20 (69) 2002: 0 (81) 2014: 0 (219) 2020: 0 (102-125 lignotuber resprouts)	Decreasing
3 (T) Oigles Road, Geeveston (State Forest)	1999: 568T 2003: 539T 2017: 299 T	Decreasing
4 (T) Derwent Park, Lutana (private land)	1999: 585T 2003: 289T 2019: 129T	Decreasing
5 (T) Boyer (private land)	1990: 611T 2002: 438T 2012: High mortality observed	Decreasing

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
6 (T) Meunna (State Forest)	1990: 931T 1991: 420T 2015: 0	No plants surviving
7 (T) Brighton (private land)	1993: 1000T 2019: >400T (>20)T	Not yet self-sustaining
8 (T) Derwent Valley (private land)	1993: 1 000T 2019: >700T	Not yet self-sustaining
9 (T) Marion Bay (private land)	2019: 300T	Unknown

Translocated individuals/subpopulation (T). *Count is the summed total for Subpopulations 1c and 1d.

Habitat and ecology

Eucalyptus morrisbyi grows on infertile soils in coastal dry sclerophyll woodland on gentle hillslopes (TSSC 2016). It tends to occupy gullies that are thought to provide some respite from moisture stress in this low rainfall region (TSSC 2016). At Cremorne, it grows on Jurassic dolerite and Quaternary sands and at Risdon Hill, it grows on Permian mudstones amongst *Acacia dealbata, A. melanoxylon and A. verticillata* (TSSC 2016). Flowering has been observed from February to May and flowers are pollinated by insects and birds (TSS 2006). Seedlings are rarely observed far from parent trees, indicating that seed dispersal is limited (TSSC 2016).

Eucalyptus morrisbyi has a lignotuber and can re-sprout following disturbance such as fire. Stems >3 m apart can belong to the same individual, and trees can live for >1000 years (Jones *et al.* 2004). Seedlings reach reproductive maturity within 10 years, and therefore generation length is estimated to be >300 years (Fensham *et al.* 2020).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	45 km^2 Decreasing	High High
Area of occupancy Trend	8 km^2 Decreasing	High High
No. of mature individuals Trend	43 Decreasing	High High
No. of locations (key threat) Trend	1 (climate change/dieback) Decreasing	High High
No. of subpopulations Trend	2 Decreasing	High High
Generation length	>300 years	Medium
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Documented	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	CR: >80% reduction observed within 3 generations (>90% from 2011-2016) where causes of decline may not be reversible, are not understood; based on direct observation.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of subpopulations/locations and number of mature individuals.
C2a(i,ii)	CR: <250 mature individuals; continuing decline observed; <50 mature individuals in each subpopulation; and 90-100% (100%) of individuals in one subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and future**	Minority	Rapid	Low	More than 50% of the species' habitat has been cleared for agriculture and urbanisation since European colonisation (TSSC 2016). The five stands at Cremorne are considered a single subpopulation that has been severely fragmented into smaller stands. The stand of trees at South Arm Road was recently bulldozed (R Wiltshire pers.comm. 2020). Another stand of trees on Honeywood Drive occurs on a roadside and is vulnerable to clearing in the future (TSS 2020).
Climate change *Ongoing*	Whole	Very rapid	High	*Eucalyptus morrisbyi* occupies relatively wet gullies in an area that receives <600 mm average annual rainfall (Bureau of Meteorology 2020; TSSC 2016). The species is known to be susceptible to drought stress, which has caused the severe decline at Risdon Hills (TSS 2006), and poor health in the Cremorne subpopulation. Warmer and drier conditions may also be facilitating increased levels of insect defoliation (TSS 2020). Drought duration is projected to increase with medium confidence (Grose *et al.* 2015).
Grazing/browsing	Whole	Rapid	High	Brushtail possums preferentially browse on regenerating foliage of *E. morrisbyi* at Cremorne (Mann *et al.* 2012), limiting the capacity of the species to recover from dieback (TSS 2020). Wildlife proof fencing at Calverts Hill Nature Reserve protecting remaining adults and juvenile plants requiring on-going monitoring and maintenance to remain possum free (Jones *et al.* 2020). Herbivory by sheep at Calverts Hill, and probably rabbits, is thought to have limited recruitment prior to their removal in 2000 (TSS 2006).
Insect defoliation	Whole	Rapid	High	The species is vulnerable to insect attack (especially *Mnesampela privata, Teratosphaeria* spp., *Paropsisterna* spp. (Gosney *et al.* in TSSC 2016), *Gonipterus scutellatus* and *Uraba lugens* (EMWG unpublished data), which can result in tree dieback and death during drought periods (TSS 2020).
Wildfire *Ongoing*	Majortity	Rapid	Medium	The extremely small number of mature *E. morrisbyi* are vulnerable to death due to wildfire, which has occurred in the species' habitat. Juveniles at Calverts Hill may not have the lignotuber reserves to resprout after fire (EMWG 2018). Conversely, fire may also be important for regeneration, although must be appropriately managed due to the range of other threats.
Hybridisation	Whole	Slow	Medium	*Eucalyptus morrisbyi* is known to hybridise with *E. viminalis*, and hybrids are becoming more common at sites due to pollen swamping (TSSC 2016; TSS 2020).
Competition	Whole	Slow	Medium	Competition with weeds (downy dodder laurel) and dense native wattle regrowth limit the capacity of the species to recover from dieback and successfully recruit (TSSC 2016).

* Only future threat scored (see Section 2)

Current management

- The recovery plan (TSS 2006) was published prior to the rapid decline at Calverts Hill Nature Reserve and current recovery actions are guided by the conservation advice (TSSC 2016) and a recently developed conservation plan (EMWG 2018). The species is listed as a priority species under the Australian Government's Threatened Species Strategy.
- Population monitoring has been undertaken by the University of Tasmania, Enviro-dynamics, NRM South and Wildcare's Threatened Plants Tasmania since 1991.
- Calverts Hill Nature Reserve was acquired as Nature Reserve in 1999, with sheep removed and the area fenced in 2000.
- In response to the recent decline at Calverts Hill Nature Reserve, wildlife proof fencing was established in 2017 by the Tasmanian Parks and Wildlife Service and has been monitored and maintained on an ongoing basis, with possum trapping and relocation in response to incursions.
- The stand at Calverts Hill Nature Reserve is protected from wildfire through the establishment of fire breaks and fuel reduction activities.
- Seed has been collected and stored for conservation. Genetic analysis of plants in seed orchards and community plantings has been undertaken by the University of Tasmania and supports seed collection activities. A seed orchard on private property was rediscovered in 2019 and represents a diverse source of seed for future translocation efforts. Seed collection from other seed orchards and wild sub-populations is also ongoing.
- Preliminary climatic niche modelling has been undertaken by the University of Tasmania, Greening Australia and the Centre For Forest Value to guide translocation site selection.
- Plants have been propagated and used in augmentation and restoration plantings by the Understorey Network, Conservation Volunteers Australia, the University of Tasmania, Greening Australia, Enviro-dynamics and NRM South. Four translocations are planned in the future climate range of the species plus additional augmentation of the Calvert Hills site (EMWG 2018, TSS 2020).
- Weed control has been undertaken at Calverts Hill Nature Reserve and is ongoing.

Conservation objectives

- Recovery actions have been developed with the goal of down-listing the species to Endangered by 2038 (EMWG 2018).
- Monitor known subpopulations.
- Maintain wildlife proof fences at Calverts Hill Nature Reserve.
- Protect remain adult plants at Calverts Hill Nature Reserve from extreme, hot dry conditions through watering and mulching.
- Protect the stand at Calverts Hill Nature Reserve from wildfire while juvenile plants mature.
- Continue translocations to increase population abundance and connect stands in the Cremorne area.
- Undertake assisted migration into the future climate range of the species.
- Continue seed banking and maintain existing seed orchards to preserve genetic diversity.
- Better understand the species' ecology and causes of decline in the population.

Information required

Theme	Specific actions	Priority
Population surveys	Monitor known population to understand population trends in relation to threats.	High
	Undertake regular surveys to determine if recruitment is occurring within subpopulations.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including germination requirements and habitat suitability for translocations.	High
	Undertake research to determine drivers of severe insect defoliation.	High
	Investigate role of fire as possible regeneration strategy at the Risdon Hills subpopulation (TSS 2020).	High
Ex situ conservation/translocations	Continue research to determine suitable habitat for translocations that may be less vulnerable to climatic drying, including field trials examining assisted migration and provenancing strategies to maximise adaptive capacity.	High

Management actions required

Theme	Specific actions	Priority
Climate change	Undertake assisted migration through translocations into the future climate range for the species.	High
	Protect remaining adults at Calverts Hill Nature Reserve through watering and mulching	High
Wildfire	Continue fuel reduction and firebreak maintenance to protect the stand Calverts Hill Nature Reserve.	High
Ex situ conservation/translocations	Continue to collect and store seed representing maximum range of genetic diversity possible.	High
	Continue to propagate individuals for translocations.	High
Browsing/grazing	Maintain fencing around Calverts Hill Nature Reserve prevent mammal browsing (brush-tailed possums).	High
	Trial augmentation of the Calverts Hill subpopulation with the Risdon Hills genotypes, that are less susceptible to browsing by possums to increase population abundance.	High
	Establishing fencing around species to promote recruitment on private land adjacent to roadside remnants.	Medium
Hybridisation	Identify and remove hybrids from subpopulations (especially seedlings) to reduce current/future pollen swamping.	Medium
Invasive weeds	Control invasive weeds at all sites, especially serrated tussock at Calverts Hill.	Medium

Experts consulted

Magali Wright, Wendy Potts and Robert Wiltshire.

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Gentiana bredboensis L.G.Adams [GENTIANACEAE]
Bredbo gentian

Gentiana bredboensis flowering plant (top left), seeds (bottom left) and short herbfield seepage habitat with *Leptospermum* shrubs burnt in 2020 (right) (images: Laura Canackle).

Overview

Gentiana bredboensis is known from a single population on private land that has been declining since the 1960s. Although the population has been fenced and is managed under a conservation agreement, the habitat continues to be threatened by invasive grasses, shrub competition and feral pigs. A wildfire burnt 80% of the site in 2020 and stimulated recruitment from soil-stored seed. The species will continue to require intensive site-based monitoring and management to ensure its persistence, along with germination trials with a view to translocation.

Conservation status

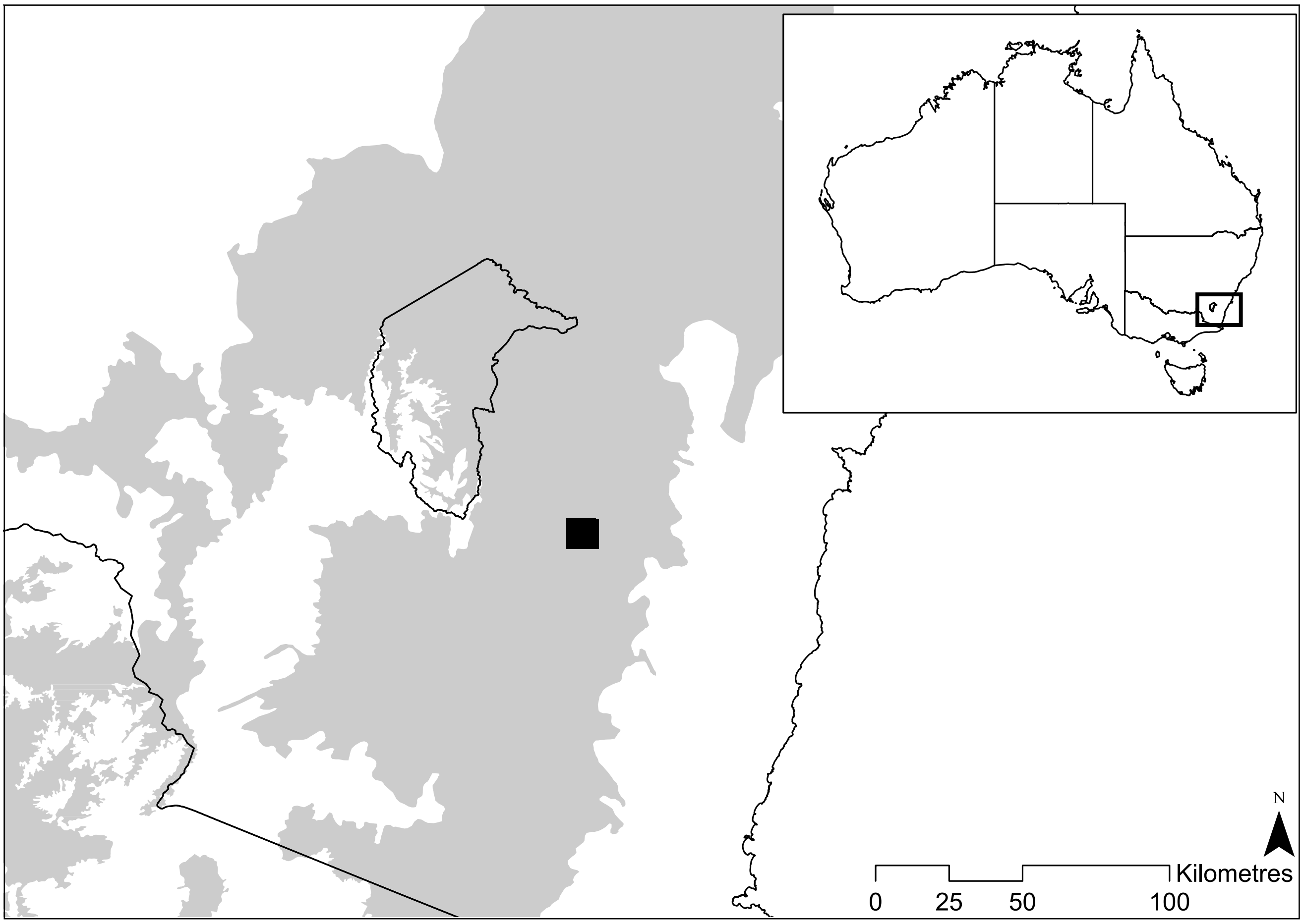
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Annual (possibly biennial) herb 2-9 cm with a slender, branched taproot (Adams and Williams 1988). Many-stemmed, erect and glabrous with 3-6 pairs of broad, sessile basal leaves to 20 mm forming a rosette, and 3-6 pairs of thicker, upper leaves 6-15 mm long. Flowers are terminal and solitary, with 1-6 per plant. Petals are fused with 4-5 lobes and very pale-blue. Fruit are oblong-ovoid, 5-6 mm long with numerous brown seeds 0.6 mm long (Adams and Williams 1988). *Gentiana bredboensis* is distinguished from the three other *Gentiana* spp. occurring in New South Wales by a combination of characters including its longer basal leaves, acute or acuminate leaf apex, corolla lobes that are white to pale-blue inside and have lacerate or 2-lobed folds, anthers 1 mm long, and a fruiting stipe 2.5 mm long (Harden 1992).

Distribution

Gentiana bredboensis is known very restricted area near Jerangle to the east of Bredbo in the South Eastern Highlands bioregion of New South Wales (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012).



Current distribution (black square) of *Gentiana bredboensis* in the South Eastern Highlands bioregion (shaded grey) of New South Wales (AVH 2020; DAWE 2012).

Population estimate and trends

Gentiana bredboensis is currently known from a single population with <300 mature individuals occurring over a 30 x 20 m area. When the species was first collected in 1967, the population contained several hundred plants in three small patches separated by about 200 m on adjacent properties (L Adams pers.comm, in Threatened Species Scientific Committee 2019). By 1999, two of these patches had disappeared, and in 2002 the population was estimated as 50-200 plants. There were 30-40 mature individuals in 2007, 200 mature individuals in 2010, and <50 since 2014 (TSSC 2019). Only 15 plants were recorded in 2019 (J Briggs pers.comm 2020). It is unclear whether these fluctuations represent variable survey effort or genuine change, although seasonal fluctuations are likely given the biology of other species in the genus (see Habitat and Ecology). In early 2020, a wildfire burnt about 80% of the site and while the 15 mature individuals were not burnt, several hundred seedlings germinated within the burnt area (L Canackle pers.comm. 2020). During a subsequent survey in November 2020, 280 flowering individuals were present (L Canackle pers.comm. 2020).

Despite surveys of suitable habitat in the region since 1967, no additional subpopulations have been located. Detectability is limited by the cryptic habit of the species, but although it could be present in other areas, potential habitat is limited and highly modified.

Gentiana bredboensis monitoring data, 2010-2018 (TSSC 2019; J Briggs, L Canackle pers.comm. 2020).

Subpopulation (tenure)	Number of mature individuals	Trend
1 Jerangle (private property)	1967: 'several hundred' 2002: 50-200 2007: 30-40 2008: 20 2010: 200 2014: 50 2019: 15 2020: 280	Stable (with fluctuations)

Habitat and ecology

Gentiana bredboensis occurs above a dam along a tributary of the Bredbo River (Adams and Williams 1988). The habitat is a wet seepage slope in granitic sandy soils amongst short herbfields interspersed with *Baeckea* spp. and *Leptospermum* spp. thickets. This naturally-restricted short herbfield habitat was probably maintained by native herbivores and perhaps fire prior to European colonisation (Adams and Williams 1988). Flowers only open in direct sunlight (Adams and Williams 1988).

Dispersal and germination of the species are poorly understood. Individuals are short-lived, either annual or biannual. Other species within the genus senesce within two months of seed-set and can disappear for multiple years before reappearing, indicating the seed is stored in the soil (Kodela *et al.* 1994; TSSC 2019). Due to this persistent seedbank, extreme fluctuations are not likely as the apparent fluctuations in number of mature individuals probably represent fluxes between different life stages (IUCN 2019). Germination trials thus far have been unsuccessful (J Briggs pers. comm. 2017), although the germination of several hundred seedlings post-fire in 2020 suggests that fire is an important factor. Generation time is estimated as <1 year.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.19 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.0004 km^2) Stable	High High
No. of mature individuals Trend	<300 Stable (with fluctuations)	High High
No. of locations (key threat) Trend	1 (invasive grasses/competition) Stable	High High
No. of subpopulations Trend	1 Decreasing	Medium High
Generation length	<1 year	High
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(iii,iv)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed in area/extent/quality of habitat and number of subpopulations.
C2a(i,ii)	EN: <2500 mature individuals; continuing decline observed and projected; and 100% of mature individuals in one subpopulation.
D1+2	VU: <1000 mature individuals; AOO <20 km^2; 1 location; and plausible future threats that could drive taxon to CR or EX in a very short time.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing, predominantly for agriculture, has resulted in the decline and severe fragmentation of available habitat for the species. Sowing of introduced pasture grasses has also contributed to overall habitat degradation.
Feral herbivores *Suspended*	Whole	Rapid	Medium	Pig rooting damages individual plants and degrades the small amount of available habitat. The population was fenced in 2009 and no breaches have occurred, although this may happen in the future with severe consequences (J Briggs pers.comm. 2020).
Grazing (domestic stock) *Suspended*	Whole	Slow	Medium	Trampling by cattle damages plants and degrades the small amount of available habitat for the species. The population was fenced from cattle in 2009 under a conservation partnership agreement.
Invasive grasses *Ongoing*	Whole	Rapid	High	Invasive pasture grasses are abundant in the area surrounding the population, and are a major threat particularly post-fire (J Briggs pers.comm. 2020).
Competition/ lack of fire *Ongoing*	Whole	Rapid	High	*Leptospermum* spp. shrub invasion due to lack of fire had increased competition and altered the habitat of the species, shading out individuals and limiting flowering and recruitment (J Briggs pers.comm. 2017). About 80% of the site burnt in wildfires in 2020, removing competition from *Leptospermum* spp. and stimulating recruitment from the soil seedbank (L Canackle pers.comm. 2020). However, the site is difficult to burn under normal circumstances due to high moisture levels, and dense *Leptospermum* spp. regeneration post-fire remains a long-term threat (J Briggs pers.comm. 2020).
Altered hydrology *Future*	Whole	Rapid	Medium	The species depends on waterlogged areas, therefore changes to hydrology including stream flow, water extraction and long-term drying driven by climate change may render the habitat unsuitable.

Current management

- Recovery actions have been identified (TSSC 2019) and are being implemented under the Saving our Species strategy (NSW Department of Planning, Industry and Environment 2020).
- Bush Heritage Australia partnered with the former NSW Office of Environment and Heritage to fence the remaining population in 2009 (Bush Heritage Australia n.d; NSW DPIE 2020).
- BHA entered into a conservation agreement with the former landholder. This agreement, transferred to the current landholder, is now managed by the NSW Biodiversity Conservation Trust.
- Seed from mature individuals was collected by NSW DPIE staff using seed bags in 2020, and >500 seeds have been sent to the Royal Botanic Gardens Sydney for germination trials and low temperature storage (L Canackle pers. comm. 2020).
- Trial thinning to reduce the abundance of *Leptospermum* spp. at the site has been undertaken (NSW DPIE 2020).
- The distribution of this species overlaps with the 'White box-yellow box-Blakely's red gum grassy woodland and derived native grassland' and the 'Natural temperate grassland of the southern tablelands of the NSW and the Australian Capital Territory' *EPBC Act*-listed threatened ecological communities.
- Monitoring of the population following the 2020 wildfire is ongoing.

Conservation objectives

- Monitor and maintain known population.
- Maintain conservation agreement over known habitat of the species. Protect additional suitable habitat for future translocations, if feasible.
- Undertake research to germinate seed and establish *ex situ* subpopulations.
- Increase the number of mature individuals and subpopulations in the wild.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in other suitable habitat, including patches where the species formerly occurred, to locate additional subpopulations, particularly post-fire.	High
	Monitor response of known subpopulations to threats and management actions.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species, particularly seed production and viability, germination requirements and habitat suitability for translocations.	High

Management actions required

Theme	Specific actions	Priority
Competition/lack of fire	Implement an appropriate fire regime for the species to reduce competition from *Leptospermum* spp. and increase the number of mature individuals.	High
	Manually remove competing native shrubs, particularly *Leptospermum* spp., and monitor effect on *G. bredboensis*.	High
Ex situ conservation/translocations	Establish an *ex situ* subpopulation representing the maximum range of genetic diversity possible for future translocation trials.	High
Invasive weeds	Manage invasive weeds, particularly grasses, within the known population. Manage invasive weeds within other potential habitat of the species.	High
Habitat protection	Maintain fencing around known population to prevent trampling and rooting by cattle and pigs.	High

Experts consulted

John Briggs and Laura Canackle.

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Gossia gonoclada (F.Mueller ex Bentham) N.Snow & Guymer [MYRTACEAE]

Angle-stemmed myrtle

Gossia gonoclada flowers and fruits (images: Glenn Leiper) and leaves infected with myrtle rust, lower left (image: Tamara Taylor).

Overview

Gossia gonoclada (formerly *Austromyrtus gonoclada*) occurs entirely in the urban footprint of Greater Brisbane and was presumed extinct for over a century. It is known from small, highly modified and weedy remnants, and only one subpopulation contains more than two naturally occurring plants. Population declines are ongoing due to a variety of threats, including high susceptibility to the introduced pathogen myrtle rust *Austropuccinia psidii*. Recovery actions have focussed on habitat protection, translocation and identification of genotypes that are less susceptible to myrtle rust dieback.

Conservation status

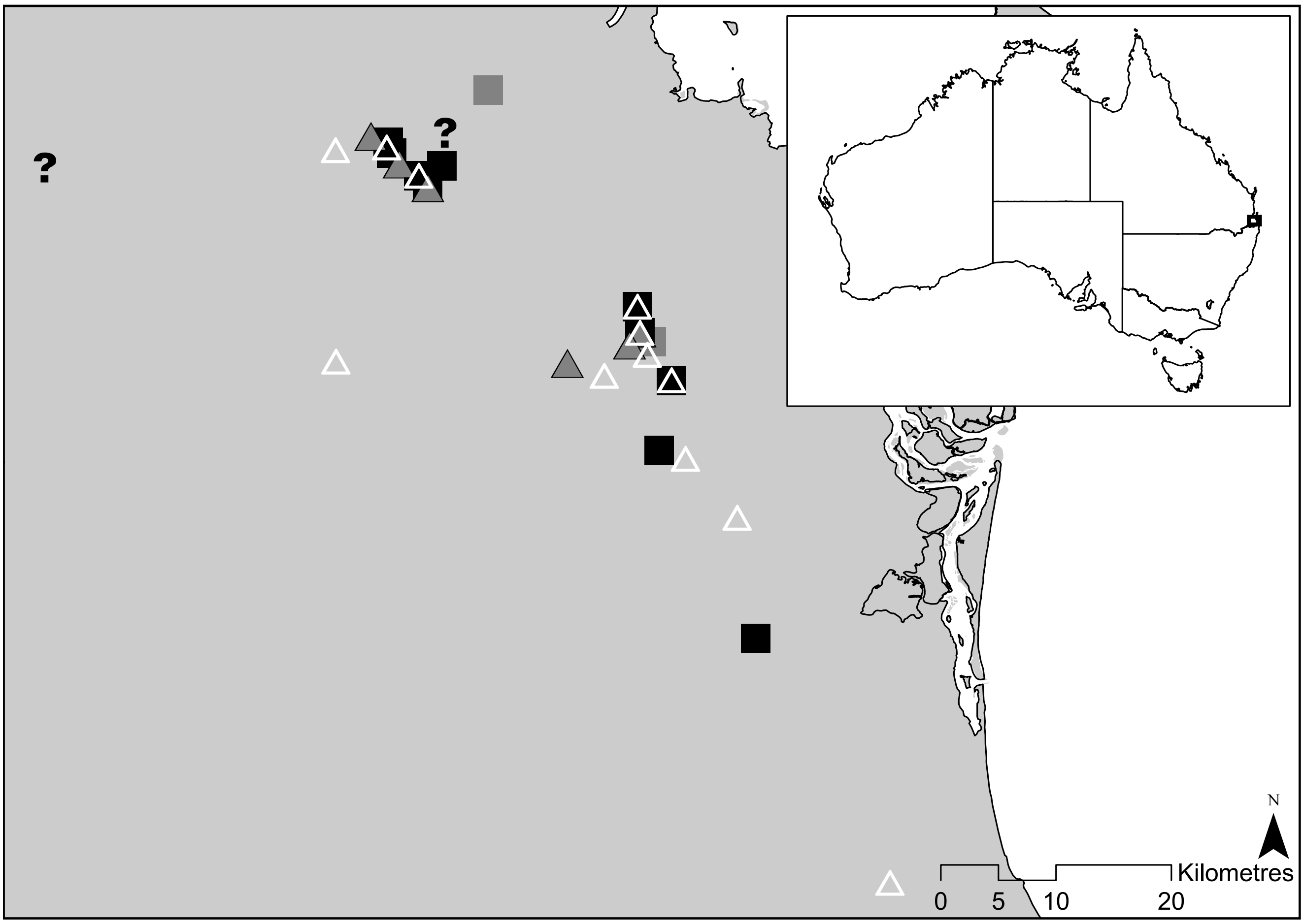
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Nature Conservation Act 1992	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Tree to 18 m with smooth to flaky, pale-brown, red, orange or grey bark (Snow *et al.* 2003). Branchlets are red-brown and distinctly four-angled to laterally compressed with winged edges. Leaves 2.5-6.0 cm long and 1.0-3.7 cm wide, slightly glossy to matte and with abundant oil glands that are aromatic when crushed. White flowers occur singly in the leaf axils. Fruit is a glabrous blue-black berry 8-10 mm long and 7-8.5 mm wide containing 1-3 ivory coloured seeds. The winged branchlets, slightly retuse leaf apex and 5-numerous flowers distinguish it from other *Gossia* spp. in the region (Snow *et al.* 2003).

Distribution

Gossia gonoclada is known from a restricted distribution along the lower reaches of the Brisbane and Logan Rivers and tributaries, in the South Eastern Queensland bioregion (Australasian Virtual Herbarium 2020; *Austromyrtus gonoclada* Recovery Team 2001; Department of Agriculture, Water and the Environment 2012; Queensland Herbarium 2020).



Current (black squares) and historic (grey squares) distribution of *Gossia gonoclada* in the South Eastern Queensland bioregion (shaded grey) of Queensland (AVH 2020; AGRT 2001; DAWE 2012; QH 2020). Several augmentation and introduction translocations have been undertaken, including some with extant plants that have not yet produced viable offspring (hollow triangles), and with no surviving plants (grey triangles). The status of two subpopulations is unknown (?).

Population estimate and trends

The first collections of *G. gonoclada* were made between 1858 and 1875 from several locations along the Brisbane River, including New Farm and Moggill (AVH 2020; QH 2020). It was thought to be extinct for >100 years due to broad-scale habitat loss for urban development. A small subpopulation was located in 1986 and with further searching several additional trees were found. In 2001, the species was known from 73 individuals at nine sites (AGRT 2001). Despite extensive survey, the species has not been relocated at Lone Pine or Long Pocket. One plant was found at Tennyson in 2007, two at Bahrs Scrub in 2016, one in Rocklea and several throughout the Gold Coast in 2020. There is potential for further individuals and small subpopulations to be found given the often-inaccessible habitat.

Gossia gonoclada is currently known from 32 (possibly 34) naturally-occurring individuals in 11 (possibly 13) subpopulations. This estimate is lower than originally thought, as individuals can have many stems, particularly where roots are exposed by erosion. The number of 'mature individuals' (IUCN 2019) may be lower again due to reproductive suppression by myrtle rust. *Gossia gonoclada* reproduces sexually, and myrtle rust has caused a reduction in the abundance and density of parent plants and thus outcrossing probability, reduced flowering rates due to shoot death and flower bud infection, and reduced seed-set due to plant stress and direct infection of fruits (B Makinson pers.comm. 2020).

The wild population has been augmented with approximately 400 planted individuals, at five existing wild subpopulations and at 22 new sites. Some of the plants propagated from cuttings are producing fruit, but only one tree grown from seed has flowered, at Rainbow Forest in 2017 (18 years after planting; R Laundon pers.comm. 2020). Although some 130 translocated plants are known to be surviving on secure tenure, no translocated plants have produced seedlings and therefore are excluded in conservation assessment parameters.

Some monitoring has occurred since 2001 and myrtle rust impacts were monitored intensively from 2013-2017 (Taylor *et al.* 2017a,b). The survival rate of 199 translocated plants in the Logan City Council LGA is 41%, while individuals planted in Brisbane, Gold Coast, Redlands and Ipswich City Council have a survival rate of about 30% (L Simmons pers.comm. 2019). Translocated plants that were recovering from myrtle rust in the latest surveys were genetically related to five wild occurring plants that appear to be less susceptible to the disease (L Simmons pers.comm. 2019).

Gossia gonoclada monitoring data, 2001-2020 (AGRT 2001; Taylor *et al.* 2017a,b; Silcock *et al.* 2019; T Taylor, L Veage, P McGruther, L Simmons, R Laundon pers.comm. 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1a Murrays Road, Tanah Merah (private property)	2001: 49 2016: 16	Decreasing
1b Murrays Environmental Reserve, Tanah Merah (State reserve)	1998: 8 2001: 8 (27T) 2017: 8 (20T) 2020: 0 (14T)	Decreasing
1c Murrays Road Reserve, Tanah Merah (council land)	2001: 1 (4T) 2017: 1(0T) 2020: 1 (0T)	Decreasing
2 Usher Park, Daisy Hill (council land)	2001: 3 (27T) 2016: 2 (19T) 2020: 2 (18T)	Stable
3 Alexander Clark Park, Loganholme (State land)	2001: 2 (55T) 2016: 2 (29T) 2020: 2 (25T)	Stable (?)
4 Nosworthy Park, Corinda (council land)	2001: 1 (18T) 2017: 1 (8T)	Decreasing
5 Cliveden Avenue, Corinda (council land)	2001: 3 (24T) 2016: 2 (0T)	Decreasing
6 Aminga Street, Fig Tree Pocket (council land)	2001: 1 2016: 1 2020: 1	Stable
7 Manaton Park, Fig Tree Pocket (council land)	2001: 1 2016: 1 2020: 1	Stable
8 Lone Pine, Fig Tree Pocket (unknown)	2001: 1 2016: ? (location of tree unknown)	Unknown
9 CSIRO Long Pocket (State land)	1999: 1 ('adventive') 2016: ? (location of tree unknown, possibly destroyed)	Unknown
10 Belivah, Beenleigh (private property)	2016: 1 (comprising 2 suckers) 2020: 1 (comprising 2 suckers)	Stable
11 Brisbane Golf Club, Tennyson (private property)	2007: 1 (planted or original unknown) 2016: 1	Unknown

12 Wongawallan Creek (council reserve, private property)	2020: 4 plants found in remnant	Unknown
13 (T) Fred Johnson Park, Pimpama (council land)	2003: 15T 2016: 6T	Decreasing
14 (T) Hinterland Regional Park, Mudgeeraba (council land)	2003: 15T 2016: 6T	Decreasing
15 (T) Opossum Creek, Springfield (council land)	2020: >10T	Unknown
16 (T) Leslie Parade Park, Slacks Creek (council land)	2003: 11T 2017: 7T 2020: 6T	Decreasing
17 (T) Logan City Golf Course, Meadowbrook (private land)	2003: 49T 2017: 24T 2020: 23T	Decreasing
18 (T) Marsden Parks Depot, Marsden (council land)	2003: 16T 2017: 0T	No extant plants
19 (T) Rafting Ground Reserve, Brookfield (council land)	2003: 21T 2017: 7T 2020: 4T	Decreasing
20 (T) Rainbow Forest, Indooroopilly (council land)	1999: 9T 2001: 14T* 2003: 14T 2020: 9T	Unknown
21 (T) Riverdale Park, Meadowbrook (council land)	2003: 20T 2017: 10T 2020: 0T	No extant plants
22 (T) Sherwood Arboretum (council land)	2003: 10T 2020: 0T	No extant plants
23 (T) Sutling Street Park, Chapel Hill (council land)	2003: 5T 2020: 0T	No extant plants
24 (T) Tansey Park, Tanah Merah (council land)	2003: 7T 2020: 5T	Decreasing
25 (T) Tygym Lagoon, Waterford West	2003: 9T 2020: 8T	Unknown
26 (T) Alexander Watt Park, Bannockburn	2020: 17T	Only planted 2019-2020

Translocated individuals/subpopulation (T). *Including five additional planted individuals. Note: *Gossia gonoclada* has been widely planted in private gardens, but only translocated subpopulations in reserved land with >4 plants are included. All naturally occurring subpopulations are included regardless of tenure.

Habitat and ecology

Gossia gonoclada occurs in dry rainforest and riverine rainforest scrubs in well-drained clay soils derived from metamorphosed sediments or Cainozoic deposits (AGRT 2001). The species grows on slopes, alluvial terraces and riverbanks at 5-50 m above sea level along permanent watercourses (Brisbane and Logan Rivers and tributaries) in areas prone to tidal inundation and flooding (AGRT 2001). Associated species include *Syzygium francisii, S. smithii, Lophostemon confertus, Acacia disparrima, Cryptocarya microneura, Elaeocarpus obovatus, Jagera pseudorhus, Argyrodendron trifoliolatum, Pouteria cotinifolia, Cupaniopsis anacardioides, Toechima tenax, Melaleuca bracteata, Acronychia pauciflora, Alyxia ruscifolia* and *Gossia bidwillii* (AGRT 2001).

Flowering occurs from October to December and fruiting from January to April (AVH 2020). As with other Myrtaceae species, the unspecialised flowers are thought to be pollinated by a variety of insects including bees and thrips (AGRT 2001). The species regenerates vegetatively from suckers and seed production is variable but generally low (AGRT 2001). Seeds are encased by a soft fruit that are probably dispersed by animals such as birds and bats. Silvereyes (*Zosterops lateralis*) and green figbirds (*Sphecotheres viridis*) are known to eat the fruit (AGRT 2001). Seeds are only viable for a short period and germination occurs 8-60 days after sowing with a variable success rate of 0-95% (AGRT 2001). *Gossia gonoclada* is a very long-lived species and reaches reproductive maturity after at least 20 years (AGRT 2001).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	193 km^2 Decreasing	Medium High
Area of occupancy (actual) Trend	48 km^2 (1 km^2) Decreasing	Medium High
No. of mature individuals Trend	<50 (32-34 known) Decreasing	Medium High
No. of locations (key threat) Trend	1 (introduced pathogens) Decreasing	Medium High
No. of subpopulations Trend	11 (possibly 13) Decreasing	Medium High
Generation length	>40 years	Low
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	EN: EOO <5000km^2; AOO <500km^2; severely fragmented and 1 location; and continuing decline in EOO, AOO, area/extent/habitat quality, number of locations/subpopulations, and number of mature individuals.
C1+2a(i)	CR: <250 mature individuals; continuing decline of >25% in 1 generation; and <50 individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Habitat for the species has been decimated for urban development, and it is now confined to small, severely fragmented remnants. Three subpopulations occur on private land that are protected under local government and State legislation (AGRT 2001).
Introduced pathogens *Suspended*	Whole	Very rapid	High	The species is highly susceptible to myrtle rust, limiting sexual reproduction and causing tree mortality (Pegg *et al.* 2014; Makinson 2018). In 2016, 75% of the population was severely impacted (Threatened Species Scientific Committee 2016), with disease incidence and severity data indicating mortality in 25% of the population and long-term impacts on the health of remaining trees (T Taylor pers.comm. 2017). Susceptibility varies within subpopulations, as some individuals are severely impacted while others display minor symptoms. However, >90% of flower buds on fertile trees were infected in the most recent surveys (Taylor *et al.* 2017a,b).
Genetic diversity *Suspended*	Whole	Rapid	High	A large proportion of the original population has been lost to land clearing and this decline will be ongoing with myrtle rust impacts. Myrtle rust limits sexual reproduction as it infects buds, flowers and fruit, while killing new shoots (Pegg *et al.* 2014). Existing levels of sexual reproduction are low and the species has low genetic fitness with very little outcrossing (Taylor *et al.* 2017a,b).
Lack of recruitment *Ongoing*	Whole	Rapid	High	Existing levels of recruitment are low, with myrtle rust further limiting seed-set and successful establishment of seedlings.
Invasive weeds *Ongoing*	Majority	Slow	Medium	Invasive weeds are present in the habitat and affect the survival, growth and reproduction of the species (TSSC 2016).
Human activities *Ongoing*	Minority	Rapid	Medium	Slashing, arson, rubbish dumping and recreational walking tracks have impacted plants at some subpopulations (TSSC 2016). Most sites are now managed for conservation (TSSC 2016), and plants at some are quite inaccessible.
Climate change *Future*	Whole	Rapid	Medium	The species occurs at low altitudes along river systems prone to inundation. Peak tides are likely to increase with sea level rise associated with climate change and are predicted to reduce the available habitat for the species (Dowdy *et al.* 2015).

Current management

- A National Action Plan (Makinson *et al.* 2020) has been developed through extensive consultation and provides a national expert consensus for the conservation of species affected by myrtle rust. *Gossia gonoclada* is listed as a 'very high' priority species in the NAP (Makinson *et al.* 2020).
- Recovery actions have been identified and were implemented from 2001-2005, including fencing, realignment of walking paths and weed control (AGRT 2001).
- Logan City Council (2019) has developed a Recovery Plan (2019-2029) and is actively protecting and managing habitat for the species, including weeding and active fungicide application.
- Bushcare groups around Brisbane also undertake work at various subpopulations, and are supported by the Brisbane City Council. Oxley Creek Catchment group received a grant to support conservation work in 2020.
- Wild subpopulations were augmented with 113 propagated individuals by 2001. Seeds (378) and cuttings have been propagated from 17 trees. Five subpopulations have been established at new locations.
- Research has been undertaken into genetic diversity and temporal leaf phenology in relation to myrtle rust susceptibility (Taylor *et al.* 2017a,b).

Conservation objectives

- Establish awareness, funding and leadership for a long-term and coordinated response to the impact of myrtle rust on *G. gonoclada*.
- Identify feasible options for maintaining wild subpopulations of *G. gonoclada*.
- Establish and maintain a viable *ex situ* collection of *G. gonoclada* as an ongoing conservation resource.
- Better understand the ecology of myrtle rust as it relates to *G. gonoclada* and the ecosystems within which it occurs.

Information required

Theme	Specific actions	Priority
Population surveys	Continue to undertake surveys in historic and potential habitat in an attempt to locate additional individuals.	High
	Monitor response of subpopulations to threats and recovery actions according to recommendations in the NAP.	High
Ex situ conservation/translocations	Undertake research to determine the most effective methods of *ex situ* germplasm capture and storage (seed, tissue culture, vegetative).	High
	Collate a national inventory of cultivated specimens (botanic gardens, private collections) that can be protected by fungicide, diversified by further sampling and used for seed production.	High
	Use *ex situ* conservation collection to undertake research (within the NAP framework where possible), including trials for more rust-tolerant genotypes that may be used as a basis for reintroduction translocations.	High
Life history and ecology	Conduct genetic analyses to ascertain more precise estimate of genetically distinct individuals.	High
	Undertake research to better understand the life history and ecology of the species to guide conservation actions.	Medium
	Investigate indirect impacts of myrtle rust on habitat of *G. gonoclada*, including ecological interactions with other threatening processes such as fire, drought, invasive weeds and climate change..	Medium
Introduced pathogens	Undertake research into biocontrol methods for myrtle rust.	Medium
	Undertake research to identify possible management actions to maintain the wild subpopulations of *G. gonoclada*, such as selective fungicide application.	Medium
Climate change	Identify possible impacts of sea level rise on existing and available habitat of the species.	Medium

Management actions required

Theme	Specific actions	Priority
Habitat protection	Secure all known habitat within appropriate conservation agreements and/or exclusion fencing.	High
Population surveys	Standardise population monitoring data methods and coordinate data storage at a national scale.	High
Ex situ conservation/ translocations	Maintain and expand secure (threat-managed) and genetically representative *ex situ* collections for seed collection and to support ongoing research efforts, including identification of genotypes less-susceptible to myrtle rust for future reintroduction translocations.	High
	Propagate genotypes that are less susceptible to myrtle rust to augment wild subpopulations.	High
Extension and awareness	Seek Indigenous stakeholder input and participation in conservation actions.	High
	Raise awareness of the impact of myrtle rust on the species with local landholders and other stakeholders to monitor and protect the species.	High
Invasive weeds	Conduct weed control in known subpopulations (especially at Logan City Golf Course) to minimise impacts of competition.	Medium
Life history, ecology and research	Assemble botanical and ecological knowledge of the species (including seedling photographs to guide field impact surveys) in a repository to expedite research, conservation planning and rapid surveys.	Medium

Experts consulted

Tamara Taylor, Laura Simmons, Lee-Anne Veage, Roslyn Laundon, Prue McGruther, Bob Makinson, Lui Weber and Julian Radford-Smith.

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Gossia hillii (Benth.) N.Snow & Guymer [MYRTACEAE]
Scaly myrtle, Hill's ironwood, Hill's lignum, mangoor, kalaara

Healthy *Gossia hillii* flowers and foliage (top left), fruit at various stages of maturity (right; images: Glenn Leiper), and foliage infected by myrtle rust *Austropuccinia psidii* (bottom left; image: Jarrah Wills).

Overview

Once a widespread and common understorey plant in rainforests in eastern Australia, *Gossia hillii* has undergone a rapid decline since the invasion of myrtle rust in 2010. The species is extremely susceptible to infection, which culminates in the death of mature trees and loss of reproductive capacity as flowers and fruit become infected and die. *Gossia hillii* urgently requires field survey assessments across its range and germplasm collection for *ex situ* conservation to facilitate reintroductions if this becomes viable in the future.

Conservation status

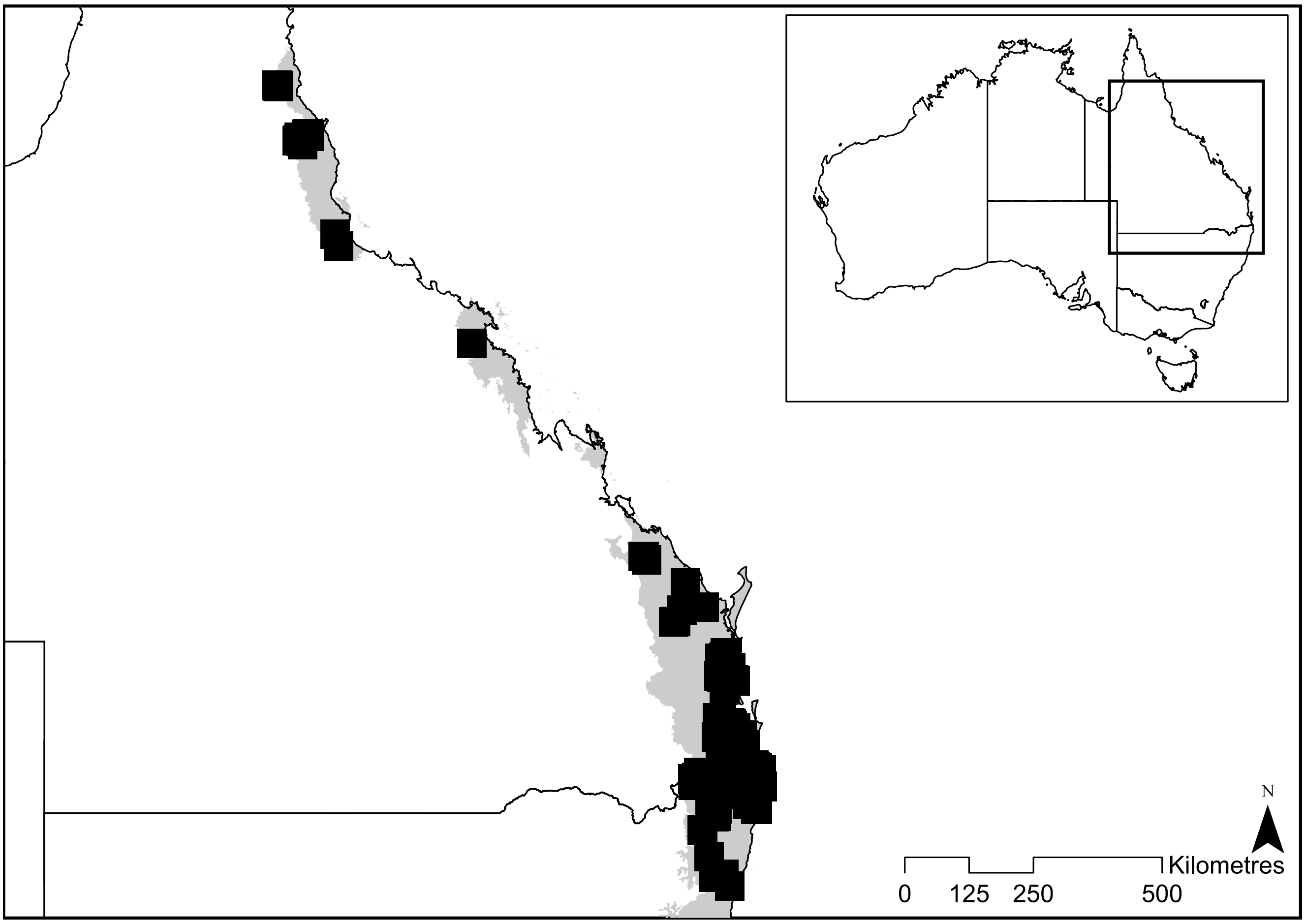
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992 (Qld)	Not listed
Biodiversity Conservation Act 2016 (NSW)	Not listed
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Shrub or tree to 12 m with grey rough, flaky, fissured bark (Snow *et al.* 2003). Branchlets rounded, light brown, without wings and smooth to flaky with some hairs. Leaves slightly discolorous, glossy above and matte below. Petioles 1-7 mm long with a deep channel. Lamina narrowly elliptic to elliptic with a cuneate base and acute apex with rounded tip; 2.0-6.2 cm long and 1.2-3.3 cm wide. Oil glands not visible from above, prominent below, and intramarginal vein obscure. Inflorescence a single cluster of 1-3 white flowers borne from the leaf axils or end of branchlets. Fruit a dark purple to black berry 7-11 mm wide, with 1-3 smooth, light-brown seeds with a hard coat (Snow *et al.* 2003).

Distribution

Gossia hillii is known from Garlambirla (Coffs Harbour) in the NSW North Coast bioregion to Gympie in the South Eastern Queensland bioregion. The species also has several disjunct occurrences throughout northern coastal Queensland including Bundaberg, Gladstone, Mackay, Townsville and Gimuy (Cairns), within the Central Mackay Coast and Wet Tropics bioregions (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Fensham *et al.* 2020; New South Wales Department of Planning, Industry and Environment 2020; Queensland Herbarium 2020). *Gossia hillii* is severely fragmented as all occurrences comprise a small number of trees, while establishment and survival after any recolonisation event is hindered by myrtle rust (IUCN 2019).



Current distribution (black squares) of *Gossia hillii* in the NSW North Coast, South Eastern Queensland, Central Mackay Coast and Wet Tropics bioregions (shaded grey) of eastern Australia (AVH 2020; DAWE 2012; Fensham *et al.* 2020; NSW DPIE 2020; QH 2020). As myrtle rust occurs throughout the range of the species (Makinson 2018), the species is now absent or very unhealthy at many of these sites.

Population estimate and trends

Gossia hillii was once a common understorey to midstorey species of well-developed rainforest (Pegg *et al.* 2017). Herbarium records (AVH 2020) and reports from field botanists indicate the species was locally common where it occurred (Makinson 2018). Since the introduction of myrtle rust, a marked decline has occurred, with tree mortality doubling to 38% in one permanent monitoring plot over one year (Pegg *et al.* 2017). *Gossia hillii* is declining towards near-term extinction at many sites and is now rare where it was formerly common (Makinson 2018). Reproduction and regeneration have also become extremely limited, with few observations of mature fruit since 2010 (Fensham *et al.* 2020; Makinson 2018), and although reports are few, seedlings that do emerge are typically killed by myrtle rust (J Halford pers.comm., in Makinson 2018). Individuals previously suffering severe dieback at Nulgul (Ormeau) were recently recorded with uninfected buds and flowers (G Leiper pers.comm. 2020).

The number of 'mature individuals' (IUCN 2019) is inferred to be <250 (and <50 for each subpopulation) due to reproductive suppression by myrtle rust. *Gossia hillii* reproduces sexually, and myrtle rust has caused a reduction in the abundance and density of parent plants and thus outcrossing probability, reduced flowering rates due to shoot death and flower bud infection, and reduced seed set due to plant stress and direct infection of fruits (B Makinson pers.comm. 2020).

Habitat and ecology

Gossia hillii occurs in a variety of soils as an understorey or midstorey tree amongst well-developed microphyll or notophyll vineforest between 20-1100 m altitude (Snow *et al.* 2003; Pegg *et al.* 2017). *Gossia hillii* can also occur on forest edges, where it behaves as a pioneer species in regenerating rainforest (Makinson 2018).

Flowers have been observed from October to December, with fruit forming from November to April (Snow *et al.* 2003). Like other rainforest Myrtaceae, pollination is presumably facilitated by insects including bees, while the fleshy fruits are dispersed by birds (Williams and Adam 2012). Under ideal conditions, *G. hillii* could become reproductively mature within 4-5 years (P Forster pers.comm. 2020). As the species can re-sprout basally and from epicormic buds, it can presumably live indefinitely. *Gossia hillii* is a confirmed host to the introduced pathogen myrtle rust (Pegg *et al.* 2014), which occurs throughout its distribution (Makinson 2018).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	265 604 km^2 (unknown) Decreasing	Low High
Area of occupancy (actual) Trend	592 km^2 (unknown) Decreasing	Low High
No. of mature individuals Trend	<250 Decreasing	Low High
No. of locations (key threat) Trend	1 (introduced pathogens) Decreasing	Medium High
No. of subpopulations Trend	Unknown Decreasing	Low High
Generation length	>40 years	Low
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Observed and estimated	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A4ce	CR: >80% reduction observed (2009-2020) and estimated (+100 years); based on decline in AOO, EOO, habitat quality; and effects of introduced pathogens.
B2ab(i-v)	AOO <2000 km^2; severely fragmented and 1 location; continuing decline observed and estimated in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and ongoing*	Minority	Rapid	Low	Land clearing (for example the decimation of the Big Scrub; Parkes *et al.* 2012) has resulted in the decline and fragmentation of *G. hillii* habitat. Land conversion is ongoing (Evans 2016), although many trees are now protected in national park.
Introduced pathogens *Ongoing*	Whole	Very rapid	High	Myrtle rust causes dieback of young shoots and reproductive organs in *G. hillii* (Pegg *et al.* 2014; 2017), and occurs throughout the species' distribution (Makinson 2018). At one site, tree mortality doubled from 18% in 2016 to 38% in 2017, with surviving plants having <10% crown cover (Pegg *et al.* 2017). Subpopulations of *G. hillii* are rapidly declining (J Radford-Smith pers.comm. 2020), seedlings are rare where they were once common, and epicormic growth is rapidly infected and killed (Makinson 2018).
Climate change *Future*	Whole	Unknown	Unknown	Myrtle rust infects foliage of other rainforest Myrtaceae recovering from drought-stress (J Radford-Smith, L Weber pers.comm. 2020) and fire (Fernandez Winzer *et al.* 2020). Myrtle rust incidence and infection severity is influenced by climatic conditions including temperature, rainfall and humidity (Makinson 2018). More frequent droughts, variable rainfall, extreme temperatures and fire weather are predicted under climate change (Dowdy *et al.* 2015; McInnes *et al.* 2015), but the interaction with myrtle rust is unknown.

Current management

- A National Action Plan (Makinson *et al.* 2020) has been developed through extensive consultation and provides a national expert consensus for the conservation of species affected by myrtle rust. *Gossia hillii* is listed as a 'very high' priority species in the NAP (Makinson *et al.* 2020).
- The species' natural distribution coincides with many protected areas that are managed for conservation.
- Limited targeted surveys have been undertaken in Queensland and NSW to determine population trends in response to myrtle rust infection (Pegg *et al.* 2017; Fensham *et al.* 2020).
- A small number of individuals have been established at the Australian Botanic Garden Mt Annan from seed and cuttings.
- Some current research on related species and on the genomics of the myrtle rust pathogen are expected to be informative of the mechanism of resistance and susceptibility in this species (B Makinson pers.comm. 2020).

Conservation objectives

- Establish awareness, funding and leadership for a long-term and coordinated response to the impact of myrtle rust on *G. hillii*.
- Identify feasible options for maintaining wild subpopulations of *G. hillii*.
- Establish and maintain a viable *ex situ* collection of *G. hillii* as an ongoing conservation resource.
- Better understand the ecology of myrtle rust as it relates to *G. hillii* and the ecosystems within which it occurs.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake field surveys as recommend by the NAP; document myrtle rust incidence, impact, resistance among plants, demographic trends and related ecological data.	High
	Continue monitoring in permanent plots to document time-series trends.	High
	Monitor subpopulations in response to threat abatement actions.	High
Ex situ conservation/translocations	Undertake research to determine the most effective methods of *ex situ* germplasm capture and storage (seed, tissue culture, vegetative).	High
	Collate a national inventory of cultivated specimens (botanic gardens, private collections) that can be protected by fungicide, diversified by further sampling and used for seed production.	High
	Use *ex situ* conservation collection to undertake research (within the NAP framework where possible), including trials for more rust-tolerant genotypes that may be used as a basis for reintroduction translocations.	High
Introduced pathogens	Undertake research into biocontrol methods for myrtle rust.	High
	Undertake research to identify possible management actions to maintain the wild population of *G. hillii*, such as selective fungicide application.	High
Life history, ecology and research	Undertake research to better understand the life history and ecology of the species to guide conservation actions.	Medium
	Continue to document indirect impacts of myrtle rust on habitat of *G. hillii*, including ecological interactions with other threatening processes such as fire, drought, invasive weeds and climate change.	Medium

Management actions required

Theme	Specific actions	Priority
Population surveys	Standardise population monitoring data methods and coordinate data storage at a national scale.	High
Ex situ conservation/translocations	Urgently secure germplasm for *ex situ* conservation efforts.	High
	Maintain and expand secure (threat-managed) and genetically representative *ex situ* collections for seed collection and to support ongoing research efforts, including identification of genotypes less-susceptible to myrtle rust for future reintroduction translocations.	High
Extension and awareness	Seek Indigenous stakeholder input and participation in conservation actions.	High
	Raise awareness of the impact of myrtle rust on the species with local landholders and other stakeholders to monitor and protect the species.	High
Life history, ecology and research	Assemble fragmented botanical and ecological knowledge of the species (including seedling photographs to guide field impact surveys) in a repository to expedite research, conservation planning and rapid surveys.	Medium

Experts consulted

Bob Makinson, Geoff Pegg, Lui Weber, Julian Radford-Smith and Rod Fensham.

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Grevillea caleyi R. Br. [PROTEACEAE]
Caley's grevillea, Terrey Hills grevillea

Grevillea caleyi inflorescence (top); Mark Ooi counting seeds on a mature *G. caleyi* plant (bottom left); Tony Auld examining a plant recently killed by fire (bottom right; images: Tony Auld).

Overview

Grevillea caleyi occurs in a restricted area within the heavily urbanised region of Sydney. It is known from <1000 individuals in three subpopulations. The population experiences extreme fluctuations due to fire but is declining due to ongoing habitat loss and fragmentation, predation of seed and grazing of seedlings, and lack of appropriate fire regimes that are difficult to implement in small urban remnants. The habitat requirements of the species are well-understood and translocation remains a viable option for conservation, although there is limited suitable habitat remaining.

Conservation status

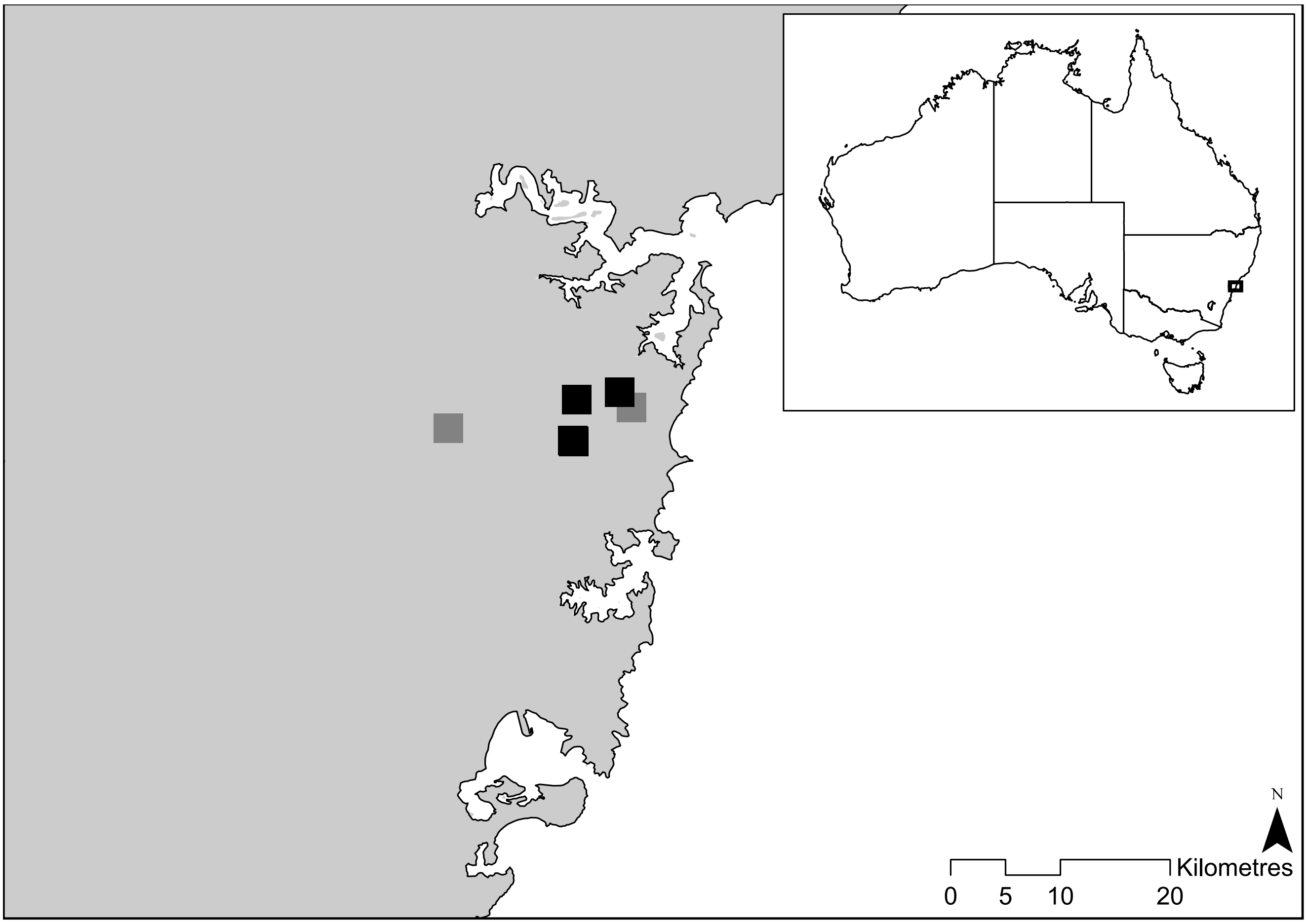
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List	Critically Endangered

Brief description

Spreading shrub to 4 m tall with hairy branches, leaves, inflorescences and petioles (Department of Environment and Conservation 2004). Leaves are green with deeply-divided margins to 15 cm and rusty red-pink when young. The inflorescence forms a terminal raceme to 8 cm and is crimson with pale green stigma tips (DEC 2004). Fruit are large and hairy with purple-brown stripes and a persistent style. Seeds are 1.5-2 cm long and weigh 318-351 mg (Auld and Denham 1999). *Grevillea caleyi* is distinct and unlikely to be confused with other species in the area.

Distribution

Grevillea caleyi is known from three broad areas in the northern suburbs of Sydney: Terrey Hills/ Duffys Forest, Belrose and Ingleside (New South Wales Department of Planning, Industry and Environment 2020a) within the Sydney Basin bioregion (Department of Agriculture, Water and the Environment 2012). Based on herbarium records, it is possible *G. caleyi* formerly occurred to the west and north-east of its current distribution, from Turramurra and Collaroy (Australasian Virtual Herbarium 2020).



Current (black squares) and historic (grey squares) distribution of *Grevillea caleyi* in the Sydney Basin bioregion (shaded grey) of New South Wales (AVH 2020; NSW DPIE 2020a; DAWE 2012).

Population estimate and trends

Grevillea caleyi was first collected in 1805 by George Caley (AVH 2020). Within the three currently known subpopulations, there are ca. 1000 mature individuals over 26 sites. Two of these sites are thought to be the product of accidental translocation (DEC 2004). Occupied habitat is considered a better indicator of conservation status than abundance, which can fluctuate by up to two orders of magnitude after fire (Scott and Auld 2004). The sites where *G. caleyi* occurs range in size from 5 m^2 to 3.5 ha, and only two patches are relatively undisturbed (DEC 2004). Time-series monitoring indicates the population continues to decline (Auld 2004).

The habitat requirements of *G. caleyi* are well-understood and potential habitat has been extensively surveyed. Ongoing surveys are recommended given the fluctuations in response to fire.

Habitat and ecology

Grevillea caleyi occurs in lateritic soils on ridgetops at 170-240 m above sea level amongst open sclerophyll forest dominated by *Eucalyptus sieberi* and *E. gummifera* (DEC 2004). Less often, it grows amongst low open forests of *E. gummifera* and *E. haemastoma*. The geology is dominated by Hawkesbury sandstone with laterite capping, weathering to orange-red, iron-rich gravelly soils (DEC 2004). Associated species include *E. capitellata, E. oblonga, Angophora costata, Banksia serrata, Acacia myrtifolia* and *B. spinulosa* (AVH 2020).

Flowering occurs between autumn and winter, and also sporadically throughout the year (DEC 2004). Fruit with a single seed mature from November to December and fall to the ground (DEC 2004). *Grevillea caleyi* usually grows in clusters due to this passive dispersal system. *Grevillea caleyi* is killed by fire, which also promotes germination of soil-stored seed (Regan *et al.* 2003). Between 55-100% of seeds germinate following fire, with high intensity fires associated with greater plant death and germination (Regan *et al.* 2003). Seedling establishment is rare in the absence of fire, thus subpopulations typically comprise single-aged cohorts (Auld and Regan 2004).

An individual aged over 10 years produces ~15 seeds annually and viability is generally high (69-95%), although declines markedly with time (Auld *et al.* 2000). Soil-stored seed can remain viable for 15-20 years post-fire (Auld *et al.* 2000). Despite this apparently persistent seedbank, the species is vulnerable to extreme fluctuations as post-fire germination can vary by an order of magnitude (or more) at the site scale. The soil seedbank is also impacted by fire and is not a sufficient buffer against these fluctuations (T Auld pers.comm. 2020). A high proportion (50-100%) of seeds are lost to predation by bush rats and swamp wallabies, which is highest after fire and declines thereafter (Auld and Denham 2001). Seed predation has also been observed at fruit stage by the weevil *Cydmaea dorsalis* (DEC 2004) and eastern whipbird (Gosper and Llorens 2008). In some cases, post-fire germination is very low (related to fire intensity), leading to long-term decay of the seedbank in the absence of additional seed input (T Auld pers.comm. 2020). Where high levels of seed germination do occur, survivorship (and thus future seed production) can be severely limited by grazing pressure from macropods and rabbits that concentrate in the burnt areas (T Auld pers.comm. 2020).

Grevillea caleyi reaches reproductive maturity 3-5 years after germination. Individuals will senesce from 8 years, with few individuals living beyond 20 years in the absence of fire (Auld and Scott 2004). Generation length is estimated between 8-15 years (TSSC 2018). However, as recruitment and mortality are regulated by fire return intervals, the actual generation length is probably 7-17 years (TSSC 2018).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	56 km^2 Decreasing	High High
Area of occupancy (actual) Trend	56 km^2 (0.08 km^2) Decreasing	High High
No. of mature individuals Trend	1000-3000 Decreasing	Low High
No. of subpopulations Trend	3 Decreasing	Medium High
No. locations (key threat) Trend	3 (habitat loss/urbanisation) Stable	High High
Probability of extinction	≥50% in 3 generations (Regan and Auld 2004; TSSC 2018).	
Generation length	7-17 years	High
Extreme fluctuations	Documented	High
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)c(iv)	CR: EOO <100 km^2; severely fragmented; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals; and extreme fluctuations in the number of mature individuals.
C2b	EN: <2500 mature individuals; continuing decline observed and projected; and extreme fluctuations in the number of mature individuals.
D2	VU: <5 locations and plausible future threat.
E	CR: extinction probability estimated as $\geq$50% within 3 generations.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss/ urbanisation *Past and ongoing*	Majority	Rapid	High	More than 85% of *G. caleyi* habitat has been cleared for urban development. The species formerly existed in three larger subpopulations, which have been severely fragmented by land clearing (DEC 2004; IUCN 2019; Llorens *et al.* 2004, 2018). Habitat loss is ongoing and operates at the subpopulation/land tenure scale (three locations), with significant losses about to occur due to road widening (T Auld pers. comm. 2019).
Inappropriate fire regimes *Ongoing*	Whole	Rapid	High	*Grevillea caleyi* requires hot fire to germinate and replace mature individuals that have senesced (Auld and Scott 2004). Too-frequent cool fires, which kill adults but fail to stimulate germination, can cause population declines. Successive fires that do not allow seed bank accumulation can also cause population declines (Auld and Scott 2004).
Seed predation *Ongoing*	Whole	Rapid	High	Replenishment of the soil seedbank is limited by high rates of seed predation. Between 50-100% of seed set each year is predated by mammals. Seed predation is highest following fire but declines thereafter (Auld and Denham 2001).
Grazing pressure (feral and native) *Ongoing*	Whole	Rapid	High	There are often high levels of seedling mortality post-fire due to grazing pressure from macropods and rabbits, which congregate in the burnt areas. This has impacts on the number of mature individuals and future seedbank input, reducing total population size in the long-term (T Auld pers.comm. 2020).
Human activities *Ongoing*	Minority	Slow	Low	Rubbish dumping including building rubble has occurred at sites close to urban development that are sources of invasive weeds (DEC 2004).
Genetic diversity *Future*	Whole	Slow	Medium	Remnant patches are genetically distinct (Llorens *et al.* 2004, 2018) and all sites need to be protected to retain this genetic diversity (DEC 2004).
Invasive weeds *Future*	Majority	Slow	Medium	*Grevillea caleyi* occurs in small remnants in close proximity to roadsides and urban development. Invasive weeds increase competition and alter fuel loads and thus fire regimes.
Introduced pathogens *Future*	Whole	Unknown	Unknown	*Phytophthora cinnamomi* occurs very close to known subpopulations, and is predicted to have impacts on some species and thus habitat quality. However, susceptibility of *G. caleyi* is unknown (T Auld pers.comm. 2020).

Current management

- Recovery actions have been identified (Scott *et al.* 1995; DEC 2004; NSW DPIE 2020b) and implemented under the Saving our Species Strategy, including weed control, rubbish removal, fencing, signage, stakeholder liaison and research into fire and germination ecology.
- Some habitat is protected in Ku Ring Gai National Park and Garigal National Park.
- Monitoring of population abundance, habitat condition and threats is ongoing (NSW DPIE 2020b).
- A small development mitigation translocation occurred in Terrey Hills, Sydney, in 2010-2011 involving the removal of 11 whole plants and soil seedbank (Total Earth Care 2011, 2012).

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Establish *ex situ sub* populations as a conservation resource.
- Increase the number of subpopulations in the wild via translocation.

Information required

Theme	Specific actions	Priority
Population surveys	Monitor subpopulations to determine response of population abundance/demographics to threats and management activities.	High
Introduced pathogens	Determine the vulnerability of the species to phytophthora, which is present in the area.	High
Ex situ conservation/translocations	Determine factors required for successful translocations. Identify suitable habitat for translocations on secure tenure.	High High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect all known habitat including historical, current and potential regardless of population abundance, which fluctuates with fire. Currently unoccupied habitat may provide sites for translocation as suitable habitat is limited.	High
Inappropriate fire regimes	Implement appropriate fire regimes to increase the abundance of the species in the longer term (Auld and Scott 2013). High severity fires that burn 20-100% of the sub populations every 10-15 years are suggested (Regan *et al.* 2003, Auld and Scott 2013).	High
Ex situ conservation/translocations	Maintain and expand seed collection to represent the maximum range of genetic diversity possible. Reinforce wild subpopulations with propagated individuals Establish translocated subpopulations in suitable habitat on secure tenure.	High High High
Seed predation	Reduce seed predation, particularly at smaller sites (Regan *et al.* 2003). Collect seed and undertake direct seeding at appropriate sites prior to burning.	Medium Medium

Experts consulted

Tony Auld.

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Grevillea calliantha R.Makinson & P.Olde [PROTEACEAE] Foote's grevillea, Cataby grevillea, black magic grevillea

Grevillea calliantha conflorescence and foliage (image: Fred and Jean Hort).

Overview

Grevillea calliantha occurs in the heavily cleared agricultural landscape of south-western Western Australia. Despite the implementation of two recovery plans, declines are continuing due to lack of appropriate disturbance to stimulate recruitment. Translocations have been undertaken with reasonable survivorship but no recruitment. Future recovery actions should focus on improving habitat quality, implementing suitable disturbance regimes to encourage natural regeneration and implementing translocations to suitable sites.

Conservation status

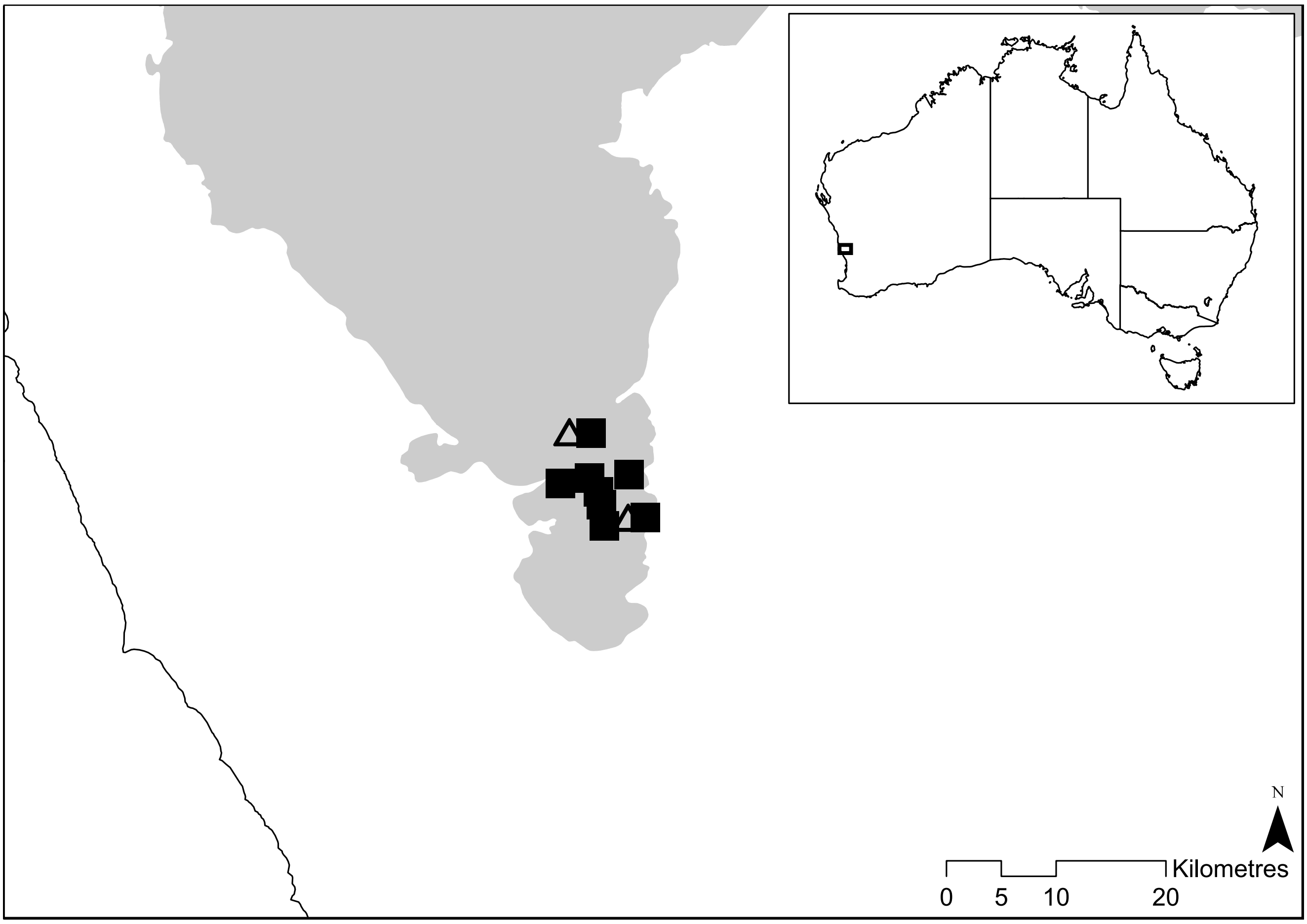
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List	Critically Endangered

Brief description

Spreading shrub to 1 m with ridged and hairy branches. The green to grey-yellow leaves reach 7.5 cm long and are deeply divided with up to seven lobes (Makinson 2000). The conflorescence comprises 15-30 hairy flowers each 8 mm long that age from green-yellow to apricot-orange and have a maroon-black style 30-40 mm long. Fruits are also densely hairy, reaching 18 mm long and 9 mm wide. *Grevillea calliantha* differs from the closely-related *G. hookeriana* in its longer pistils and decurved confloresences (Makinson 2000).

Distribution

Grevillea calliantha is known from a very restricted distribution near Cataby in the Geraldton Sandplains bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution (black squares) of *Grevillea calliantha* including translocation sites that are not yet self-sustaining (hollow triangles) within the Geraldton Sandplains bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020; Silcock *et al.* 2019).

Population estimate and trends

Grevillea calliantha is currently known from six subpopulations with 27 mature individuals, which has declined from 42 mature individuals in 2017 (L Monks pers.comm. 2021).. In 2014, there were 168 mature individuals across the six subpopulations (DPW 2014). The species was first recorded in 1981 and five additional subpopulations were located with subsequent searching (AVH 2020; Department of Parks and Wildlife 2014). Heavy clearing within the distribution of the species has fragmented the habitat, with most individuals occurring on roadsides or private property (DPW 2014). Surveys have been undertaken within the range of the species although further surveys are recommended (DPW 2014).

Two translocations have been implemented in remnant bushland (Silcock *et al.* 2019). A translocation was established in 1998 near Subpopulation 1 and has been augmented on several occasions, most recently in 2015 and 2018. In 2018, there were 309 extant plants including 245 recently-planted seedlings. A second translocation was established in 2010 with ongoing augmentation, and contained 189 plants in 2018, including 43 recently-planted seedlings. Three natural recruits were recorded at the first translocation in 2013, but none survived their first summer (DPW 2014; Silcock *et al.* 2019).

Grevillea calliantha monitoring data, 1988-2018 (DBCA 2020; DPW 2014; Silcock *et al.* 2019; L Monks pers.comm. 2021).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 WSW of Dandaragan (Shire water reserve)	1988: 4 (4) 1993: 6 (16) 1994: 1 (10) 1998: 6 (0) + 106T 2000: 5 (0) + 22T 2002: 7 (1) + 302T 2007: 5 (0) + 98T 2011: 0 + 63T 2016: 0 + 64T 2018: 0 + 309T (including 245T seedlings)	Decreasing
2* WSW of Dandaragan (Shire road reserve)	1988: 14 1995: 17 1998: 18 (1) 2000: 34 (9) 2002: 35 2007: 1 2010: 10 (1) 2011: 10 2012: 10 2014: 7 2016: 6 2017: 6 2020: 6	Decreasing
4 WSW of Dandaragan (Private property)	1988: 5 1990: 14 1993: 104+ 1998: 100 2007: 27 (2) 2009: 23 2011: 32 2016: 15 2017: 13 2020: 10	Decreasing
5 WSW of Dandaragan (Shire road reserve)	1988: 7 1995: 5 1998: 3 2000: 6 2002: 4 2007: 3 2010: 3 2014: 0 2016: 0	Decreasing
6 WSW of Dandaragan (Shire road reserve)	1990: 14 1992: 14 1995: 14 1998: 6 (1) 2000: 12 2007: 14 2010: 14 2016: 11 2020: 9	Stable
7 WSW of Dandaragan (private property)	2003: 20 2008: 13 (1) 2011: 23 2012: 25 2016: 10 2017: 12 2020: 2	Decreasing

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
8 (T^) W of Dandargan (nature reserve)	2010: 177T 2012: 183T 2013: 169T 2014: 147T 2016: 146T 2018: 189T (including 43T seedlings)	Stable (not yet self-sustaining)

Translocated individuals/subpopulation (T). *Subpopulations 2 and 3 are combined given close proximity. ^Multiple translocation plantings have occurred.

Habitat and ecology

Grevillea calliantha occurs in sandy to sandy-clay soils among low open woodland of *Eucalyptus todtiana* and *Corymbia calophylla* on lower to mid-hillslopes (DPW 2014). Associated species include *Acacia saligna, A. pulchella, Adenanthos cygnorum, Allocasuarina humilis, Anigozanthos humilis, Banksia attenuata, Calothamnus sanguineus, C. quadrifidus, Conostephium pendulum, Conostylis teretifolia, Dianella revoluta, Elythranthera brunonis, Eremaea asterocarpa, Gastrolobium spinosum, Hakea incrassata, H. prostrata, H. trifurcata, Hibbertia hypericoides, Hypocalymma angustifolium, Stirlingia latifolia, Synaphea spinulosa, Thryptomene mucronulata* and *Xanthorrhoea preissii* (DPW 2014).

Flowering is prolific in spring and summer with >70 000 flowers per plant recorded, but seed is typically limited to ca. 120 seeds per plant (Armstrong 2001). Seed set increases alongside pollinator activity and individuals in more disturbed sites produce fewer seeds (Armstrong 2001). Seed is released over summer and germination is stimulated by disturbance including fire (Armstrong 2001). This indicates the species has a persistent soil seedbank, and therefore extreme fluctuations are not likely (IUCN 2019). *Grevillea calliantha* can also sprout from lower stems and 'daughter' plants appear from the roots of mature plants following fire (Armstrong 2001). Survivorship of seedlings is generally low and individuals do not flower for at least 5 years (Armstrong 2001), although plants at the translocation site began to flower and set seed at 3-4 years of age (Dillon *et al.* 2010 in DPW 2014). Individuals can live for at least 30 years (L Monks pers.comm. 2020) and generation length is estimated at 15 years.

A population viability analysis indicated subpopulations were in decline and possibly not viable in the long-term (Armstrong 2001). Adult deaths exceeded the recruitment rate due to few germination events between fires. The model determined autumn fires every 7-15 years would reduce extinction probability (DPW 2014).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	24 km^2 (15 km^2) Decreasing	High High
Area of occupancy Trend	24 km^2 Decreasing	High High
No. of mature individuals Trend	42 Decreasing	High High
No. of locations (key threat) Trend	6 (lack of recruitment/fire) Decreasing	High High
No. of subpopulations Trend	6 Decreasing	High High
Generation length	15 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented; continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture has resulted in the decline and fragmentation of available habitat for the species. The species is considered severely fragmented as all subpopulations are very small, and isolated in narrow roadside strips surrounded by cleared land.
Lack of recruitment/ inappropriate fire regimes *Ongoing*	Whole	Very rapid	High	Most subpopulations are declining as mature individuals reach senescence in the absence of appropriate disturbance to stimulate recruitment. The recommended fire regime is autumn burns every 7-15 years (DPW 2014). The species occurs at six locations, as fire is managed at the subpopulation/land tenure scale.
Infrastructure maintenance *Ongoing*	Majority	Slow	Medium	All subpopulations are small and the majority occur on roadside reserves or private property. These are threatened by activities associated with the maintenance of roads, fences and firebreaks including mowing, herbicide spraying, grading and drain construction. Roadside subpopulations have been marked and the Shire is aware of them.
Grazing (native and feral) *Ongoing*	Majority	Slow	Medium	Macropods and rabbits are known to forage on *G. calliantha* (DPW 2014), but impacts are not well-documented. Two subpopulations are fenced and some plants have been caged.
Invasive weeds *Ongoing*	Majority	Unknown	Unknown	Invasive weeds are present at most subpopulations, which may increase competition and alter fuel loads but specific impacts on subpopulations are not well-documented.
Introduced pathogens *Future*	Whole	Unknown	Unknown	Under laboratory conditions one individual tested as susceptible to phytophthora *Phytophthora cinnamomi*. Further testing with a larger sample size is required (DPW 2014).

Current management

- Recovery actions have been identified (Department of the Environment, Water, Heritage and the Arts 2008; DPW 2014).
- Relevant stakeholders have been notified of the subpopulations and legal obligations regarding protection. Markers have been installed at roadside subpopulations.
- Some subpopulations have been fenced to prevent grazing and cages were installed over emerging seedlings to prevent defoliation by macropods and rabbits.
- Research on the population dynamics has been undertaken (Armstrong 2001).
- Two translocations have been undertaken, including experimental treatments to determine factors that influence successful establishment.
- 1468 seeds have been stored at the Western Australian Seed Centre and germination trials have been undertaken. The Botanic Gardens and Parks Authority have eight plants from four clones in the nursery.
- The species is widely cultivated in the horticultural industry.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Maintain and expand *ex situ* seed collections.
- Increase the number of mature individuals and subpopulations by improving habitat quality and undertaking translocations (augmentation, introductions).

Information required

Theme	Specific actions	Priority
Introduced pathogens	Undertake research to better understand the potential/actual impact of phytophthora on wild subpopulations of *G. calliantha* to inform management strategies.	High
Inappropriate disturbance regimes/ lack of recruitment	Undertake research to better understand the disturbance requirements of the species.	High
	Determine appropriate measures to increase survivorship of seedlings/juveniles post-germination.	High
Population surveys	Monitor subpopulations to better understand response to recovery actions and threats, particularly invasive weeds and grazing.	High
	Undertake systematic surveys in potential habitat to locate additional populations.	Medium

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known habitat in appropriate conservation agreements.	High
Inappropriate disturbance regimes	Implement suitable fire regime or other soil disturbance to stimulate germination at all subpopulations.	High
Grazing	Protect subpopulations from grazing via caging of seedlings and fencing, particularly after translocations or germination events.	High
Invasive weeds	Control invasive weeds within habitat to reduce competition, particularly after disturbance events.	High
Ex situ conservation/translocations	Maintain and expand *ex situ* seed collections to represent maximum range of genetic diversity.	High
	Continue existing translocations through site maintenance, further augmentation and implementation of appropriate disturbance to stimulate recruitment.	High
	Continue to implement translocations to establish additional subpopulations.	High
Introduced pathogens	Maintain disease hygiene measures and adapt management as necessary.	High
Extension and awareness	Raise awareness of the species with relevant stakeholders in attempts to locate additional subpopulations.	Medium

Experts consulted

Leonie Monks, Andrew Crawford and Tanya Llorens.

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Grevillea hodgei Olde&Marriot [PROTEACEAE]
Coochin Hills grevillea


Grevillea hodgei conflorescence at Rupari Hill (image: Glenn Leiper) and growing on Western Peak of Coochin Hills (image: Jen Silcock).

Overview

Grevillea hodgei is known from three subpopulations on two hills surrounded by urbanised areas near Beerwah in the Sunshine Coast hinterland. Two subpopulations occur in national park but some plants are hybridising with garden escapee *G. banksii*, which is planted in urban gardens nearby. The third subpopulation at Rupari Hill has undergone a substantial decline due to infrastructure development and lack of recruitment. Several other threatened species occur on this hill, making it an important potential conservation reserve.

Conservation status

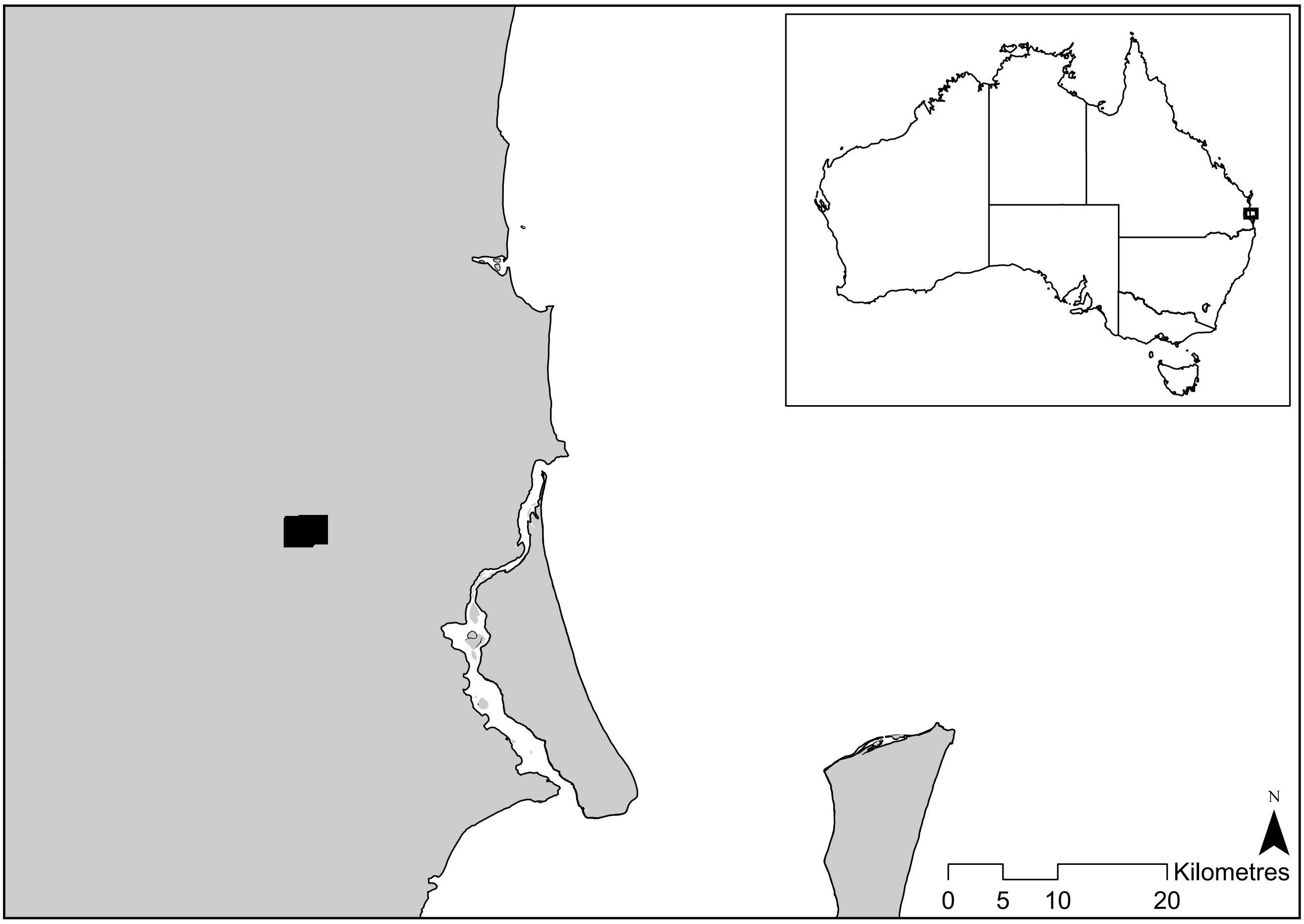
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992	Critically Endangered
IUCN Red List (eligible)	Endangered (Critically Endangered)

Brief description

Erect shrub to 5 m tall (Makinson 2000). Leaves 6-19 cm long, deeply divided into 6-14 parallel, linear lobes each 5-12 cm long and 1.5-2.8 mm wide that are hairy underneath. Confloresence simple, erect and cylindrical with creamy-yellow flowers that have dense brown hairs (Makison 2000). Follicles hairy and 13-14 mm long. *Grevillea hodgei is* similar to *G. whiteana*, but has shorter confloresences (2-8 cm rather than 8-12 cm), shorter pistils (26-35 mm rather than 43-46 mm) and more abundant and persistent rusty-brown hairs on the outer perianth (Makinson 2000).

Distribution

Grevillea hodgei is known from Rupari Hill and Mt Coochin near Beerwah in the South East Queensland bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Queensland Herbarium 2020). *Grevillea hodgei* is considered severely fragmented as all subpopulations are small and occur on isolated mountain peaks, with dispersal capacity further limited by ongoing urbanisation.



Current distribution (black squares) of *Grevillea hodgei* in the South Eastern Queensland bioregion (shaded grey) in Queensland (AVH 2020; DAWE 2012; QH 2020).

Population estimate and trends

Grevillea hodgei is currently known from three small subpopulations with <250 mature individuals. Time-series monitoring has not been undertaken, but population trends can be gleaned from historical records (AVH 2020; QH 2020) and observations.

At Rupari Hill, historical collections indicate the species was growing across the site proposed for the water tower in 1973 (QH 2020). Despite destruction of these individuals, the species remains common in a thicket on the southern summit in 1993 (G Leiper pers.comm. 2020). In 2014, 35 individuals were recorded at this subpopulation (R Callen pers.comm. 2020), which had declined to 15 in 2020. In 2020, four plants were growing on the summit and 11 plants over 150 m below outcropping rock on the mid-slopes (J Silcock, R Callen unpublished data).

At Mt Coochin in 1967 *G. hodgei* was 'scattered over several acres near the top of the NW slope' (QH 2020). In 2020, two separate subpopulations were identified. On the western peak, 115 plants were counted within 300 x 150 m, and on the lower slopes of the eastern peak there were 27 plants over 300 x 100 m (J Silcock, R Fensham unpublished data). An estimated 70% of potential suitable habitat was searched during this survey, thus the total population size is likely to be <250 plants (J Silcock, R Fensham unpublished data). Demographic structure of these subpopulations suggests no past or ongoing decline, but there are reports of plants being killed during recreational activities.

This species occurs in the well-surveyed region of south-eastern Queensland. Targeted surveys have been undertaken on the Glasshouse Mountains peaks and unrecorded subpopulations are unlikely.

Habitat and ecology

Grevillea hodgei occurs on well-drained, skeletal, sandy loam soils amongst exposed trachyte rock outcrops (QH 2020). At Rupari Hill, it grows on mid-upper slopes in shrubby woodland where the trachyte soil meets the underlying sandstone layer (R Callen pers.comm. 2020) and in montane heath on the summit. Suitable habitat is relatively limited at Mt Coochin, where *G. hodgei* is typically restricted to exposed trachyte outcrops and open grassy woodland on low slopes, rather than the more ubiquitous heathland and wet sclerophyll forests (J Silcock pers.comm. 2020). Commonly associated species include *Allocasuarina littoralis, Lophostemon suaveolens, Corymbia trachyphloia* and *Xanthorrhoea latifolia* (QH 2020).

Flowering occurs all year but peaks in March and October (QH 2020). Flowers provide an abundant food source for nectivorous birds and arboreal mammals, which pollinate the species. *Grevillea hodgei is* thought to be killed by fire and regenerates from seed after this disturbance, but can also germinate after mechanical disturbance as observed on Rupari Hill (R Callen pers.comm 2020). Generation length is unknown, however individuals can live for at least 10 years (R Callen pers.comm. 2020) and possibly much longer, given that many plants have been observed re-sprouting from the base (J Silcock pers.obs. 2020).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.574 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.03 km^2) Decreasing	High High
No. of mature individuals Trend	<250 Decreasing	High High
No. of locations (key threat) Trend	1 (hybridisation) Stable	High High
No. of subpopulations Trend	3 Stable	High High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(iii,v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed and projected in area/extent and quality of habitat, and number of mature individuals.
C2a(ii)	CR: <250 mature individuals; continuing decline observed and projected; and >90% of mature individuals in one subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Genetic diversity *Ongoing and future*	Whole	Rapid	High	*Grevillea hodgei* can hybridise with horticultural *Grevillea* varieties when grown in cultivation (G Leiper pers.comm. 2019). There is evidence of hybridisation occurring with garden escapee *G. banksii* on the eastern peak of Mt Coochin, where both species and intermediates were found (R Fensham pers.comm. 2020). Given the proximity of all subpopulations to urban areas, hybridisation is considered a threat to all subpopulations.
Infrastructure maintenance *Ongoing*	Minority	Rapid	Medium	Water and microwave tower construction removed a large proportion of habitat on Rupari Hill crest. Further clearing for easements and access tracks has occurred. Ongoing maintenance has resulted in damage to at least two of the few remaining mature *G. hodgei* and poisoning of several seedlings at this site (G Leiper pers.comm. 2020).
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	*G. hodgei* is thought to be killed by fire and regenerate from seed. Appropriate fire regimes to ensure long-term persistence are unknown. Rupari Hill has not burnt in the past 15 years, vegetation is dense and no young plants were observed (J Silcock per.obs. 2020). Mt Coochin burnt in 2010 (North Australian Fire Information 2020). In 2020, plants were healthy and included a range of sizes, although no seedlings were recorded (J Silcock pers.obs. 2020).
Invasive weeds *Ongoing*	Minority	Slow	Low	Ochna and lantana are scattered at the subpopulation on Rupari Hill, and in low densities at the eastern peak subpopulation on Mt Coochin. At present they are not impacting the *G. hodgei*, but may increase.
Human impacts *Future*	Minority	Slow	Low	The subpopulation on Rupari Hill occurs on freehold tenure and is surrounded by housing development. Firewood collection, tree ringbarking and poisoning have been reported. The Mt Coochin subpopulations occur close to a well-used hiking trail and incidental damage has been reported in the past, but there were no signs of people leaving the trail in the vicinity of the plants in 2020.

Current management

- Two subpopulations are protected in the Glasshouse Mountains National Park and listed in the management plan, which includes implementation of appropriate fire regimes (Department of National Parks, Recreation, Sport and Racing 2013), although the requirements of *G. hodgei* are not known.
- A campaign to raise awareness of the ecological values of Rupari Hill and protect the site from further development has been underway for a number of years (G Leiper pers.comm. 2019).
- Some surveys are undertaken intermittently by the Glasshouse Mountains Advancement Network Inc. to monitor the trends and threats.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect subpopulations from hybridisation with *Grevillea* garden varieties.
- Protect habitat at Rupari Hill in appropriate conservation agreements.
- Increase the number of individuals at Rupari Hill through translocation.
- Increase knowledge about the species' disturbance requirements.

Information required

Theme	Specific actions	Priority
Population surveys	Commence regular monitoring of subpopulations to understand responses to threats and management actions, particularly fire and hybridisation.	High
	Monitor incursions of horticultural *Grevillea* spp. into habitat of *G. hodgei*.	High
	Undertake targeted surveys at unsurveyed but potentially suitable habitat (based on satellite imagery) on Mt Coochin.	High
Life history and ecology	Investigate the life history, ecology and germination requirements of the species, particularly population age structure and response to fire.	High
	Undertake research on conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations at Rupari Hill.	High

Management actions required

Theme	Specific actions	Priority
Habitat quality	Acquire land at Rupari Hill if possible, or protect under appropriate conservation agreements. The remnant vegetation at Rupari Hill would protect several other threatened species including *Leucopogon recurvisepalus* and *Eucalyptus curtisii*, making it an important conservation reserve.	High
Inappropriate fire regimes	Implement appropriate fire regimes to ensure persistence of the species, particularly at Rupari Hill.	High
Invasive weeds	Remove *G. banksii* plants and hybrids growing with *G. hodgei* at Mt Coochin (east peak).	High
	Monitor invasive weeds at Rupari Hill and Mt Coochin eastern peak subpopulation, and remove by hand and targeted spraying if necessary.	Medium
Ex situ conservation/translocations	Plan and implement translocation to increase the number of individuals at Rupari Hill.	Medium

Experts consulted

Glenn Leiper, Roger Callen, Paul Forster, Rod Fensham and Jen Silcock.

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Grevillea sp. Gillingarra (R.J.Cranfield 4087) [PROTEACEAE]
Gillingarra grevillea

Grevillea sp. Gillingarra (R.J. Cranfield 4087) flower, and seedpod and seed (images: Andrew Crawford).

Overview

Grevillea sp. Gillingarra is known from a single small population on a disturbed, weedy rail reserve in south-western Western Australia. While abundance has fluctuated since it was first recorded in 1983, half the population was destroyed in 2011 due to railway maintenance and flooding, with declines projected to continue. Life history research, habitat protection and restoration, and translocation to secure tenure are required to ensure its survival.

Conservation status

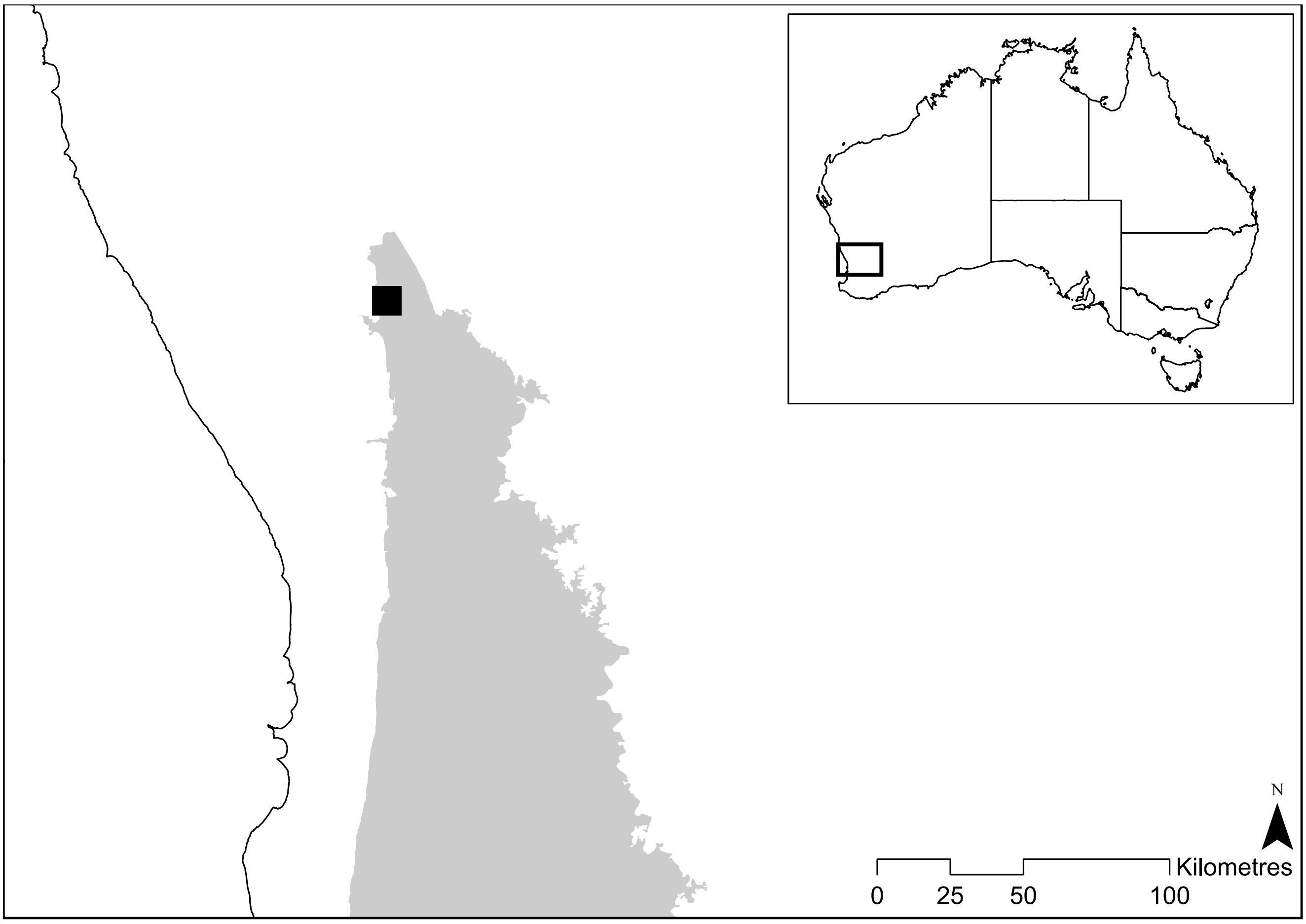
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect to spreading shrub to 2 m tall and 1.5 m wide, lacking a lignotuber (Threatened Species Scientific Committee 2018). Branches are glabrous without obvious furrows or ridges. Leaves 1.5-2.0 cm long and deeply-divided into narrow, linear lobes 0.5 mm wide with incurved to revolute margins. Lamina glabrous above and hairy below. Conflorescence 4-5 cm long with 36-56 red flowers that are densely hairy inside with a pistil 22-28 mm long (TSSC 2018). Genetic studies indicate this taxon is distinct, and part of the *G. thelemanniana* complex, allied to the *G. delta/hirtella* species group (Department of Parks and Wildlife 2016). Collections have previously placed the taxon in the *G. preissii* complex, although it lacks a lignotuber and is larger with almost glabrous stems/flowers and shorter leaves (TSSC 2018).

Distribution

Grevillea sp. Gillangara is known from a single area south of Gillingarra in the Jarrah Forest bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution (black square) of *Grevillea* sp. Gillingarra in the Jarrah Forest bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020).

Population estimate and trends

Grevillea sp. Gillingarra was first collected in 1983 (DPW 2016). The species is currently known from a single population of 21 mature individuals, that has declined from >100 mature individuals in 2007. A population reduction of 52% occurred in 2011, due to infrastructure maintenance and flooding (DPW 2016). Targeted surveys have been undertaken along the rail verge between Moora and Bindoon but have failed to locate additional subpopulations.

Grevillea sp. Gillingarra monitoring data, 1985-2020 (DBCA 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles [dead]	Trend
1 Gillingarra south (rail reserve)	1983: 'occasional' 1991: 12 2007: >100 2008: 6-20 2011: 23 2011: 12 [11]* 2013: 21 2015: 15 2017: 21	Decreasing

*Plants removed during infrastructure maintenance.

Habitat and ecology

Grevillea sp. Gillingarra occurs along red ironstone clay ephemeral creek banks in species-rich Kwongan (TSSC 2018). It grows amongst open *Eucalyptus wandoo* woodland and low open heath (DPW 2016). Associated species include *Allocasuarina huegeliana, Isopogon dubius, Banksia kippistiana, Darwinia acerosa, Banksia* spp. and other grevilleas (DPW 2016). Flowering occurs from winter to spring, which are pollinated by nectivorous birds (DPW 2016). Seed is released from the fruit once it becomes mature and soil seedbank dynamics are unknown (DPW 2016), so extreme fluctuations cannot be accepted with certainty (IUCN 2019). Plants are killed by fire as they have no lignotuber (DPW 2016), indicating fire may also stimulate recruitment. Generation length is unknown, but is probably >3 years.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.0002 km^2) Stable	High High
Area of occupancy (actual) Trend	4 km^2 (0.0002 km^2) Stable	High High
No. of mature individuals Trend	21 Decreasing	High High
No. of locations (key threat) Trend	1 (infrastructure maintenance) Stable	High High
No. of subpopulations Trend	1 Stable	High High
Generation length	>3 years	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	EN: >50% reduction within 3 generations (52% in 2011); causes may not have ceased; based on direct observation.
B1+2ab(iii,v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; continuing decline observed and projected in number of mature individuals and habitat extent/quality.
C2a(i,ii)	CR: <250 mature individuals; continuing decline observed and projected; <50 mature individuals in each subpopulation; and 100% of mature individuals in one subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture has resulted in the decline and fragmentation of available habitat for the species. The species is considered severely fragmented as the only subpopulation is very small, and isolated by cleared land.
Infrastructure maintenance *Ongoing*	Whole	Very rapid	High	The entire population occurs on a railway/road reserve where grading, chemical spraying and mowing take place. In 2011, the population declined by 50% due to rail maintenance (DPW 2016). The species occurs at one location when assessed against this threat.
Lack of recruitment/ inappropriate disturbance regimes *Ongoing*	Whole	Slow	Medium	Some recruitment has been observed. The species is likely to require disturbance to recruit, but if disturbance is too-frequent the population may not recover. The impact of current disturbance regimes is not well-understood.
Invasive weeds *Ongoing*	Whole	Slow	Medium	Invasive weeds are present in the habitat of *G.* sp. Gillingarra (DPW 2016). Invasive weeds increase competition and alter fuel loads and thus fire regimes.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	Although the species may germinate from soil-stored seed following fire, adult plants are killed by fire and the population may not recover if fire intervals are too short. The effect of current fire regimes is not well-documented.
Genetic diversity *Future*	Whole	Unknown	Unknown	Given the small population size the species may have limited genetic diversity (DPW 2016).
Stochastic events *Future*	Whole	Very rapid	Medium	Given the small population and single location, this species is extremely vulnerable to stochastic events such as drought, flooding or repeated wildfires.

Current management

- Recovery actions have been identified (DPW 2016; TSSC 2018).
- *Grevillea* sp. Gillingarra occurs on a rail reserve managed by Arc Infrastructure (DPW 2016). Arc Infrastructure have been made aware of the species and their conservation obligations, and markers are installed at the location.
- There have been no translocations of this species. Seed was collected from 13 individuals in 2013, with 178 seeds stored at the Western Australian Seed Centre and 75 stored at the Millennium Seed Bank. Viability of this seed was high (>75%) during trials. A further 121 seeds from six individuals were collected in 2016, five seeds from one individual were collected in 2018 and 41 seeds from three individuals were collected in 2019, and are stored at the Western Australian Seed Centre.
- The taxon is morphologically and genetically distinct (TSSC 2018), but is yet to be formally described.

Conservation objectives

- Monitor and maintain the known population.
- Detect additional subpopulations through targeted surveys.
- Protect habitat of the known population in an appropriate conservation agreement.
- Continue to collect seed for storage for potential future translocation
- Increase the number of mature individuals and subpopulations in the wild via translocation (introductions).

Information required

Theme	Specific actions	Priority
Taxonomy	Undertake taxonomic study and formally describe the species.	High
Population surveys	Undertake targeted surveys in potential habitat during spring, particularly post-fire, in an attempt to locate additional subpopulations.	High
	Undertake regular monitoring to observe impacts of recovery actions and threatening processes.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known and potential habitat in appropriate conservation agreements. The species co-occurs with *Banksia serratuloides* subsp. *serratuloides, Conospermum densiflorum* subsp. *unicephalatum* and *Darwinia acerosa*, so this may benefit multiple threatened species.	High
Ex situ conservation/translocations	Collect and store seed representing the maximum range of genetic diversity possible. Implement translocation to secure tenure.	High
Invasive weeds	Control invasive weeds within the immediate population and broader habitat of *G.* sp. Gillingarra.	Medium
Habitat rehabilitation	Revegetate habitat that was lost during 2011 due to rail infrastructure maintenance.	Medium
Extension and awareness	Raise awareness of the species with conservation groups and other relevant stakeholders in an attempt to locate additional subpopulations.	Medium

Experts consulted

Andrew Crawford, Bree Phillips and Tanya Llorens.

References

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Hibbertia circinata K.L.McDougall & G.T.Wright [DILLENIACEAE]

Mt Imlay hibbertia, Connie's guinea flower

Hibbertia circinata flowers and foliage (image: McDougall *et al.* 2018).

Overview

Hibbertia circinata was described in 2018 after it was located on Balawan (Mt Imlay in south-eastern New South Wales) during fieldwork on the threatened *Eucalyptus imlayensis*. The species is known from a single, small population and is highly susceptible to the introduced root-rot fungus phytophthora *Phytophthora cinnamomi*, which occurs close by. Measures to limit the spread of phytophthora at the site are in place, but propagation with a view to translocation is urgently needed. The entire population was burnt and killed in the 2019 wildfires but seedlings have been observed where the parent plants were growing.

Conservation status

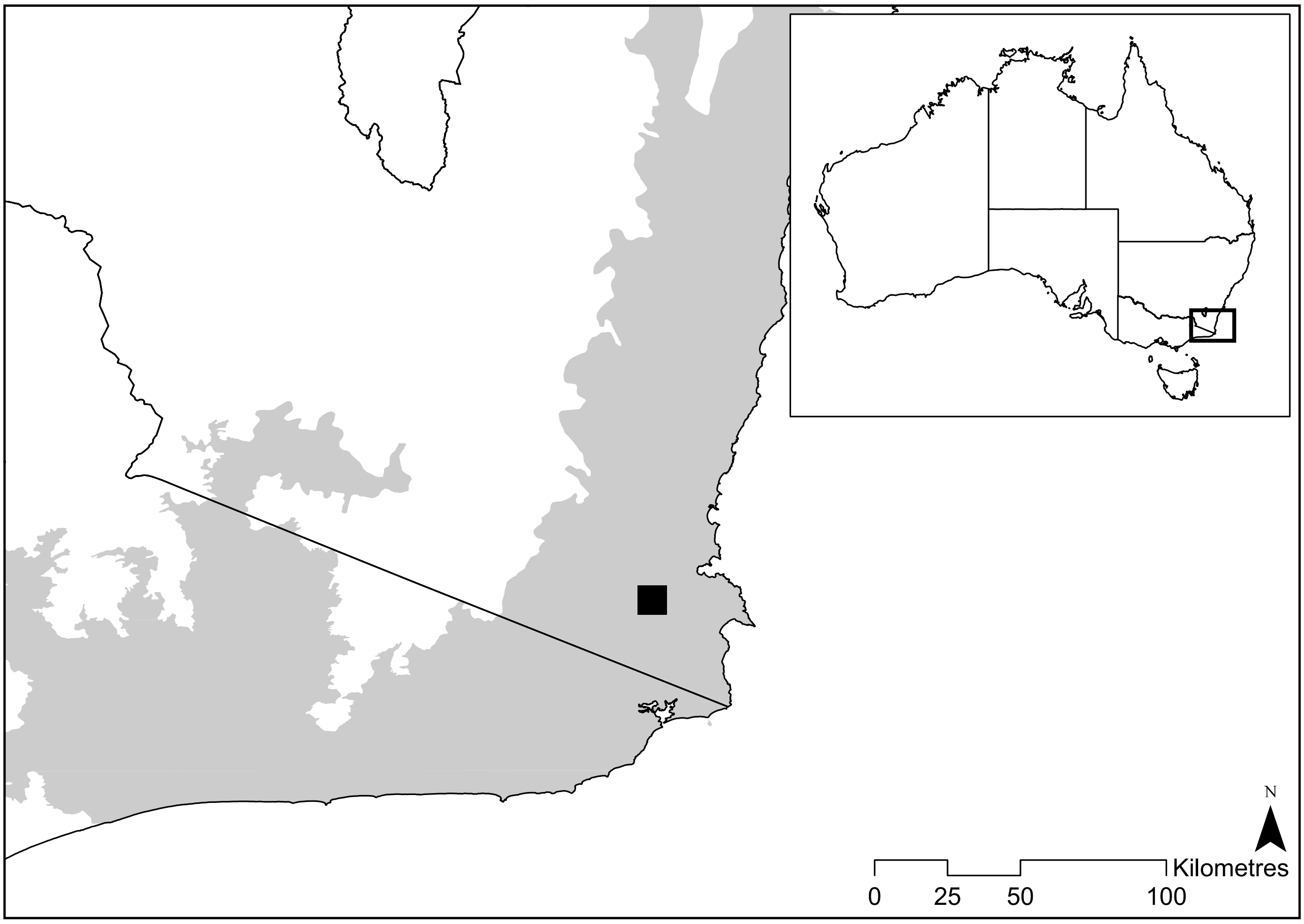
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Shrub to 1.5 m tall with several to many pubescent stems (McDougall *et al.* 2018). Leaves entire, discolorous and sessile with broad, partly stem-clasping bases, 15-55 mm long and 5-8 mm wide. Flowers are solitary and axillary, with five yellow petals and a very short peduncle. Fruit not seen. Differs from *H. linearis* by having villous stems and young branches, relatively long and broad leaves that are pubescent on both surfaces, larger petals and few stamens (McDougall *et al.* 2018).

Distribution

Hibbertia circinata is only known from the summit of Balawan (Mt Imlay), to the south-west of Eden in the South East Corner bioregion of New South Wales (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012). The species is considered severely fragmented as it occurs on a single, isolated mountain peak and recolonisation after local extinctions is limited by the spread of phytophthora (IUCN 2019).



Current distribution (black square) of *Hibbertia circinata* in the South East Corner bioregion (shaded grey) of New South Wales (AVH 2020; DAWE 2012; McDougall *et al.* 2018).

Population estimate and trends

Hibbertia circinata was known from an estimated 200-250 mature individuals in 2018. The species is highly susceptible to phytophthora. Its absence from areas where the pathogen occurs indicates a probable past decline. Further declines are anticipated as a walking track dissects the population, providing high risk of disease spread (K McDougall pers. comm. 2020). All mature plants were killed during the 2019 wildfires, but regeneration has been observed under parent plants (K McDougall pers.comm. 2020). The species has not been located at other sites during targeted surveys.

Habitat and ecology

Hibbertia circinata is only known from ridges immediately below the summit of Balawan (Mt Imlay), in a narrow elevation range of 800-850 m above sea level (McDougall *et al.* 2018). It grows amongst a diverse understorey in shrubby woodland dominated by *E. sieberi* and some individuals grow beneath *E. imlayensis*. Flowering has been observed at most times of the year and is prolific in spring.

Hibbertia circinata is an obligate-seeder, but little is known of its seedbank dynamics. The population appeared to be even-aged before it was burnt in the 2019 wildfires (McDougall *et al.* 2018). Recruitment may be rare due to the dense shrub cover of its habitat, and was observed following the fires in April 2020 (K McDougall pers.comm. 2020). Generation length is estimated to be at least 15 years and probably a few decades (McDougall *et al.* 2018).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (<0.01 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (<0.01 km^2) Decreasing	High High
No. of mature individuals Trend	<250 Decreasing	Medium High
No. of locations (key threat) Trend	1 (introduced pathogens) Stable	High High
No. of subpopulations Trend	1 Decreasing	High High
Generation length	>15 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Inferred and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and one location; continuing decline inferred and projected in EOO, AOO, area/extent and quality of habitat, number of subpopulations, number of mature individuals.
C2a(ii)	CR: <250 mature individuals; continuing decline projected; and 100% of mature individuals in one subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Introduced pathogens *Ongoing*	Whole	Very rapid	High	*Hibbertia circinata* is known to be highly susceptible to phytophthora (K McDougall pers.comm. 2020). Within available habitat, plants occur at the end of a ridge where phytophthora has not yet reached. Plants at the base of the cliff and growing amongst rocks may be somewhat protected. Phytophthora may also indirectly affect the species by causing dieback in other species and thus altering habitat structure and condition, and severely fragmenting the already restricted and isolated mountaintop habitat of the species.
Inappropriate fire regimes *Unknown*	Whole	Unknown	Unknown	*Hibbertia circinata* is an obligate-seeder. Fire killed all mature individuals in 2019, and seedlings were observed in April 2020. Too-frequent fire may be a threat, but this is largely unknown (K McDougall pers.comm. 2020).
Stochastic events *Future*	Whole	Very rapid	Medium	Given the restricted range and small population size, *H. circinata* is vulnerable to stochastic events.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Climate change *Future*	Whole	Unknown	Unknown	Effects of climate change on mountain-top species are predicted to be severe including increased average temperatures, lower cool season rainfall and harsher climate weather (Grose *et al.* 2015), but likely effects on *H. circinata* are unknown.

Current management

- There is no recovery plan for this species. A Saving our Species strategy is under development, which will identify priority actions for recovery (New South Wales Department of Planning, Industry and Environment 2020).
- This species occurs entirely within Mt Imlay National Park.
- Research has confirmed that the species is highly susceptible to phytophthora.
- Disease hygiene measures are in place to mitigate the risk of phytophthora infestation, including a hygiene station for bushwalkers.
- There is a small *ex situ* collection at the Canberra Botanic Gardens.
- A glasshouse phosphite trial will be undertaken in 2021.

Conservation objectives

- Monitor and maintain known population.
- Detect more subpopulations through targeted surveys.
- Develop plan for translocation including commencement of propagation trials and identifying suitable recipient sites that are disease-free.

Information required

Theme	Specific actions	Priority
Introduced pathogens	Monitor population and site for signs of disease infestation. Determine effective methods for controlling phytophthora dieback.	High High
Ex situ conservation/translocations	Determine viable propagation methods (seed/cuttings). Identify suitable habitat in secure, disease-free areas for translocation trials.	High
Population surveys	Establish permanent monitoring transects to inform population trends in response to recovery actions and threats, particularly post-fire. Targeted surveys in other suitable habitat to locate additional subpopulations.	High Medium

Management actions required

Theme	Specific actions	Priority
Introduced pathogens	Maintain and adapt disease hygiene measures at population site.	High
Ex situ conservation/translocations	Collect and store seed representing maximum range of genetic diversity to spread risk of extinction. Undertake propagation trials preparation for translocation. Translocate species to secure, disease-free locations (including areas within the existing population that are more protected). Ensure translocated population contains maximum range of genetic diversity.	High High High
Extension and awareness	Raise awareness of species with relevant stakeholders in attempt to locate additional subpopulations.	Medium

Experts consulted

Keith McDougall.

References

Australasian Virtual Herbarium (2020) '*Hibbertia circinata* specimen records'. (The Australasian Virtual Herbarium, Council of Heads of Australian Herbaria) Accessed at: avh.chah.org.au [Verified 20 October 2020]

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Kelleria bogongensis C.E.Marks [THYMELEACEAE]
Snow daphne, kelleria

Kelleria bogongensis in flower on the Bogong High Plains (image: Neville Walsh).

Overview

Kelleria bogongensis is known from a single location on Victoria's Bogong High Plains. Substantial decline was recorded in a monitoring plot between 1993 and 2002, which may be associated with climatic drying. Wild horses occur within the vicinity of the population and *K. bogongensis* is vulnerable to grazing and trampling pressures. Ongoing monitoring is required to better understand population dynamics in relation to threats, as well as investigation into the feasibility of translocation.

Conservation status

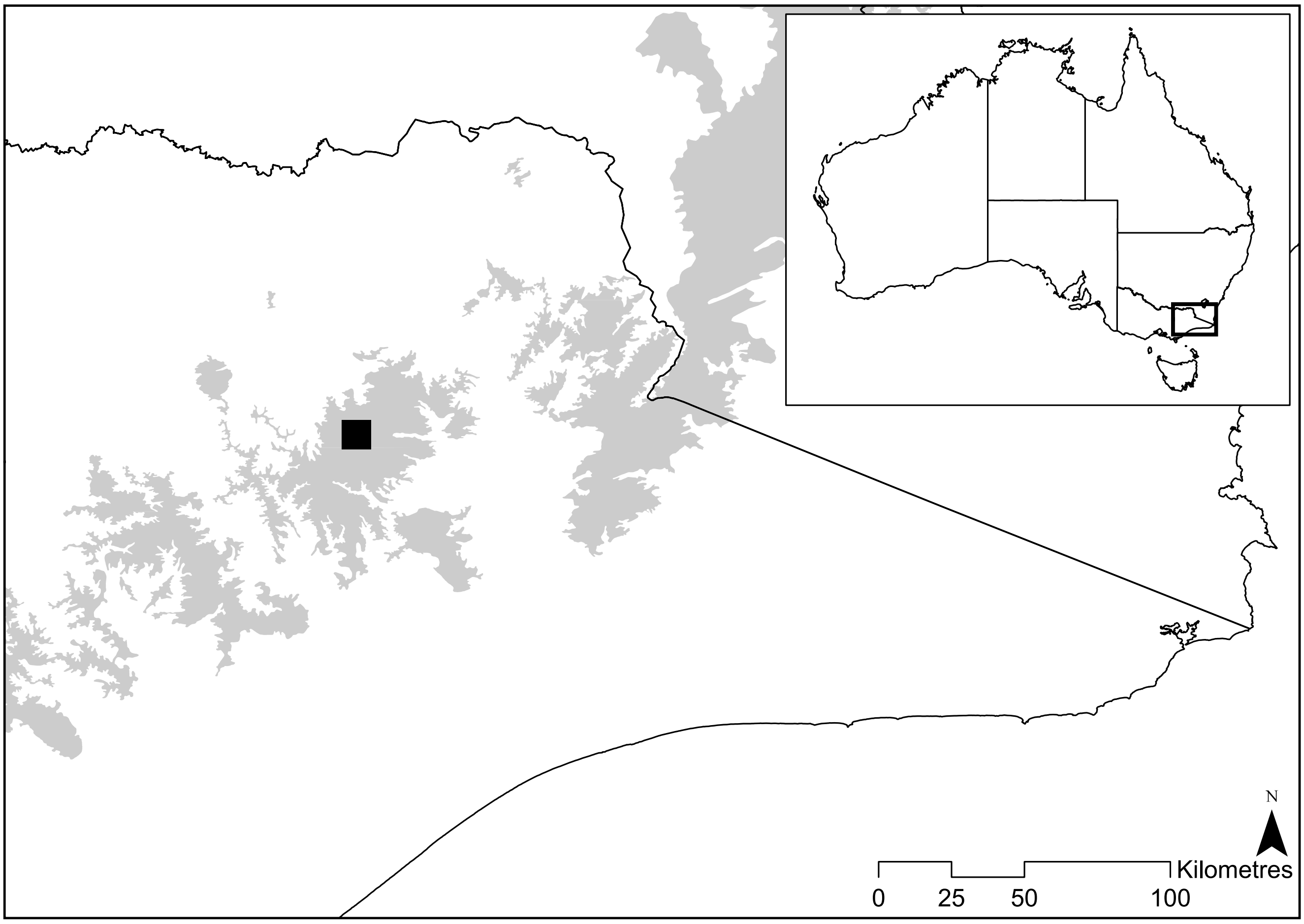
Environment Protection and Biodiversity Conservation Act 1999	Vulnerable
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Spreading, mat-forming shrub to 3 cm tall, but growing to at least 40 cm (and possibly 200 cm) in diameter (Carter and Walsh 2006). Stems are hairy and form adventitious roots along their length (Marks and Walsh 2004). Leaves are narrow, grey-green with 1-3 nerves on short shoots 1.9-2.5 mm long and 0.4-0.6 mm wide (Marks and Walsh 2004). Terminal inflorescence of 1-4 (usually 2) white-cream tubular flowers. Seeds are black and glossy, 1.9-2.2 mm long and 0.95-1.0 mm wide (Marks and Walsh 2004).

Distribution

Kelleria bogongensis is known from one location on the Bogong High Plains near Mt Jim, in the Australian Alps bioregion of north-eastern Victoria (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012). The subpopulations are not considered severely fragmented as they occur in close proximity to each other in intact habitat where dispersal between subpopulations is possible (IUCN 2019).



Current distribution (black square) of *Kelleria bogongensis* near Mount Jim in the Australian Alps bioregion (shaded grey) of Victoria (AVH 2020; DAWE 2012).

Population estimate and trends

Kelleria bogongensis is currently known from three subpopulations within 1 km^2. Population size is difficult to estimate due to the mat-forming habit of the species. The species was first collected in 1980, with 'only one stand of <20 plants seen' (AVH 2020). A 1991 collection noted that 400-500 plants were scattered over ca. 1 ha (AVH 2020). In 2006, there were 19 discrete patches varying in size from 0.01 m^2 to 700 m^2 within 1 km^2, and population estimates ranged from 400 to 2000 plants (Carter and Walsh 2006). In 2009, 1700 individuals were estimated to occur in 19 patches (Department of Sustainability and Environment 2009). In 2014, the population consisted of 18 patches varying in size from 0.1 m^2 to 5 m^2 (Marks and Walsh 2014).

Monitoring data from a 10 m^2 plot shows the species' extent in area occupied between 1993 and 2002 (Marks and Walsh 2014). No monitoring has occurred since 2002, but declines are suspected due to dry years and increased horse numbers (N Walsh pers.comm. 2020). Here the total population size is conservatively estimated as <500 plants. Targeted surveys have been conducted in similar habitat in the area, which is relatively rare in terms of hydrology and geology (N Walsh pers.comm. 2020), and it is unlikely that additional sub populations exist.

Habitat and ecology

Kelleria bogongensis occurs in shallow organic loams overlying basalt on flat to sloping topography at ~1800 m above sea level (AVH 2020). It typically occurs on the edges of seasonally inundated pools amongst alpine grassland dominated by *Poa costiniana* (Carter and Walsh 2006). Small patches (0.1-0.5 m2) comprising multiple individuals form typically in association with *Argyrotegium nitidulum* (Marks and Walsh 2014). Plants tend to occur in slight depressions, and it is suspected that moist sites are important for plant survival (Carter and Walsh 2006). Flowering occurs from November to February and fruit develop from December through to March (Carter and Walsh 2006). Generation length is unknown.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4km^2 (1 km^2) Decreasing	Medium High
Area of occupancy (actual) Trend	4 km^2 (<0.1 km^2) Decreasing	Medium High
No. of mature individuals Trend	<500 Decreasing	Medium High
No. of locations (key threat) Trend	1 (introduced vertebrate pests) Stable	High High
No. of subpopulations Trend	3 Stable	Medium High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	No	Medium
Continuing decline	Observed and projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-iii,v)	CR: EOO <100 km^2; AOO <10 km^2; 1 location; continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, and number of mature individuals.
C2a(i)	EN: <2500 mature individuals; continuing decline observed and projected; and <250 mature individuals in each subpopulation.
D1+2	VU: <1000 mature individuals; AOO <20 km^2; <5 locations and plausible future threat.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Grazing (domestic stock) *Suspended*	Whole	Slow	Medium	*Kelleria bogongensis* is vulnerable to trampling by cattle, which were permitted to graze in Alpine National Park until 2003. Cattle grazing has now been removed from the park, although could recommence in the future.
Introduced vertebrate pests *Ongoing*	Whole	Rapid	High	There is a population of feral horses within the vicinity of this species. The species occurs in one location as feral horses are known to trample and browse this species at all sites and management occurs at the land tenure scale. Feral horse numbers have markedly increased in the Mt Jim area in recent years, although they are due to be removed following the findings of a 2020 court case (N Walsh pers.comm. 2020).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Human activities *Ongoing*	Majority	Slow	Medium	This species is vulnerable to trampling by bushwalkers as some plants grow directly on a walking track.
Climate change *Future*	Whole	Rapid	Medium	Decline was observed during a period of prolonged drought. Climate change may increase the frequency and severity of dry periods and fires, causing further population declines in the future (Grose *et al.* 2015). The population did not burn in the extensive wildfires of 2003 or 2020 (Carter and Walsh 2006; N Walsh pers.comm. 2020), suggesting that fire is not a major threat.

Current management

- Recovery actions have been identified (Carter and Walsh 2006; DSE 2009; Threatened Species Scientific Committee 2016).
- All subpopulations occur within Alpine National Park that is managed for conservation.
- Detailed monitoring was undertaken between 1993 and 2002 (N Walsh pers.comm. 2020).
- Plants have been grown from cuttings at the Royal Botanic Gardens Victoria, and research into seed germination is required (N Walsh pers.comm. 2020).

Conservation objectives

- Monitor and maintain known population.
- Detect more subpopulations through targeted surveys.
- Protect habitat of known population from feral horse grazing.
- Establish *ex situ* subpopulations to reduce extinction risk.
- Increase the number of mature individuals and subpopulations in the wild.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the life history and ecology of the species including population dynamics, fire ecology, seed germination requirements and habitat suitability for translocations.	High
Ex situ conservation/translocations	Undertake research to inform translocations in the future. Seed germination requirements, habitat suitability and factors that ensure successful establishment of translocated plants are important.	High
Population surveys	Monitor population to determine response to management activities and ongoing threats.	High
	Conduct surveys in potential habitat to detect unrecorded populations.	Medium

Management actions required

Theme	Specific actions	Priority
Introduced vertebrate pests	Manage feral horse populations through culling and/or exclusion fencing to reduce immediate impacts on *K. bogongensis*.	High
Grazing	Continue to exclude domestic stock from the park to prevent trampling and habitat degradation.	High
Extension and awareness	Raise awareness of the species and impacts of feral horses to gain wider public support for feral horse culling in the national park.	High
Ex situ conservation/translocations	Establish an *ex situ* subpopulation of the species representing maximum genetic diversity in preparation for translocations in the future.	High

Experts consulted

Neville Walsh.

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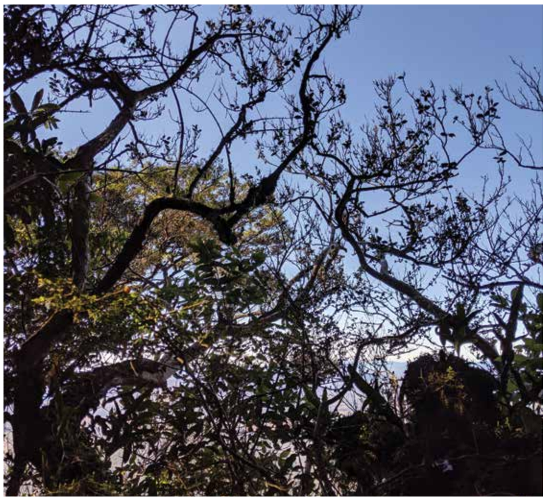
Lenwebbia sp. Main Range (P.R.Sharpe+ 4877) [MYRTACEAE]
Main Range lenwebbia

Lenwebbia sp. Main Range foliage (left; image: Gavin Phillips) and severe canopy dieback at Lizard Point in Main Range National Park (right; image: Julian Radford-Smith).

Overview

Lenwebbia sp. Main Range is an undescribed species restricted to small patches of high altitude cloud forest. Since the invasion of myrtle rust *Austropuccinia psidii* in 2010 a widespread and rapid decline has been observed. Numerous dead individuals have been found in recent surveys and where the species persists, new growth is often severely infected. Recovery options are currently focussed on survey, mapping and germplasm capture at all known sites. The aim of these efforts is to establish a genetically representative collection for *ex situ* management and potential future reintroductions.

Conservation status

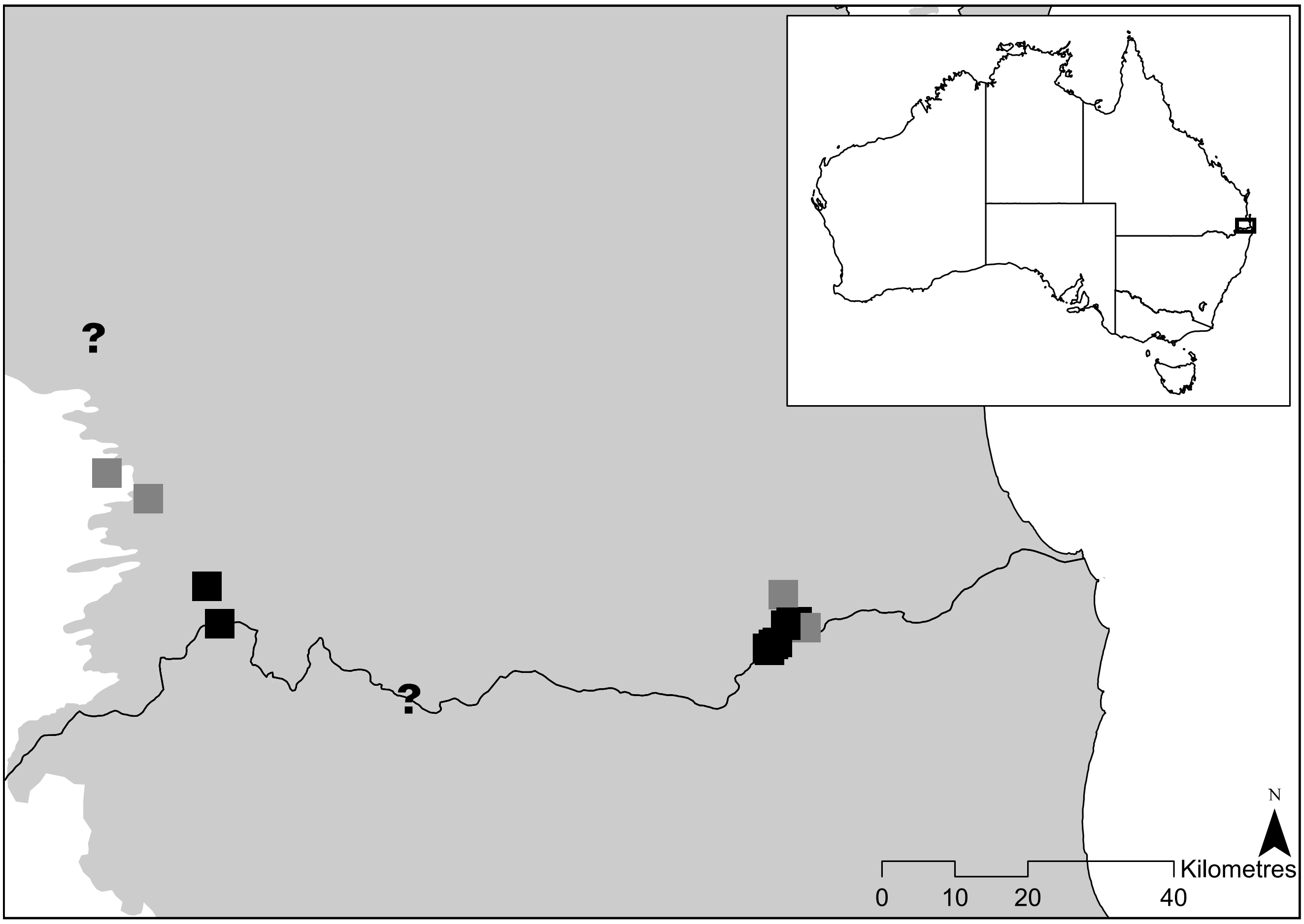
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992 (Qld)	Critically Endangered
Biodiversity Conservation Act 2016 (NSW)	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Small tree to 5 m with densely hairy branchlets (Wilson 2018). Leaves are elliptical to obovate, 3-5 cm long and 1-2.5 cm wide with sparse hairs above and a hairy midvein below. Solitary flowers form in the leaf axils and fruits are black when mature (Wilson 2018). The species is distinguished from *L. prominens* by the hairy mid-vein and less prominent lateral veins on the underside of the leaf (Harden *et al.* 2015).

Distribution

Lenwebbia sp. Main Range is known from several disjunct sites in Main Range National Park in Queensland, and along both sides of the Queensland-New South Wales border in the South East Queensland bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and Environment 2012; Saving Our Species unpublished data). Subpopulations are small and occur in isolated patches of specific habitat. In NSW, subpopulations are separated by distances ranging from ca. 1 km to 40 km, generally exceeding the normal foraging range of the presumed insect pollinators, but not necessarily of the seed-dispersing birds when plants were still producing fruit (B Makinson pers. comm. 2020). Seedling establishment and survival is further hindered by the introduction of myrtle rust, therefore the species is considered severely fragmented (IUCN 2019).



Current distribution of *Lenwebbia* sp. Main Range includes sites where the species persists but is declining rapidly due to dieback (black squares), is presumed extinct (grey squares), or status unknown (?). *Lenwebbia* sp. Main Range occurs in the South Eastern Queensland bioregion (shaded grey) of Queensland and New South Wales (AVH 2020; DAWE 2012; SOS unpublished data).

Population estimate and trends

Lenwebbia sp. Main Range was first collected from Mount Mistake in 1948 (AVH 2020). Subsequent collections were made from various mountain peaks until 1999, when the species was known from 15 sites (AVH 2020). Currently, *L.* sp. Main Range persists at 11 of these sites, is presumed extinct from four, and remains unsurveyed at Mt Mistake (SOS unpublished data; Fensham *et al.* 2020; T Collingwood pers.comm. 2020; AVH 2020). Even where species counts have been stable between years, the canopy cover is deteriorating rapidly due to myrtle rust infection (SOS, unpublished data) and a population reduction of >90% is projected in the next 100 years. The number of 'mature individuals' (IUCN 2019) is inferred to be <50 due to reproductive suppression by myrtle rust. *Lenwebbia* sp. Main Range reproduces sexually, and myrtle rust has caused a reduction in the abundance and density of parent plants and thus outcrossing probability, reduced flowering rates due to shoot death and flower bud infection, and reduced seed set due to plant stress and direct infection of fruits (B Makinson pers.comm. 2020).

The population size of *L.* sp. Main Range prior to the introduction of myrtle rust is not well-documented. The species was recorded as 'locally common' at Jirramun (Wilsons Peak) in 1994 (Queensland Herbarium 2020). Twenty trees were recorded below Jirramun (Wilsons Peak) in 2019, 12 were dead by 2020, and another seven of 16 newly recorded trees were also dead (SOS unpublished data). While some of these deaths can be attributed to extreme drought conditions that affected the species habitat, many trees were in severe decline prior to the drought, with an average canopy cover of 28% (SOS unpublished data). The average canopy cover by 2020 was only 7% (J Mallee pers.comm. 2020). By contrast, collection records (AVH 2020) indicate the species was 'rare' at Garagoolba Lookout (1986), Joahlah Lookout (1994) and Mt Wagawn (1994). The species is probably inherently rare across its distribution given its habitat is naturally restricted in the landscape (L Weber, J Mallee pers.comm. 2019).

Targeted surveys have been undertaken throughout the known and potential habitat of *L.* sp. Main Range in both Queensland and New South Wales from 2016-2020. Despite intensive searching, the species has not been relocated at Niamboyoo (Mt Cordeaux) or Mt Wagawn. The species was not relocated at Barguggan/Binkinjoora (Spicers Peak) during surveys in 2020 (T Collingwood pers.obs. 2020). Mt Mistake requires re-survey but is extremely remote, and a fire in 2019 has made resurvey of the single individual at Jalgumbun (Mt Lindesay) unsafe (L Weber, J Mallee pers. comm. 2020). Up to 50 mature individuals with severe dieback persist along an exposed ridgeline to Lizard Point (J Radford-Smith, T Collingwood unpublished data).

Lenwebbia sp. Main Range monitoring data, 1948-2020 (SOS unpublished data; Fensham *et al.* 2020; T Collingwood pers.comm. 2020; AVH 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles) (dead)	Trend
1 Niamboyoo (Mt Cordeaux) (Main Range National Park)	1989: present 2019: 0 2020: 0	Presumed extinct
2 Mt Mistake (Main Range National Park)	1948: present 2020: unknown	Unknown
3 Bunkoo (Mt Roberts) to Lizard Point (Main Range National Park)	1986: present 1994: present 2020: <50	Decreasing
4 Barguggan/Binkinjoora (Spicers Peak) (Main Range National Park)	1995: present 2020: 0	Presumed extinct
5 Jirramun (Wilsons Peak) (Koorelah National Park and Main Range National Park)	1994: locally common 2016: 23 2019: 20 2020: 17 [12 of 2019 census] + [7 of 16 newly recorded]	Decreasing
6 Dacelo, Woonoongoora (Lamington National Park)	2019: 6 (several) 2020: 4	Decreasing
7 Joalah Lookout, Woonoongoora (Lamington National Park)	1994: rare 2013: 1 2016: 1 2019: 0 2020: 0	Presumed extinct
8 Jalgumbun (Mt Lindesay) (Border Ranges National Park)	2019: 1 [1] 2020: ? (possibly burnt) 2019: 5 (1 with immature fruit) 2020: 4	Decreasing
9 Mt Merino (Limpinwood Nature Reserve)	2019: 5 (1 with immature fruit) 2020: 4	Decreasing
10 Mt Wagawn/ Garragoolba Lookout (Limpinwood Nature Reserve)	1986: rare 1994: rare 2019: 0	Presumed extinct
11 Mt Worendo (Limpinwood Nature Reserve)	2019: 3 2020: 3	Decreasing
12 Echo Point/gorge (Limpinwood Nature Reserve)	2019: 9 (3) 2020: 9	Decreasing
13 Mt Wupawn (Limpinwood Nature Reserve)	2019: 10 2020: 10	Decreasing
14 Mt Wunungara (Limpinwood Nature Reserve)	2019: 0 (1) 2020: 0 (1)	Decreasing
15 Mt Cominan (Limpinwood Nature Reserve)	2019: 0 (1)	Decreasing

Habitat and ecology

Lenwebbia sp. Main Range is restricted to volcanic escarpments in high altitude areas at 900-1200 m above sea level (Weber and Box 2016). It grows on exposed, steep, rocky areas in skeletal clay-loam soils over volcanics (basalt or rhyolite) amongst mossy cloud rainforest thickets and complex notophyll vine forest (Weber and Box 2016). Associated species include *Nothofagus moorei, Archirhodomyrtus beckleri, Syzygium smithii, Cassinia compacta, Cryptocarya foveolata, Diospyros pentamera, Leptospermum petersonii, Leucopogon spathaceus, Leucopogon* sp. Lamington*, Olearia elliptica, Prostanthera ovalifolia, Tristaniopsis collina, Uromyrtus lamingtonensis* and *Xanthorrhoea latifolia* (Queensland Herbarium 2020). Historically, fruit have been collected in August, September and February (QH 2020).

The species is long-lived and slow-growing; cultivated specimens take >20 years to reach reproductive maturity, and life span estimates are up to 100 years (G Phillips pers.comm. 2019). The generation length is therefore estimated as >40 years. The species is a known host to myrtle rust, which causes severe dieback in new shoots and infects flowers, fruit and damages seed viability.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	2049 km^2 Decreasing	Low High
Area of occupancy Trend	44 km^2 Decreasing	Low High
No. of mature individuals Trend	<50 Decreasing	Medium High
No. of locations (key threat) Trend	1 (introduced pathogens) Decreasing	Medium High
No. of subpopulations Trend	11 Decreasing	Medium High
Generation length	>40 years	Low
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Observed and estimated	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A4ce	CR: >80% reduction observed (2009-2020) and estimated (+100 years); based on decline in AOO, EOO, habitat quality; and effects of introduced pathogens.
B1ab(i-v)	EN: EOO <5000 km^2; AOO <500 km^2; severely fragmented and 1 location; continuing decline observed and estimated in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and estimated; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Introducted pathogens *Ongoing*	Whole	Very rapid	High	Myrtle rust causes dieback of young shoots and reproductive organs in *L.* sp. Main Range and occurs throughout the species' distribution (Makinson 2018). One fruit has been collected since myrtle rust invasion. More than 80% of individuals died in Limpinwood NR and Woonoongoora (Lamington NP) from 2016-2018, and >50% of the individuals at Jirramun (Wilsons Peak) have died in the past 4 years (22 of 39; SOS unpublished data). Even where species counts have been stable between years, canopy cover is deteriorating rapidly (SOS unpublished data). As all subpopulations are infected with no viable *in situ* management options, the species occurs at one location.
Drought/wildfire/ climate change *Ongoing*	Whole	Rapid	Medium	More than 10 individuals died at Jirramun (Wilsons Peak) in 2019-2020 due to drought-induced water stress. Those with re-shooting foliage were heavily infected with myrtle rust (L Weber, J Mallee pers. comm. 2020). At some sites in Main Range NP, the species occurs in montane heath that is vulnerable to wildfire under dry conditions (L Weber pers. comm. 2020). Fire may have killed the individual at Jalgumbun (Mt Lindesay) in 2019, although the substrate is too unstable for re-survey (L Weber, J Mallee pers.comm. 2020). Wildfire killed many trees (including rainforest Myrtaceae) within the habitat of *L.* sp. Main Range at Barguggan/Binkinjoora (Spicers Peak) in 2019, although specific impacts on *L.* sp. Main Range are unknown. Drought duration and extreme fire weather are predicted to increase under climate change (Dowdy *et al.* 2015; Tanner-McAllister *et al.* 2018; L Weber, unpublished data). Moreover, the capacity for highly restricted mountaintop species to survive under climate change is tenuous (Cartwright 2019).
Accidental destruction *Ongoing*	Minority	Slow	Low	Seedlings on the trackside between Mt Merino and Mt Wanungara are prone to trampling by hikers, although many of these may be hybrids with *L. prominens* (G Phillips pers.comm. 2019). An illegally lit campfire at Echo Point escaped and burnt 1.5 ha of vegetation, narrowly avoiding the individuals of *L.* sp. Main Range (L Weber pers.comm. 2020).
Hybridisation *Ongoing*	Minority	Slow	Low	*Lenwebbia* sp. Main Range readily hybridises with *L. prominens*. Although a natural process, if *L.* sp. Main Range receives respite from myrtle rust and can reproduce, a high proportion of viable seed is likely to be of hybrid origin due to the relative abundance of *L. prominens*, which is less susceptible to myrtle rust dieback. The only seedling germinated from wild-sourced fruit since myrtle rust arrived has been a hybrid (L Weber, G Phillips pers.comm. 2020).

Current management

- A National Action Plan (Makinson *et al.* 2020) has been developed through extensive consultation and provides a national expert consensus for the conservation of species affected by myrtle rust. *Lenwebbia* sp. Main Range is listed as an 'emergency' priority species in the NAP (Makinson *et al.* 2020).
- Current conservation actions under the NSW Saving our Species program (New South Wales Department of Planning, Industry and Environment 2020) include surveys of known and potential habitat to determine distribution, documenting population size and demographics (including marking individual trees), documenting reproduction/ recruitment, and recording extent and severity of myrtle rust infection (J Mallee pers.comm. 2020). Cuttings are being collected from the maximum number of living individuals for *ex situ* conservation at the Australian Botanic Gardens Mount Annan (J Mallee pers.comm. 2020).
- The species occurs exclusively in conservation reserves/national park.
- Limited targeted surveys have been undertaken in NSW and Qld to assess and monitor the status of subpopulations. Given the species occupies remote habitat, a complete census has never been possible for safety and access reasons (B Makinson pers.comm. 2020).

Conservation objectives

- Establish awareness, funding and leadership for a long-term and coordinated response to the impact of myrtle rust on *L.* sp. Main Range.
- Identify feasible options for maintaining wild subpopulations of *L.* sp. Main Range.
- Establish and maintain a viable *ex situ* collection of *L.* sp. Main Range as an ongoing conservation resource.
- Better understand the ecology of myrtle rust as it relates to *L.* sp. Main Range and the ecosystems within which it occurs.

Information required

Theme	Specific actions	Priority
Taxonomy	Formally describe the taxon to consolidate knowledge of the species.	High
Population surveys	Undertake field surveys as recommend by the NAP; document myrtle rust incidence, impact, resistance among plants, demographic trends and related ecological data.	High
	Undertake rapid field surveys (especially Mt Mistake and Jalgumbun (Mt Lindesay)) and also establish permanent monitoring plots to capture time-series trends and document decline rates.	High
	Monitor subpopulations in response to threat abatement actions.	High
Ex situ conservation/translocations	Undertake research to determine the most effective methods of *ex situ* germplasm capture and storage (seed, tissue culture, vegetative).	High
	Collate a national inventory of cultivated specimens (botanic gardens, private collections) that can be protected by fungicide, diversified by further sampling and used for seed production.	High
	Use *ex situ* conservation collection to undertake research (within the NAP framework where possible), including trials for more rust-tolerant genotypes that may be used as a basis for reintroduction translocations.	High
Introduced pathogens	Undertake research into biocontrol methods for myrtle rust.	High
	Undertake research to identify possible management actions to maintain the wild population, such as selective fungicide application.	High
Life history, ecology and research	Undertake research to better understand the life history and ecology of the species to guide conservation actions.	High
	Investigate indirect impacts of myrtle rust on habitat of the species, including ecological interactions with other threatening processes such as fire, drought, invasive weeds and climate change.	High

Management actions required

Theme	Specific actions	Priority
Population surveys	Standardise population monitoring data methods and coordinate data storage at a national scale.	High
Ex situ conservation/ translocations	Urgently secure germplasm for *ex situ* conservation efforts.	High
	Maintain and expand secure (threat-managed) and genetically representative *ex situ* collections for seed collection and to support ongoing research efforts, including identification of genotypes less-susceptible to myrtle rust for future reintroduction translocations.	High
Extension and awareness	Seek Indigenous stakeholder input and participation in conservation actions.	High
	Raise awareness of the impact of myrtle rust on the species with local landholders and other stakeholders to monitor and protect the species.	High
Accidental destruction	Protect individuals that are vulnerable to trampling at high visitation sites with appropriate fencing.	Medium
	Maintain and enforce fire bans at campsites near *L.* sp. Main Range in high-risk weather.	Medium
Life history, ecology and research	Assemble fragmented botanical and ecological knowledge of the species (including seedling photographs to guide field impact surveys) in a repository to expedite research, conservation planning and rapid surveys.	Medium

Experts consulted

Bob Makinson, Justin Mallee, Gavin Phillips, Lui Weber, Teghan Collingwood, Julian Radford-Smith and Rod Fensham.

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Petrophile latericola Keighery [PROTEACEAE]
Laterite petrophile, ironstone petrophile, ironstone pixie mop

Petrophile latericola inflorescence (left) and seeds (right; images: Andrew Crawford).

Overview

Petrophile latericola was described in 2010 and is declining despite implementation of recovery actions. The species occurs on an extremely restricted soil type that has been heavily cleared for agriculture, and is suspected to be susceptible to the introduced root-rot fungus phytophthora *Phytophthora cinnamomi*. No young plants have been observed, and surviving plants in 2020 were in poor condition following extremely dry conditions. Recovery actions including translocations are ongoing.

Conservation status

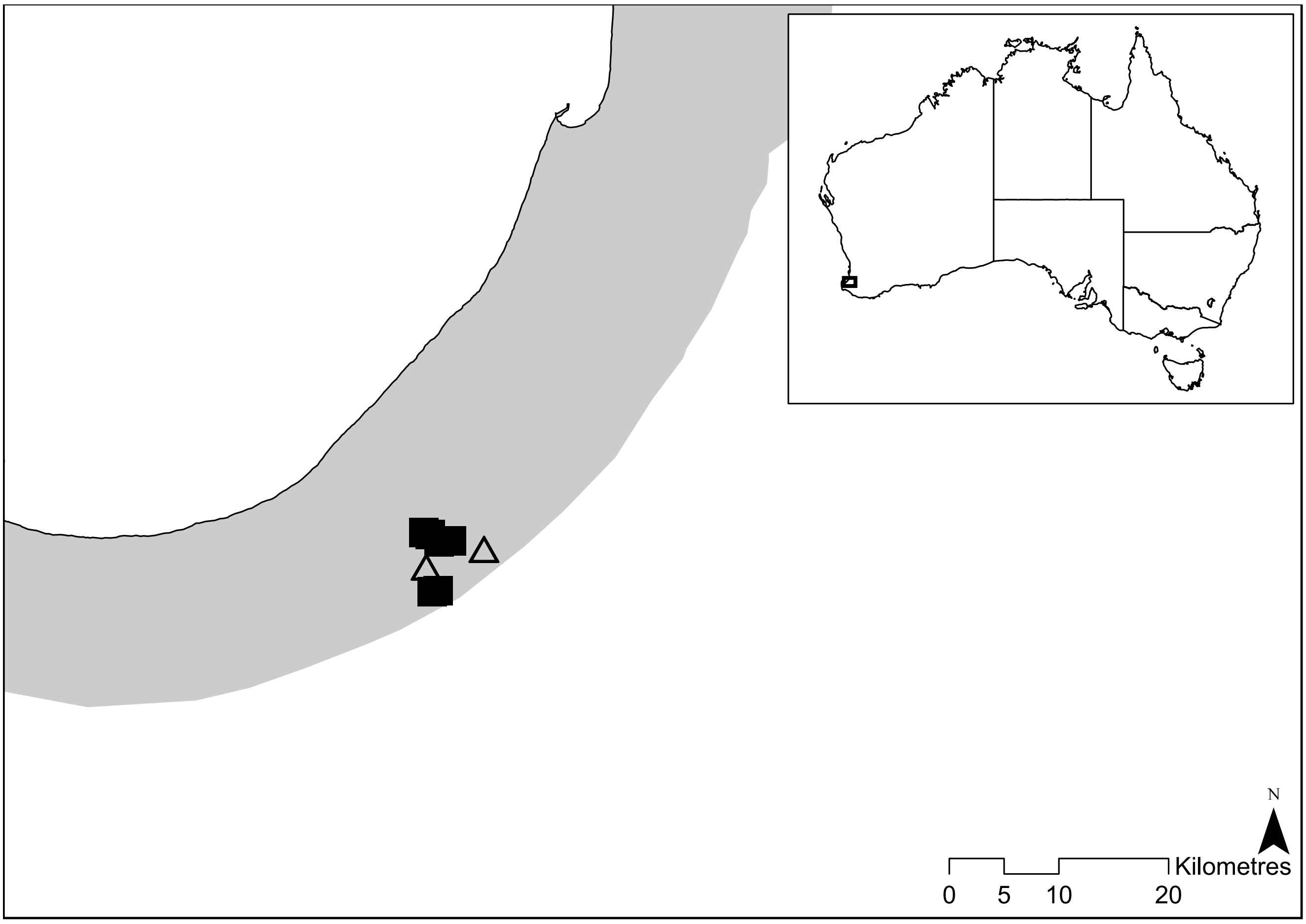
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Upright, single-stemmed shrub with few branches to 1.5 m tall and 40 cm wide (Keighery 2010). Leaves are rigid, linear and have a circular cross-section with a sharp tip, 15-50 mm long. The terminal inflorescences have brown bracts at the base and reach 20 mm long, comprising many hairy, bright-yellow flowers with pollen presenters 3-5 mm long (Keighery 2010). The species is part of the *P. brevifolia* complex, which occurs widely in southern Western Australia. *Petrophile latericola* differs from co-occurring *Petrophile* spp. by lacking a lignotuber, having longer spreading leaves, more floriferous inflorescences and bright yellow flowers (Keighery 2010; Department of the Environment, Water, Heritage and the Arts 2008).

Distribution

Petrophile latericola is known from a very restricted range at the base of the Whicher Scarp near Busselton within the Swan Coastal Plain bioregion of south-western Western Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Biodiversity, Conservation and Attractions 2020).



Current distribution (black squares) of *Petrophile latericola* including translocated subpopulations (hollow triangles) in the Swan Coastal Plain bioregion (shaded grey) of Western Australia (AVH 2020; DAWE 2012; DBCA 2020; Silcock *et al.* 2019). The translocated subpopulations are not yet self-sustaining.

Population estimate and trends

Petrophile latericola is currently known from 171 mature individuals in five naturally occurring subpopulations. It was first collected in 1983 at Subpopulation 2, with subsequent collections from 1989 to 1996 indicating the species was 'fairly common' at this site (AVH 2020; Phillimore *et al.* 2001). In 2001, there were about 200 plants known from three subpopulations (Phillimore *et al.* 2001). Two additional populations containing single plants were located in 2006, and in 2013 the species was known from five subpopulations with 108 mature individuals, most occurring in one subpopulation (DBCA 2020). Two translocated subpopulations were established in 2001 and have been maintained with subsequent plantings in the absence of recruitment (Silcock *et al.* 2019).

Time-series monitoring from 1992 indicates an overall population decline, with future declines projected in the largest subpopulation due to lack of recruitment and poor habitat condition. Targeted surveys have been conducted across the species' range and additional subpopulations are unlikely to exist (A Webb pers.comm. 2020).

Petrophile latericola monitoring data, 1991-2020 (DBCA 2020; A Webb pers.comm. 2020).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 ESE Busselton (rail reserve/ Shire road reserve)	1991: 1 1992: 1 1993: 0 1996: 0 2000: 2 2001: 2 2006: 1 (2) 2013: 3	Stable
2 ESE Busselton (state forest)	1992: 287 1996: >200 2000: >200 2002: 310 2006: >100 2020: 162	Decreasing
3 ESE Busselton (rail reserve)	1991: 1 1992: 0 1996: 3 1997: 3 1999: 4 2000: 6 2001: 3 2002: 3 2004: 1 2013: 0 2017: 2	Decreasing
4 ESE Busselton (rail reserve)	2006: 1 2012: 4	Unknown
5 ESE Busselton (Crown Reserve)	2006: 1 2012: 1 2013: 1 2014: 0	Decreasing
4 (T*) (nature reserve)	2001: 123T 2002: 26T 2010: 56T 2019: 112T (22T)	Not yet self-sustaining
6 (T*) (nature reserve)	2001: 54T 2002: 22T 2010: 48T 2019: 34T	Not yet self-sustaining

Translocated individuals/subpopulation (T). *Plant counts do not reflect subpopulation trend as multiple plantings have occurred.

Habitat and ecology

Petrophile latericola occurs on winter-wet flats amongst heath or *Banksia squarrosa* subsp. *argillacea* shrubland in brown to red sandy clays over ironstone or laterite, known as the Abba Wet Ironstone Flats (Keighery 2010). Associated species include *Viminaria juncea, Banksia grandis, Chamelaucium roycei, Grevillea elongata, Xanthorrhoea preissii, Pericalymma ellipticum, Loxocarya magna* and *Regalia ciliata* (Keighery 2010).

Flowering occurs between October and November (Keighery 2010). *Petrophile latericola* is a serotinous obligate-seeder, which lacks a lignotuber and stores seed in its canopy (Keighery 2010). Fire kills adult plants and triggers release and germination of seed. The length of time seed remains viable in the canopy is not yet known. Where fire is absent, habitat becomes denser and mature individuals senesce in the absence of recruitment (Phillimore *et al.* 2001). It is unknown whether there is also a persistent soil seedbank and given that the species is known to be serotinous, extreme fluctuations are considered probable (IUCN 2019). Plants can flower the second spring after a fire (Keighery 2010), but lifespan and generation length are unknown.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	16 km^2 Decreasing	High High
Area of occupancy (actual) Trend	16 km^2 (<0.05 km^2) Decreasing	High High
No. of mature individuals Trend	171 Decreasing	High High
No. of locations (key threat) Trend	5 (lack of recruitment) Decreasing	Medium High
No. of subpopulations Trend	5 Decreasing	Medium High
Generation length	Unknown	Low
Extreme fluctuations	Probable	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(iii-v)c(iv)	CR: EOO <100 km^2; severely fragmented; continuing decline observed and projected in area/ extent and quality of habitat, number of subpopulations, number of mature individuals; and extreme fluctuations in number of mature individuals probable.
C2a(ii)b	CR: <250 mature individuals; continuing decline observed and projected; 90-100% (92.6%) of mature individuals in one subpopulation; and extreme fluctuations in number of mature individuals probable.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably quantify extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture has resulted in the decline and fragmentation of available habitat for the species. The species is considered severely fragmented as all subpopulations are very small, and isolated by cleared land.
Infrastructure maintenance *Suspended*	Majority	Rapid	Medium	Three subpopulations occur on road/railway reserves and are vulnerable to firebreak maintenance, chemical spraying, drainage channel construction, mowing and proliferation of invasive weeds post-disturbance. Individuals have been lost to these activities in the past, but all subpopulations are now protected by physical barriers and restricted access.
Lack of recruitment/ inappropriate disturbance regimes *Ongoing*	Whole	Very Rapid	High	Limited recruitment has been observed at all subpopulations possibly due to a lack of fire. Further information on appropriate disturbance regimes is required, but the species is known to decline over the long-term in the absence of fire. The species is serotinous (holds a portion of its seed in the canopy), but the relative importance and longevity of the soil-seedbank is unknown. Conversely, too-frequent fire could deplete the seedbank while killing mature individuals. As fire can be managed at the subpopulation scale, the species occurs at five locations.
Introduced pathogens *Ongoing*	Whole	Rapid	High	Field observations indicate the species is susceptible to *Phytophthora cinnamomi* dieback, which is present at multiple subpopulations. Test results conducted on dead *P. latericola* remain inconclusive (A Webb pers.comm. 2020).
Invasive weeds *Ongoing*	Whole	Slow	Medium	Invasive weeds are present in all subpopulations and can increase competition and alter fuel loads and thus fire regimes, which may have substantial impacts on recruitment and population abundance.
Grazing (feral and native) *Ongoing*	Majority	Slow	Medium	Rabbits may limit survivorship of juveniles especially after fire and germination. Macropod grazing is having an impact on mature plants. Subpopulations 2, 4T and 6T have been fenced to exclude grazing.
Changed hydrology/ climate change *Future*	Whole	Unknown	Unknown	Adjacent mining developments and reduced rainfall under projected climate change may lower the water-table with unknown effects on *P. latericola* (B Lullfitz pers.comm. 2020).

Current management

- Implementation of recovery actions is ongoing.
- One subpopulation is protected in a nature reserve and one in state forest.
- Subpopulations 2, 4T and 6T have been fenced to exclude grazing.
- Two translocations have been undertaken in secure tenure with subsequent augmentations. These have been partially successful, however the species is difficult to grow and there has been no recruitment and these are not yet considered self-sustaining.
- Approximately 121 909 fruits were collected between 1994 and 2020 from Subpopulations 1, 2, 4 and 5 and are stored at the Western Australian Seed Centre. These are estimated to contain >7415 germinable seeds.

- The species forms part of the living collection at Kings Park and Botanic Gardens, with 56 plants from 9 clones (28 plants in the Conservation Garden and 28 in the nursery collection). This number is expected to fluctuate as the plants are difficult to maintain in cultivation.
- Phosphite has been used to manage phytophthora dieback since the late 1990s.
- In 2009, two dead plants were tested for phytophthora infection from Subpopulations 2 and 6; both results were negative despite visible phytophthora fronts in the area. Other species known to be susceptible also returned negative results, raising concerns aerial phosphite spraying may have generated false negative results. Further research is required to determine whether phosphite spraying can mask the presence of phytophthora and the mechanisms for this (A Webb pers.comm. 2020).
- All subpopulations are protected from human disturbance by physical barriers and restricted access.
- The species is associated with the 'Shrubland on the Southern Swan Coastal Plain Ironstones' EPBC Act-listed threatened ecological community.

Conservation objectives

- Protect habitat of known subpopulations in appropriate conservation agreements.
- Monitor known subpopulations and increase the number of mature individuals and subpopulations in the wild.
- Expand and maintain *ex situ* collection to represent maximum genetic diversity.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations, particularly after fire events. Monitor population to determine trends in response to threats and management actions.	High High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, seed storage and longevity, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High
Introduced pathogens	Conduct further sampling to assess susceptibility of species to phytophthora. Determine effective management strategies if required.	High

Management actions required

Theme	Specific actions	Priority
Inappropriate fire regimes	Implement appropriate fire regime to increase the number of mature individuals in the long-term.	High
Grazing	Exclude grazers; kangaroos from mature plants and rabbits from juvenile plants, particularly after fire.	High
Introduced pathogens	Continue to implement hygiene measures and phosphite application to reduce impact of phytophthora.	High
Extension and awareness	Raise awareness with appropriate conservation groups and other stakeholders to protect the species and in an attempt to locate additional subpopulations.	High
Ex situ conservation/translocations	Continue translocation program of species to secure tenure. Maintain and expand *ex situ* seed collections to represent maximum range of genetic diversity. Upgrade to high priority if recruitment events occur at the small populations (once plants reach reproductive maturity).	High Medium

Experts consulted

Andrew Webb, Ben Lullfitz, Natasha Moore, Andrew Crawford and Tanya Llorens.

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Phebalium daviesii Hook.f. [RUTACEAE]
Davies' waxflower, St Helens waxflower

Phebalium daviesii foliage and flowers (image: Rob Wiltshire).

Overview

Phebalium daviesii is currently known from a single population comprising fewer than 50 plants along the George River in north-eastern Tasmania. The population occurs on private land under a conservation covenant but is vulnerable to flooding, native and domestic herbivores and weed invasion. Disturbance and germination requirements are poorly understood and recruitment is limited. Translocations have been undertaken with limited success and the persistence of the species remains precarious and dependent on landholder liaison, grazing exclusion, weed control and further translocation.

Conservation status

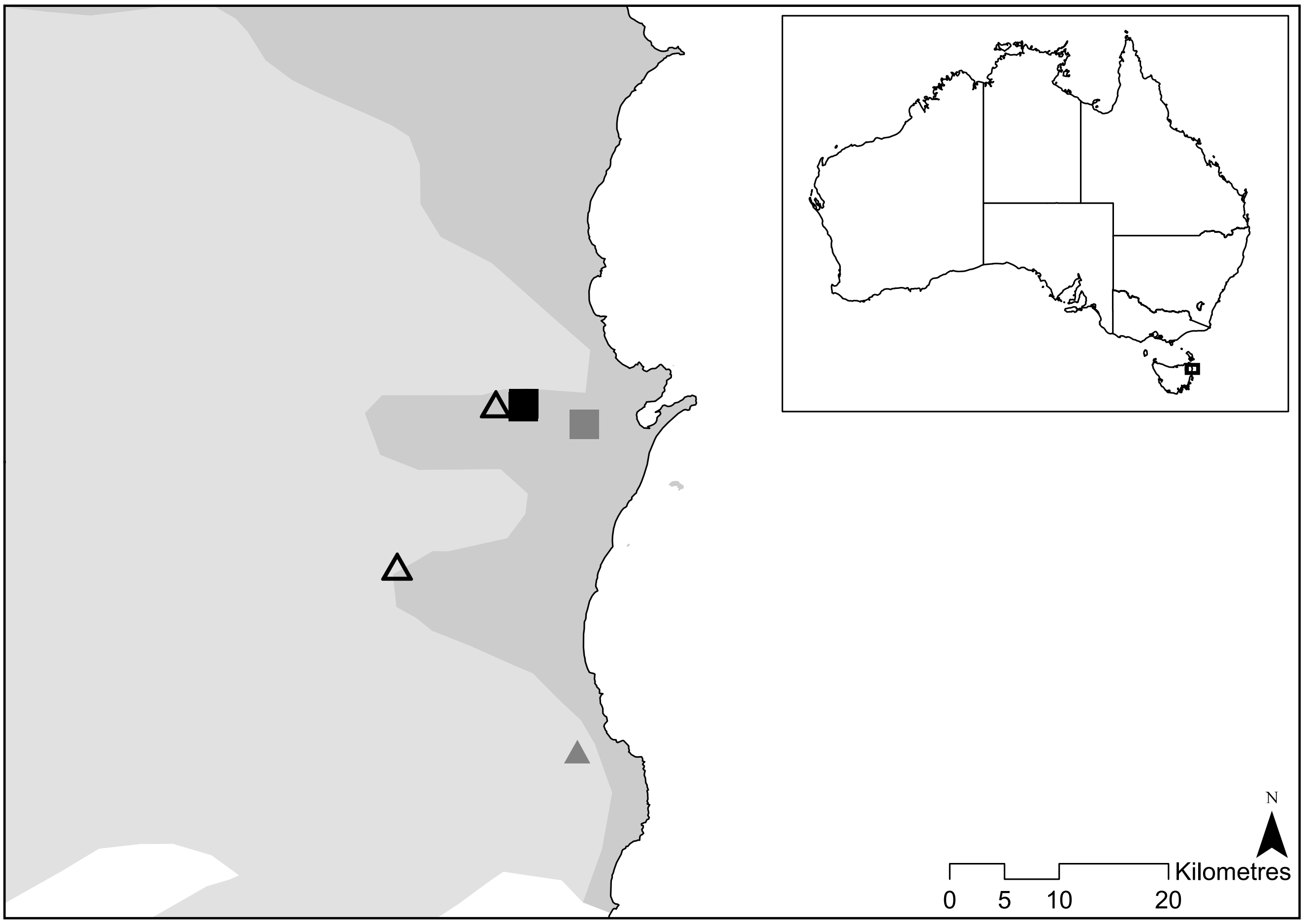
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Threatened Species Protection Act 1995	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Slender shrub to 3 m with smooth or minutely glandular leaves (Wilson 2013; Threatened Species Section 2011). Leaves petiolate and narrow, the mid-vein is deeply impressed, with a bi-lobed apex, 20-30 mm long. The lower leaf surface is silvery and covered in scales, and the upper surface is dark green, with a row of glands along margins. Inflorescence of 5-8 flowers occurring at the end of branchlets, flowers 5-lobed with brown glands on the back of petals. Stamens protrude from flowers and are approximately twice as long as petals (TSS 2011). *Phebalium daviesii* is the only member of this genus in Tasmania (TSS 2011).

Distribution

Phebalium daviesii is known only from the lower reaches of the George River near St Helens in the Furneaux bioregion of north-east Tasmania (Department of Agriculture, Water and the Environment 2012). The species was historically known from Constable Creek and 'near St Helens Bay' (Australasian Virtual Herbarium 2020).



Current (black square) and historical (grey square) distribution of *Phebalium daviesii* in the Furneaux (shaded dark grey) and Ben Lomond (shaded light grey) bioregions of Tasmania (AVH 2020; DAWE 2012). Two translocations (including one augmentation) are extant but not self-sustaining (hollow triangles), while another was unsuccessful (grey triangle; Silcock *et al.* 2019).

Population estimate and trends

Phebalium daviesii was first collected before 1860, with subsequent collections in 1876 and 1892 (AVH 2020). It was presumed extinct until five plants were found in 1990 (Wapstra *et al.* 2006). The species is currently known from 25 mature plants in one subpopulation spread over 40 m on the eastern bank of the George River. A second subpopulation some 450 m away on the western bank did not contain any naturally-occurring plants in 2019 (O Carter pers.comm. 2020). A single individual was located near the main subpopulation in Mt Pearson State Reserve in 2001, but subsequently died.

Translocations have been attempted at three sites, including augmentation of one naturally-occurring subpopulation (Silcock *et al.* 2019). Ten translocated plants persist at Scamander River, although the subpopulation continues to decline and is not self-sustaining, and four on the western bank of the George River.

Targeted surveys have been conducted across the range of the species and it is unlikely that additional subpopulations exist.

Phebalium daviesii monitoring data, 1990-2019 (DPIPWE 2020; O Carter pers.comm. 2020; Threatened Species Section 2011).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 George River eastern bank (private property with conservation covenant)	1993: 38 1997: 42 1999: 28 2001: 20 2002: 19 2004: 14 2007: 13 (30) 2008: 12 (40) 2010: 10 (48) 2011: 15 (26) 2014: 17 (37) 2016: 20 (24) 2017: 25 (19)	Fluctuating
2 George River western bank (private property with conservation covenant)	1990: 5 1997: 5 + 134T 1998: 169T 1999: 2 +118T 2000: 0 + 10T 2001: 2 + 98T 2002: 2 + 89T 2004: 2 + 42T 2007: 1 + 20T 2010: 1 + 21T 2011: 0 + 9T 2014: 0 (several) + 6 (52)T 2016: 0 (7) + 6 (16)T 2017: 0 (4) + 6 (2)T 2019: 0 + 2 (2)T	Decreasing
3 Mt Pearson (state reserve)	2001: 1 2004: 1 2007: 1 2010: 0	Presumed extinct
4 (T) Scamander River (state forest)	1998: 262T 2000: 66T 2002: 140T 2004: 49T 2010: 47T 2017: 10T 2019: 10T	Decreasing
5 (T) Banticks Creek and Golden Fleece Rivulet (state reserve)	1997: 111T 1998: 108T 2000: 64T 2002: 56T 2004: 38T 2010: 0T 2019: 0T	Presumed extinct

Translocated individuals/subpopulation (T).

Habitat and ecology

Phebalium daviesii occurs along river banks at ~20 m above sea level in well-drained, coarse sandy soils among exposed granite boulders and riparian woodland vegetation, dominated by *Eucalyptus viminalis* and a shrubby understorey (TSS 2011). Associated species include *Allocasuarina littoralis, Pomaderris apetala, Zieria arborescens, Micrantheum hexandrum, Leptospermum langierum* and *Hovea corrickiae* (TSS 2011).

Phebalium daviesii produces large amounts of seed but germination requirements remain poorly-understood. The age structure of the population indicates recruitment may occur from the seedbank after disturbance such as fire or flooding. As the species appears to have a persistent seedbank, extreme fluctuations are not likely. The species is thought to be a palaeoendemic; restricted to refugial habitat since the end of the last glaciation (Kirkpatrick and Brown 1984). Subpopulations display relatively high genetic diversity suggesting that the population decline is relatively recent and at least partially anthropogenic (Lynch and Vaillancourt 1995). The species is considered severely fragmented (IUCN 2019) as all individuals occur in very small, isolated subpopulations adjacent to cleared land. Generation length is unknown.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.0004 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.0002 km^2) Decreasing	High High
No. of mature individuals Trend	25 Fluctuating	High Medium
No. of locations (key threat) Trend	1 (lack of recruitment) Stable	High High
No. of subpopulations Trend	1 Decreasing	High High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-iv)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations.
C2a(i,ii)	CR: <250 mature individuals; continuing decline observed and projected; <50 mature individuals in each subpopulation, 90-100% of mature individuals in one subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Suspended*	Majority	Rapid	Medium	All wild plants occur on private land adjacent to historically cleared land. Both naturally-occurring subpopulations are now protected under conservation covenants, but future changes in land ownership may alter land management activities including clearing. The species is considered severely fragmented as all individuals occur in very small, isolated subpopulations adjacent to cleared land.
Herbivores (domestic stock) *Suspended*	Whole	Rapid	High	The population occurs adjacent to grazing pasture, with trampling and defoliation observed. The subpopulations were fenced in 1996 but cattle had breached the fence on the western side of the river in 2017 and the fence was in very poor condition (R Schahinger pers.comm. 2017).
Lack of recruitment *Ongoing*	Whole	Rapid	High	Few seedlings have been observed; germination requirements particularly in relation to disturbance are not well-understood. The species occurs at one location as this threat operates at the subpopulation scale, or larger, given it is not well-understood and management activities have not been able to abate population declines.
Herbivores (native) *Ongoing*	Majority	Rapid	Medium	Browsing by native animals reduced the establishment success of translocated plants and continues to impact the health of remaining individuals.
Invasive weeds *Ongoing*	Whole	Slow	Medium	Invasive weeds including gorse, blackberry, hawthorn, foxglove and willow are present within the habitat (O Carter pers.comm. 2020). Invasive weeds increase competition and alter fuel loads and thus fire regimes, which may have substantial impacts on recruitment and overall population abundance.
Introduced pathogens *Future*	Whole	Unknown	Unknown	*Phebalium daviesii* is susceptible to phytophthora under laboratory conditions (Barker and Wardlaw 1995) although wild subpopulations remain uninfected (Threatened Species Unit 2001).
Stochastic events *Future*	Whole	Rapid	Medium	The entire population occurs within 5 m of a river that is prone to flooding (O Carter pers.comm. 2020). Individuals have been lost in past floods. This disturbance may facilitate germination although at inappropriate intervals or severity could destroy the whole population.

Current management

- Recovery actions have been identified in a recovery plan (TSS 2011).
- Invasive weed control was conducted from 1996-2004 and the population was fenced to exclude cattle, although the fence was breached in 2017 and the fence was in poor condition. The population is protected under a perpetual conservation covenant.
- Measures have been undertaken to minimise the risk of phytophthora spread.
- *Ex situ* populations have been established and translocations using cuttings have been attempted at four sites (three introductions and one augmentation of a natural subpopulation) with limited success. Floods, fire and herbivore browsing reduced the number of translocated individuals from 347 to 18 (O Carter pers.comm. 2020). A collection of all genotypes has been maintained at the Royal Tasmanian Botanic Gardens and propagated individuals have been made available to the public. Individuals have been planted at St Helens town to raise awareness of the species.

Conservation objectives

- Monitor and maintain known subpopulations.
- Detect more subpopulations through targeted surveys, especially after disturbance.
- Maintain *ex situ* collection with maximum range of genetic diversity possible.
- Increase the number of mature individuals and subpopulations in the wild via translocations to spread extinction risk.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate disturbance regimes	Investigate the response of the species to fire/ flooding in terms of recruitment and population recovery.	High
Population surveys	Monitor population to determine response to threats and management actions.	High
	Undertake targeted surveys at historic locations after disturbance in attempts to locate additional subpopulations.	Medium

Management actions required

Theme	Specific actions	Priority
Stakeholder engagement	Continue to liaise with the owners of the covenanted properties on either side of the George River to ensure compliance.	High
Grazing	Continue to protect all subpopulations (wild/translocated) from grazing impacts. Repair and maintain fence on Marthavale (western bank of George River).	High
Invasive weeds	Continue invasive weed management, including systematic mapping of weeds in the vicinity of all subpopulations.	High
Ex situ conservation/translocations	Maintain *ex situ* collections and establish more translocated subpopulations in secure habitat, considering lessons learnt from previous plantings.	High

Experts consulted

Oberon Carter, Andrew Crane and Richard Schahinger.

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Pimelea cremnophila L.M.Copel & I.Telford [THYMELEACEAE] Gorge rice-flower

Pimelea cremnophila flowers and leaves (left), and rocky habitat of the species in October 2020 after wildfire in late 2019 (right; images: Lachlan Copeland).

Overview

Pimelea cremnophila was first collected in 2002, when it occurred in three small subpopulations along a gorge rim. Two of the three subpopulations now have no extant plants, and <100 individuals remain. Declines appear to be caused by low recruitment and herbivory from goats and macropods, which is exacerbated in dry years. Further monitoring is required to document population dynamics, particularly in response to fire, drought and browsing.

Conservation status

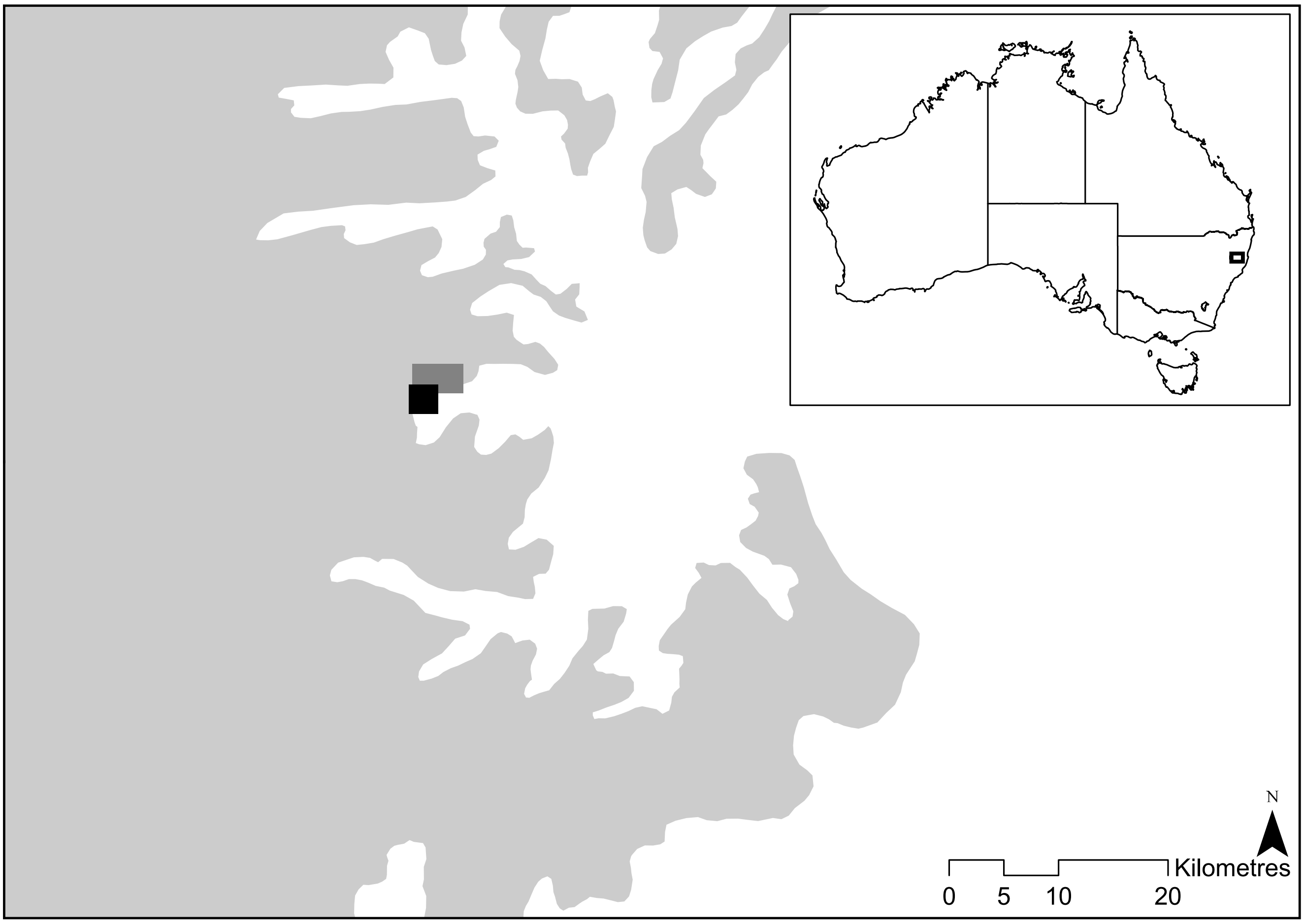
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect shrub to 2.5 m with red-brown stems that are hairy when young (Copeland and Telford 2006). Leaves are opposite, narrow, 10-37 mm long and 2.5-6 mm wide, with densely hairy petioles. Inflorescences are axillary or terminal with 1-4 flowers that are either male, bisexual or functionally female. Fruits are green and dry with red-brown seeds 3-3.5 mm long and 2 mm wide (Copeland and Telford 2006). *Pimelea cremnophila* appears most similar to *P. umbractica*, from which it differs by its longer denser indumentum, less prominent secondary leaf venation, predominantly axillary inflorescences, and smaller anthers on distinct filaments (Copeland and Telford 2006).

Distribution

Pimelea cremnophila is known from a single location in Oxley Wild Rivers National Park to the east of Walcha in the New England Tablelands bioregion of New South Wales (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; New South Wales Department of Planning, Industry and Environment 2020a). The species is not considered severely fragmented as it occurs in an area of contiguous remnant habitat (IUCN 2019).



Current (black square) and historic (grey squares) distribution of *Pimelea cremnophila* in Oxley Wild Rivers National Park, within the New England Tablelands bioregion (shaded grey) of New South Wales (AVH 2020; DAWE 2012; NSW DPIE 2020a).

Population estimate and trends

Pimelea cremnophila is currently known from one subpopulation with <100 individuals. When it was first observed by botanists in 2002, three subpopulations were scattered along ca. 5 km of gorge rims on tributaries feeding into the Macleay River. Monitoring occurred in 2003, 2004 and 2008, and no individuals were present at the two northern subpopulations by November 2015 (Threatened Species Scientific Committee 2017). Wildfire in 2019 burnt the entire habitat of *P. cremnophila*, killing the remaining mature individuals at the southern subpopulation, but ca. 70 seedlings <20 cm tall were observed in a single patch of 20 m^2 in October 2020 (L Copeland pers.comm. 2020). No recruitment occurred at the northern subpopulations, indicating the species may be locally extinct. Relatively few juvenile plants have been recorded overall and the species is thought to be declining due to a range of threats.

Targeted surveys in suitable habitat since 2005, including a major survey in 2012-2013, have failed to locate new subpopulations. A large area of similar habitat is present throughout the region and further searches are recommended (TSSC 2017).

Habitat and ecology

Pimelea cremnophila occurs in shallow, skeletal loams over Walcha-metasediments on exposed or sheltered cliffs at 1050-1090 m above sea level (Copeland and Telford 2006). All individuals occur at sites with a south-westerly to south-easterly aspect amongst open forest with a shrubby understorey (Copeland and Telford 2006). Associated species include *Allocasuarina littoralis, Eucalyptus retinens, E. campanulata, Acacia blakei, Denhamia sylvesytris, Prostanthera rhombea, Dodonaea rhombifolia, Astrotricha longifolia, Ozothamnus obcordatus, Persoonia media, Callistemon* sp., *Correa reflexa, Lepidosperma elatius, L. laterale, Rhodanthe* sp. and *Notodanthonia longifolia* (Copeland and Telford 2006).

Flowering has been recorded in October, although the species probably flowers throughout spring. Plants are polygamous, with functionally male and bisexual flowers on the same plants, and only functionally female on others (Copeland and Telford 2006). The species appears to be fast-growing and its lifespan is estimated to be between 5-10 years; thus generation length is estimated as seven years. The species is probably an obligate-seeder and maintains a long-lived soil-stored seedbank like other species in the genus, so extreme fluctuations are not considered likely (IUCN 2019). Fire killed all mature individuals in 2019, with seedlings observed thereafter (L Copeland pers.comm. 2020). However no seed germinated at the two subpopulations where adults have been absent for 5-7 years.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (1.6 km^2) Decreasing	Medium High
Area of occupancy (actual) Trend	4 km^2 (<0.1 km^2) Decreasing	Medium High
No. of mature individuals Trend	<100 Decreasing	Medium High
No. of locations (key threat) Trend	1 vertebrate pests Decreasing	Medium High
No. of subpopulations Trend	1 Decreasing	Medium High
Generation length	7 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	No	High
Continuing decline	Observed	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; 1 location; and continuing decline observed in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(ii)	CR: <250 mature individuals, continuing decline observed; and 90-100% of mature individuals in one subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Vertebrate pests (introduced and native) *Ongoing*	Whole	Rapid	High	There is evidence of defoliation and trampling by feral goats, which may be contributing to the apparent lack of juvenile plants. Macropods may also contribute to this browsing pressure (L Copeland pers.comm. 2017).
Lack of recruitment/ inappropriate fire regimes *Ongoing*	Majority	Rapid	Medium	Few juvenile plants have been observed while mature individuals have died, resulting in an overall population decline. The species appears to be an obligate-seeder that relies on appropriately-timed fires to simulate recruitment and allow sufficient replenishment of the soil seedbank, but further information on population dynamics is required (TSSC 2017). A particularly intense fire burnt the entire population in late 2019, and killed all adult plants, with 70 seedlings emerging by October 2020 (L Copeland pers.comm. 2020).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Stochastic events *Future*	Whole	Rapid	Medium	Due to the small population size and restricted range, the species is vulnerable to stochastic events.
Climate change *Future*	Whole	Unknown	Unknown	Mortality of mature individuals was observed during a very dry period from 2002-2003 (L Copeland pers. comm. 2017). Increased drought frequency (Dowdy *et al.* 2015) may increase drought-induced mortality.

Current management

- There is no national recovery plan or conservation advice for this species. Site-based recovery actions for this species are detailed under the Saving our Species program including further surveys and monitoring, seed collection and propagation for translocation, feral goat control and implementing an appropriate fire regime (NSW DPIE 2020b).
- This species is protected in Oxley Wild Rivers National Park.

Conservation objectives

- Monitor and maintain known population.
- Detect more subpopulations through targeted surveys.
- Establish *ex situ* population representing maximum range of genetic diversity possible.
- Increase the number of mature individuals and subpopulations in the wild via habitat management or translocations (augmentation).

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations, especially after disturbance. Monitor subpopulations to determine response to threats and management actions.	High High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High

Management actions required

Theme	Specific actions	Priority
Grazing	Control feral goat abundance within the habitat of this species. Fence individuals where possible to protect from grazing.	High High
Inappropriate fire regimes	Implement appropriate fire regime to increase abundance of mature individuals in the long term.	High
Ex situ conservation/translocations	Develop and maintain *ex situ* collection representing maximum range of genetic diversity possible as an insurance population and in preparation for future translocations.	High

Experts consulted

Lachlan Copeland.

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Pimelea venosa Threlfall [THYMELEACEAE]
Bolivia Hill pimelea, Bolivia Hill rice-flower

Pimelea venosa (clockwise from top left) inflorescence (image: © Murray Fagg 2017), habit and seedlings that germinated post-fire and rain in July 2020 (images: Todd Soderquist).

Overview

Pimelea venosa was first collected in 1886 and has rarely been observed since then. When found, subpopulations are very small and have vanished without observed recruitment. Most recently, a subpopulation declined gradually from 46 individuals in 2012 to zero by 2018, despite intensive threat management. This patch was burnt during summer 2019 followed by consistent rainfall, which trigged a flush of seedlings by July 2020. An *ex situ* subpopulation derived from six individuals has been established to research threats via adaptive translocation. Given the species has been historically difficult to locate, it may be another decade before further subpopulations are documented.

Conservation status

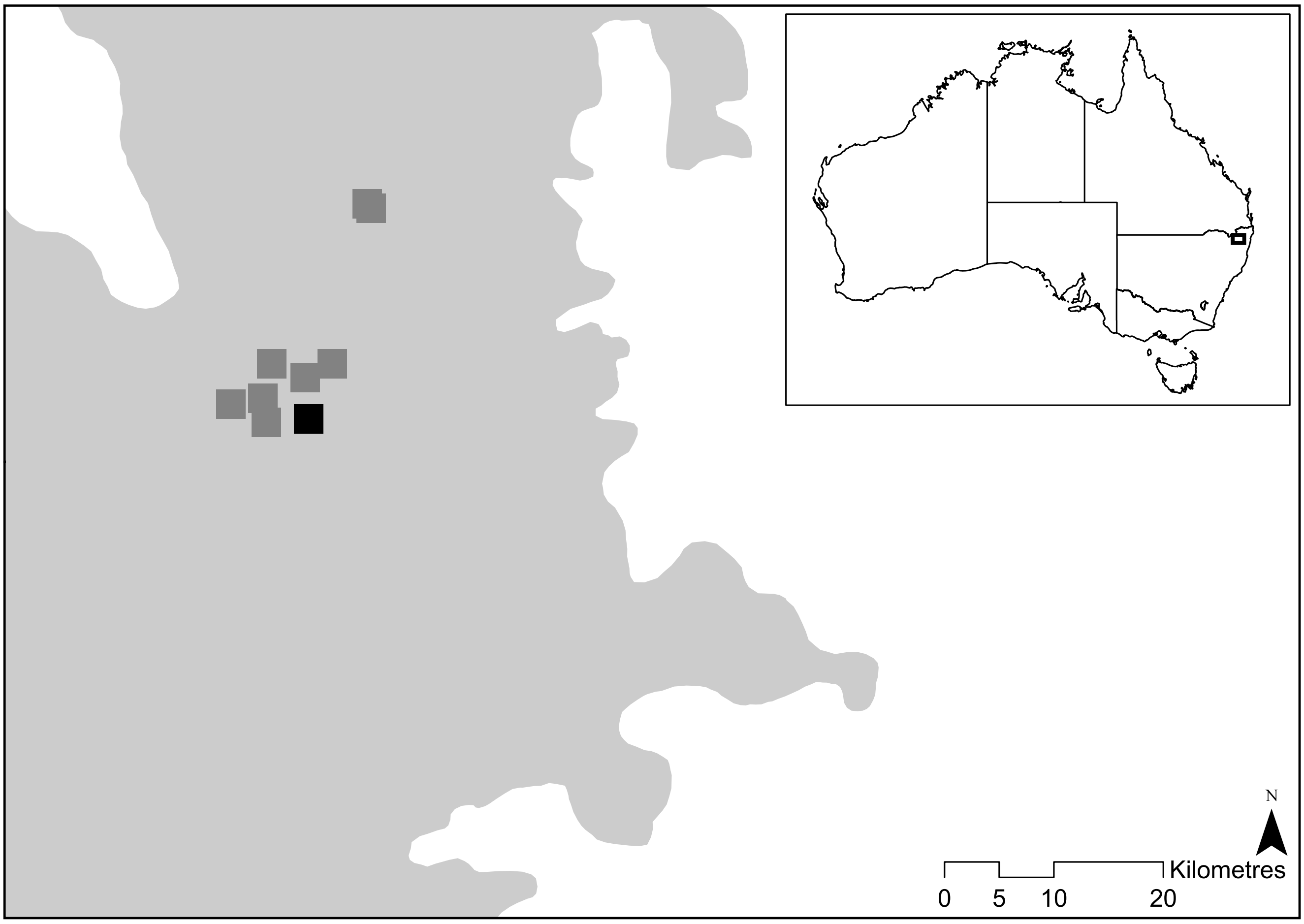
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Biodiversity Conservation Act 2016	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Dense, hairy, erect shrub to 2 m tall (Rye 1990). Leaves 10-15 mm long and 4-6 mm wide, with prominent brown primary and secondary veins. Flowers are typically bisexual, white and 8-10 mm long (Rye 1990). The species is distinguished by the densely hairy leaves and stems, and the prominent brown primary and secondary leaf veins (Department of Environment, Water, Heritage and the Arts 2008). Although individual plants can grow to 2 m in height, 1 m is more typical as they become recumbent with age (T Soderquist pers.comm. 2020).

Distribution

Pimelea venosa is known from the Bolivia region between Deepwater and Tenterfield in the New England Tablelands bioregion of New South Wales (Department of Agriculture, Water and the Environment 2012; New South Wales Department of Planning, Industry and Environment 2020a). Although naturally fragmented, *P. venosa* occurs in relatively intact habitat and is not considered severely fragmented (IUCN 2019).



Current (black square) and historic (grey squares) distribution of *Pimelea venosa* in the New England Tablelands bioregion (shaded grey) of New South Wales (AVH 2020; DAWE 2012; NSW DPIE 2020a).

Population estimate and trends

Pimelea venosa is currently known from a single subpopulation comprising >200 seedlings and no mature individuals. The species was first collected in 1886, and subsequent records indicate the species was localised and occasional. (Australasian Virtual Herbarium 2020; NSW DPIE 2020a).

Additional sites were recorded in the 1980s, but the species was not re-found during an extensive survey in 1999. In 2012, one healthy subpopulation was found with 46 individuals including numerous juveniles. Threatened species managers only became aware of the subpopulation in 2014, when only 15 individuals remained (T Soderquist pers. comm. 2020). Despite hand watering during drought and caging to protect from herbivores, only three plants remained alive in 2017. A further five individuals found 200 metres away also declined, and by 2018 no plants survived at the site. After a low-intensity summer fire followed by consistent rainfall in 2019, >200 seedlings sprouted in July 2020 (T Soderquist pers.comm. 2020).

Targeted searching is difficult as the habitat requirements and vegetation associations of the species are not well-understood. The species also occurs in small, isolated patches, and can be present in the seedbank while plants are absent making detection difficult. Further opportunistic searching in suitable/potential habitat is required, especially in areas that were burnt in the extensive 2019 wildfires.

Habitat and ecology

Pimelea venosa has been found in skeletal or black sandy soils among outcropping granite boulders. Associated vegetation is open eucalypt woodland or forest with *Xanthorrhoea* spp., *Solanum* spp. and *Pteridium esculentum* (NSW DPIE 2019). Partial shade seems to benefit the species, although it can grow in sun as well (NSW DPIE 2019). Generation length is estimated as 3 years; plants flower within 1-2 years and can live for 8 years (T Soderquist pers. comm. 2020).

Flowers are bisexual and have been observed from October to December. Heavy flowering has been occurring during winter in the extant subpopulation (NSW DPIE 2019). Recruitment had not been observed in the wild until 2020. Seeds have been propagated *ex situ* both with and without the effect of smoke or scarification, but success is typically low (e.g. 10%) (T Soderquist pers.comm. 2020). Self-seeding in *ex situ* environments (pots and gardens) indicates consistent water may be fundamental for seed germination. The flush of wild seedlings in 2020 further suggests that heat, lack of competition and water percolating through ash are important (T Soderquist pers.comm. 2020). Although fluctuations in abundance have been observed following disturbance, the species is thought to have a persistent seedbank and therefore is not prone to extreme fluctuations (IUCN 2019).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.01 km^2) Decreasing	Medium Medium
Area of occupancy (actual) Trend	4 km^2 (0.01 km^2) Decreasing	Medium Medium
No. of mature individuals Trend	0 Unknown	Medium Low
No. of locations (key threat) Trend	1 (lack of recruitment/ inappropriate fire regimes) Decreasing	Medium Medium
No. of subpopulations Trend	1 Decreasing	Medium Medium
Generation length	3 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	No	High
Continuing decline	Observed and projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; 1 location; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Lack of recruitment/ inappropriate fire regimes *Ongoing*	Majority	Rapid	Medium	No recruitment had been observed until 2020. Mature individuals in the last known subpopulation senesced despite threat abatement, but >200 seedlings germinated after fire and follow-up rain in July 2020 (T Soderquist pers.comm. 2020). The species appears to be an obligate-seeder so sufficient time is required for the species to produce seed, but fire is also required to stimulate germination.
Grazing (feral and native) *Ongoing*	Whole	Slow	Medium	The species is vulnerable to grazing by goats and macropods, especially during dry periods. Although plants were grazed in the only extant subpopulation, this did not seem to be the cause of death or lack of recruitment. Grazing may also degrade habitat by compacting soils and altering vegetation structure, but may provide benefits by reducing competition in granite substrates where water penetration may be limited (T Soderquist pers.comm. 2020).
Herbivory *Ongoing*	Minority	Unknown	Unknown	Caterpillars have been observed attacking plant stems. Diurnal and nocturnal examination of the last known subpopulation detected no insect herbivory on leaves although borers of an unknown species weakened some large stems, causing them to break off (T Soderquist pers.comm. 2020).
Infrastructure maintenance *Future*	Minority	Rapid	Low	Subpopulations may occur along vehicle tracks and near rail and road easements, and are thus are vulnerable to maintenance activities.
Stochastic events *Future*	Minority	Rapid	Low	Due to the very restricted range and small population size the species is vulnerable to stochastic events including drought.

Current management

- There is no national recovery plan for this species. Recovery actions are outlined in the conservation advice (Department of the Environment, Water, Heritage and the Arts 2008) and under the Saving our Species program (NSW DPIE 2020b).
- The species has been recorded in Bolivia Hill Nature Reserve.
- The distribution of this species overlaps with the White box-yellow box-Blakely's red gum grassy woodland and derived native grassland EPBC Act-listed ecological community.
- Intensive recovery actions have been undertaken by NSW DPIE staff with the support of private landholders. Individual wild plants were watered during dry periods, caged to protect against vertebrate herbivory, fertilised with foliar nutrients, released from understorey competition and protected from insect herbivory. Despite slowing decline, the plants continued to senesce.
- Material from six individuals has been successfully propagated at the Royal Botanic Gardens, the Australian National Botanic Gardens, and in private nurseries and gardens. Efforts to stimulate sprouting from the soil seedbank were made by spreading ash on trial plots, watering, removal of competition and soil disturbance. None were successful.
- The 2020 seedlings have been protected from grazing, and once old enough will provide cuttings for further *ex situ* propagation. A new seed crop is expected from these plants in winter 2021 (T Soderquist pers.comm. 2020).
- An *ex situ* subpopulation has been established with cuttings and seed. Translocations are planned with these individuals. Experiments to stimulate recruitment will also be undertaken (NSW DPIE 2020b).
- Seeds collected from the 1986 subpopulation have low viability but may still add some genetic diversity to the translocations.
- Trial plantings of individual cultivated plants using multiple techniques have been conducted in several 'wild-garden' scenarios where health and survival could be closely monitored. Results have been highly variable and do not yet indicate best practice (T Soderquist pers.comm. 2020).

Conservation objectives

- Protect and monitor single known extant subpopulation.
- Maintain and expand *ex situ* subpopulation.
- Detect more subpopulations through opportunistic surveys, e.g. while informed individuals are conducting other projects in potential habitat.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Determine the threats limiting survival and recruitment of the species in the wild through adaptive trials with translocated individuals.
- Translocate species to secure habitat and re-establish wild subpopulations via augmentation.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High
Population surveys	Monitor subpopulations to determine response to threats and management actions, especially survival of seedlings post-fire.	High
	Undertaken opportunistic surveys in historic locations and other suitable habitat to locate additional subpopulations, particularly after fire (the cost-benefit of another extensive targeted survey does not warrant searching for this enigmatic species alone).	Medium

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Implement translocation to secure habitat and use long-term trials to examine the ecology/threats of the species.	High
	Collect cuttings and seeds from 2020 seedlings to expand *ex situ* collection.	High
Extension and awareness	Raise awareness of the species with local stakeholders in attempts to locate additional subpopulations, especially after disturbance including fire or substantial rainfall.	High
Habitat protection	Protect habitat and any future subpopulations of the species in appropriate conservation agreements.	Medium
	Manage feral goats within these areas to improve habitat quality.	Medium

Experts consulted

Todd Soderquist.

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Pomaderris delicata N.G.Walsh & F.Coates [RHAMNACEAE]
Delicate pomaderris

Pomaderris delicata flowers and leaves (image: Neville Walsh).

Overview

Pomaderris delicata is an extremely rare species that has recently undergone a substantial decline due to roadworks. Despite recovery actions including translocations, and locating previously unrecorded individuals at one subpopulation, life history and threats to the species remain poorly-understood.

Conservation status

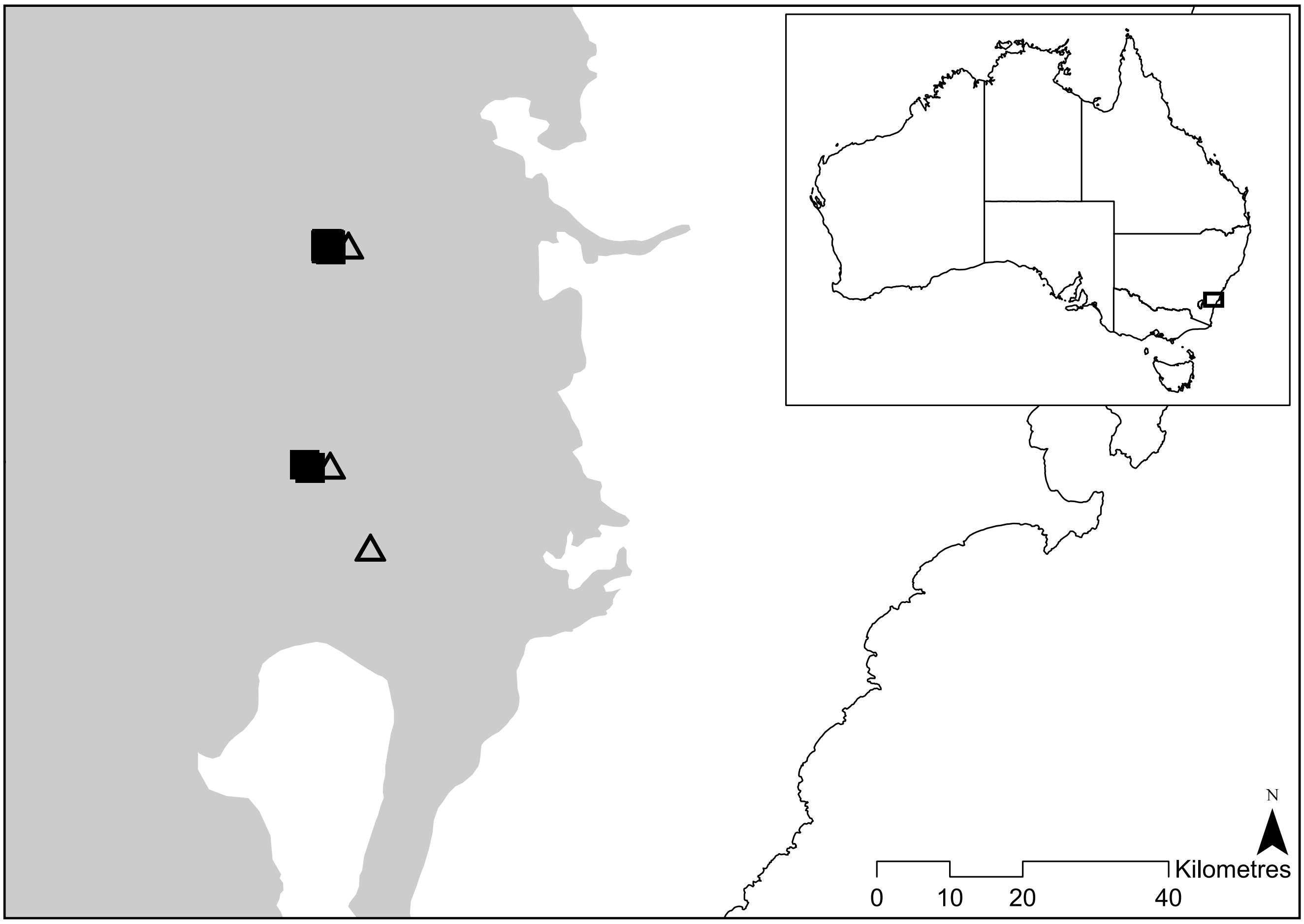
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Threatened Species Protection Act 1995	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Upright, perennial shrub to 2 m with hairy young stems that become glabrous by their second year (Walsh and Coates 1997). Leaves are elliptic, 13-30 mm long and 5-15 mm wide with entire margins. Inflorescence is terminal, 1.5-4 cm long and 2-5 cm wide, with 20->50 yellow, hairy flowers. The brown fruit are ellipsoid to obovoid, 2.5-3.5 mm long, with seeds to 2 mm. Before 1997, this species was considered as *P. andromedifolia*, which occurs nearby but has longer leaves that are always silky-pubescent on the abaxial surface and larger, more persistent stipules (Walsh and Coates 1997).

Distribution

Pomaderris delicata is known from a narrow range south-west of Goulburn in the South Eastern Highlands bioregion of New South Wales (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; New South Wales Department of Planning, Industry and Environment 2020a).



Current distribution (black squares) of *Pomaderris delicata* in the South Eastern Highlands bioregion (shaded grey) of New South Wales (AVH 2020; DAWE 2012; NSW DPIE 2020a). Three translocations have occurred but are not yet considered self-sustaining (hollow triangles), including an augmentation at both extant subpopulations, and one introduction (Silcock *et al.* 2019).

Population estimate and trends

Pomaderris delicata is currently known from two subpopulations >30 km apart with <150 mature individuals (NSW DPIE 2020a; Threatened Species Scientific Committee 2017). There were >215 plants in 2002, but this declined to 86 plants in 2016 (TSSC 2017). Sixty additional individuals were located at one subpopulation in 2017, increasing the 2019 census to 142 mature individuals. Long-term viability of either remaining site is not certain and no seed dispersal between patches is likely (TSSC 2017).

Both subpopulations have been augmented with propagated individuals since 2015, although survival has been variable and natural plants have continued to decline (Silcock *et al.* 2019). The species was introduced to Nadgigomar Nature Reserve in 2018 but all plants died within two months of planting despite favourable growing conditions (McDougall *et al.* 2018; Silcock *et al.* 2019). Two subsequent plantings were undertaken and 115 individuals were present in September 2019 (K McDougall pers.comm. 2020). Targeted surveys have been conducted since the species was first recorded in 1995, although additional subpopulations may exist and further survey is recommended (Walsh and Coates 1997).

Pomaderris delicata monitoring data, 2002-2016 (TSSC 2017; K McDougall unpublished data).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 (road reserve, private property and nature reserve)	2002: 200 2012: 74 2014: 19 2016: 19 2019: 76* (55T)	Decreasing
2 (road reserve, private property and Crown Land)	2002: >15 2007: road destroyed plants 2012: 30 2016: 67 2019: 66 (64T)	Decreasing

Translocated individuals/subpopulation (T). *Includes 60 additional plants found in 2017.

Habitat and ecology

Pomaderris delicata occurs on shallow, rocky soils derived from Silurian and Ordovician sandstones and siltstones (Walsh and Coates 1997). It grows amongst dry open forest dominated by *Eucalyptus sieberi*. Associated species include *E. macrorrhyncha, E. agglomerata, Allocasuarina littoralis* and other *Pomaderris* spp. The species occurs in sheltered situations but also on exposed roadsides (Walsh and Coates 1997). Mychorrhizal associations have not been recorded for *Pomaderris* spp. but may be important (McDougall *et al.* 2018).

Flowering is regular from September to October although seed-set is poor (Walsh and Coates 1997; McDougall *et al.* 2018). *Pomaderris delicata* is an obligate-seeder and mass recruitment can occur from the soil seedbank after disturbance. At both subpopulations, the cohorts are multi-aged (McDougall *et al.* 2018), indicating recruitment may also occur in the absence of disturbance. In spring 2019, seedlings were observed at Subpopulation 1 despite mature plants being absent for nearly a decade. This indicates the seedbank may persist for many years (K McDougall pers. comm. 2020) and therefore extreme fluctuations are unlikely (IUCN 2019). Plants may live for 15-50 years and generation length is estimated at 8-26 years (TSSC 2017).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	19 km^2 Stable	Medium High
Area of occupancy (actual) Trend	8 km^2 (1 km^2) Stable	Medium High
No. of mature individuals Trend	<100 Decreasing	Medium High
No. of locations (key threat) Trend	2 (infrastructure maintenance) Stable	Medium High
No. of subpopulations Trend	2 Stable	Medium High
Generation length	8-26 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(iii,v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented; continuing decline observed and projected in area, extent and quality of habitat, and number of mature individuals.
C1	CR: <250 mature individuals; and continuing decline of 25% in one generation observed.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing, primarily for agriculture, has resulted in the decline and fragmentation of available habitat for the species. The species is considered severely fragmented as both subpopulations are small, separated by >30 km and isolated on roadside reserves and private property.
Infrastructure maintenance *Ongoing*	Majority	Very rapid	High	Half of one subpopulation was destroyed during road construction in 2007. Although some recovery has occurred, both subpopulations occur on road/rail reserves and are vulnerable to maintenance activities including spray drift, slashing, drainage construction and weed incursion. The species occurs at two locations when assessed against this threat, which is managed at the subpopulation scale.
Browsing (native and feral) *Ongoing*	Majority	Rapid	Medium	The species is vulnerable to defoliation by macropods (especially swamp wallabies) and feral herbivores (deer). Some plants are now caged.
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	As an obligate-seeder, *P. delicata* requires appropriate fire intervals to reach reproductive maturity and contribute to the seedbank, and regenerate from seed following fire. Regeneration has occurred recently at one subpopulation. Disturbance and fire ecology are poorly-understood.
Stochastic events *Future*	Whole	Rapid	Medium	Due to the small population size and restricted distribution this species is vulnerable to stochastic events including repeated hot wildfires and prolonged droughts.
Climate change *Future*	Whole	Unknown	Unknown	Climatic drying may exacerbate stochastic events such as repeated wildfires and prolonged droughts.

Current management

- A national conservation advice has been developed (TSSC 2017). Recovery actions are being implemented at three management sites under the Saving our Species program including grazing protection, stakeholder liaison, translocation and ongoing monitoring (NSW DPIE 2020b).
- Part of one subpopulation occurs within Pomaderris Nature Reserve.
- Existing subpopulations have been augmented with translocated individuals since 2015, although survival has been variable. The species was translocated to Nadgigomar Nature Reserve in 2017, but all plants died rapidly, possibly due to an insecticide used in propagation (McDougall *et al.* 2018). Subsequent plantings have been more successful and future translocations will use plants propagated from seed, which may be more enduring (K McDougall pers.comm. 2020).
- Research has confirmed the species is not vulnerable to phytophthora (K McDougall pers.comm. 2020).
- A seed orchard has been established for future translocation efforts.

Conservation objectives

- Monitor and maintain known subpopulations.
- Detect more subpopulations through targeted surveys.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Maintain and expand *ex situ* subpopulations.
- Increase the number of mature individuals and subpopulations in the wild via translocations (introductions and ongoing augmentation).

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations.	High
	Monitor subpopulations (including translocated) to better understand threats and response to management actions.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate disturbance/fire regimes	Determine a suitable disturbance/fire regime for the species to increase the number of mature individuals.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known habitat of the species in appropriate conservation agreements.	High
Grazing	Exclude herbivores from known subpopulations by fencing and caging, especially after recruitment events.	High
Ex situ conservation/translocations	Maintain and expand *ex situ* subpopulations for ongoing translocation efforts.	High
Invasive weeds	Manage invasive weeds at known subpopulations and in potential habitat where translocations may occur.	Medium
Extension and awareness	Raise awareness of the species with appropriate stakeholders in attempts to locate additional subpopulations.	Medium

Experts consulted

Keith McDougall.

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Prasophyllum correctum D.L.Jones [ORCHIDACEAE]
Gaping leek-orchid


Prasophyllum correctum flowers (image: Jeff Jeanes, State Botanical Collection, Royal Botanic Gardens Victoria) and inflorescence (image: Marc Freestone).

Overview

Prasophyllum correctum is restricted to two small subpopulations along the Melbourne-Bairnsdale rail line. The majority of its grassy habitat has been cleared for agriculture and despite considerable research and recovery actions, both subpopulations are still declining with limited recruitment. This decline appears to be driven by competition with native grasses, while changing rainfall patterns may also contribute to lower emergence rates.

Conservation status

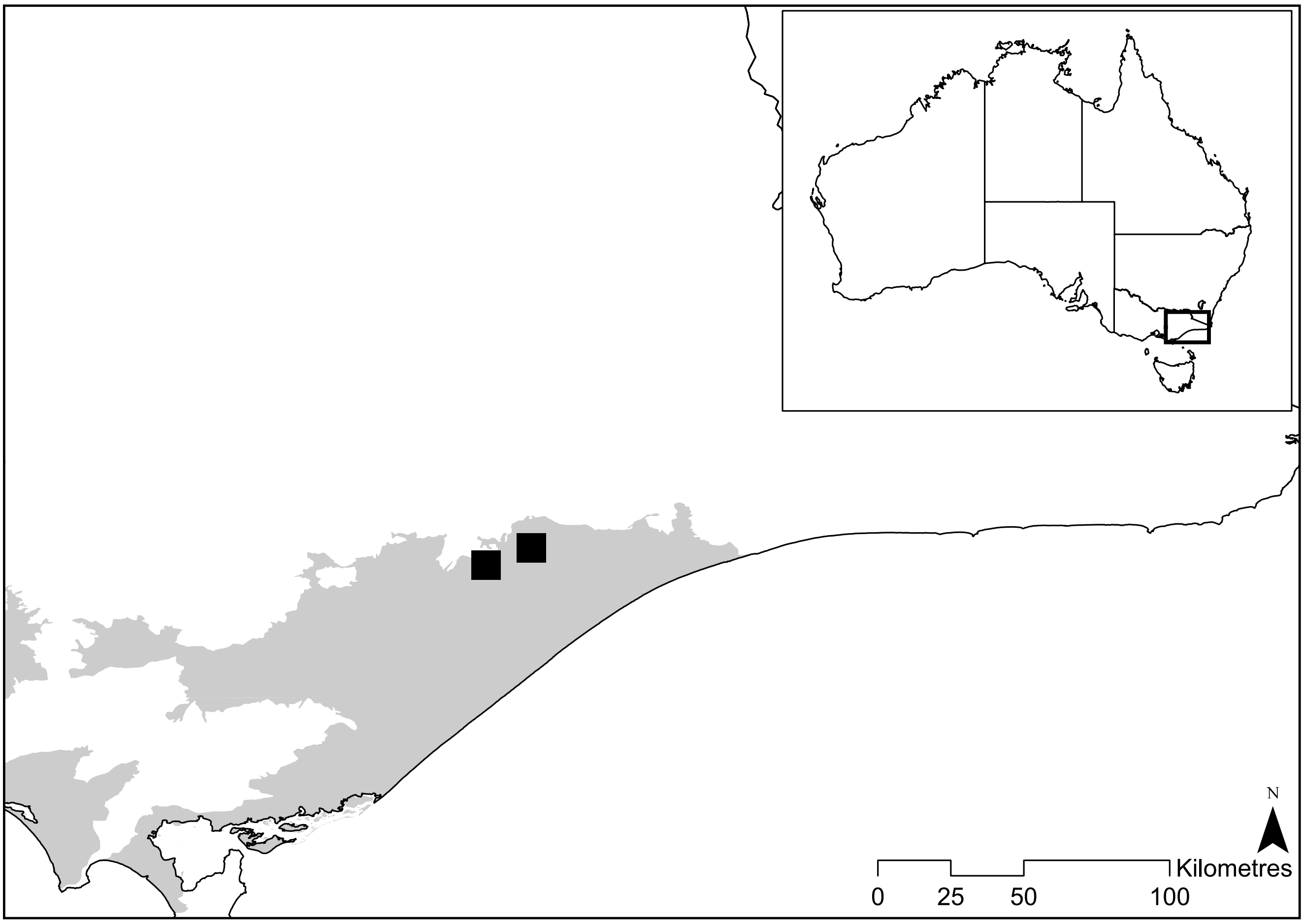
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare and Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Terrestrial orchid with a single, hollow, terete leaf 11-40 cm long and 0.5-4.5 mm wide (Jones 2003). Inflorescence is an erect, open spike to 47 cm of 5-27 yellow-green flowers (Jones 2003). Despite past taxonomic confusion with *P. chasmogamom* (Victoria) and *P. incorrectum* (Tasmania), *P. correctum* is now accepted to be endemic to Victoria (Kahout and Coates 2010). Morphologically similar plants have been reported at several sites on the volcanic plain west of Melbourne and further study is required to confirm their identity (Jeanes 2015).

Distribution

Prasophyllum correctum is known from a very restricted area near Bairnsdale in the South Eastern Coastal Plain bioregion of Victoria (Department of Agriculture, Water and the Environment 2012; Department of Environment, Land, Water and Planning 2020). Although it was probably more widespread prior to extensive land use change, there are no historical collections of the species (Australasian Virtual Herbarium 2020).



Current distribution (black squares) of *Prasophyllum correctum* in the South Eastern Coastal Plain bioregion (shaded grey) of Victoria (AVH 2020; DAWE 2012; DELWP 2020).

Population estimate and trends

Prasophyllum correctum is currently known from two subpopulations, and <15 mature individuals have been sighted in the last 9 years. Accurate population estimates are difficult as mature individuals can persist dormant underground, or resemble seedlings (Kahout and Coates 2010). At Munro Rail Reserve, 124 individuals have been marked, but only a subset will emerge and reproduce annually (Coates *et al.* 2006). Only two individuals were recorded in 2019 (N Reiter pers.comm. 2019).

Time-series monitoring indicates both subpopulations are declining. Targeted surveys have been conducted across the potential and known range of the species and additional subpopulations have not been located.

Prasophyllum correctum monitoring data, 1992-2019 (Kohout and Coates 2006; Coates *et al.* 2006; N Reiter pers. comm. 2019).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Munro (rail line easement)	1992: 54 1993: 2 1994: 25 1995: 29 1996: 4 1997: 28 1998: 37 1999: 6 2000: 12 2001: 6 2002: 0 2003: 2 2017: 10 2019: 0	Decreasing
2 Lindenow (rail line easement)	1992: 4 2010: <15 2017: 4 2018: 0 2019: 2	Declining

Habitat and ecology

Prasophyllum correctum occurs in well-drained sandy loams derived from alluvium, in grassland and grassy woodland dominated by *Themeda triandra*, *Poa clelandii* and *Eucalyptus tereticornis* (Kahout and Coates 2006). Common inter-tussock species include *Chrysocephalum apiculatus, Craspedia variabilis, Burchardia umbellata, Bulbine bulbosa, Leptorhynchos squamatus, Dichopogon strictus, Thysanotus patersonii, Caesia calliantha* and *Lomandra longifolia* (Kahout and Coates 2006). Associated shrubs include *Dillwynia cinerascens, Grevillea lanigera* and *Pimelea humilis* (Kahout and Coates 2006). *Prasophyllum correctum* occurs alongside other orchids including *Diuris punctata, D. chryseopsis, D. sulphurea, Microtis unifolia, Lyperanthus suaveolens* and *Thelymitra pauciflora* (Kahout and Coates 2006).

Plants are dormant during summer when they persist underground as tubers (Kahout and Coates 2006). Flowering occurs in spring, with seed maturing in late November to December (Kahout and Coates 2006). *Prasophyllum correctum* is a nectar rewarding orchid, although the specific pollinators are not known (Kahout and Coates 2006). Fruit set varies from 26-77% between years (Coates *et al.* 2006) and seed germination depends on the mycorrhizal fungi *Ceratobasidium* spp. (M Freestone pers.comm. 2020). The time to maturity and senescence is difficult to estimate and generation length is unknown (Coates *et al.* 2006).

Plants rarely emerge for more than two consecutive years and can remain dormant for up to 5 years, although 1-2 years is more typical (Coates *et al.* 2006). Extended periods of dormancy are associated with mortality (Coates *et al.* 2006). Flowering is positively associated with fire intervals of <3 years (Coates *et al.* 2006), although abundance has not increased despite implementation of this fire regime over the past decade (N Reiter pers.comm. 2019). The species is thought to respond to above average winter-autumn rains, with very few plants seen in years of below average rainfall (N Reiter pers.comm. 2019). However, Coates *et al.* (2006) found that total number of emergent plants was negatively correlated with winter-autumn rainfall in the previous year, possibly due to competition from grasses under wetter conditions.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	8 km^2 (0.37 km^2) Stable	High High
Area of occupancy (actual) Trend	8 km^2 (0.001 km^2) Decreasing	High High
No. of mature individuals Trend	<15 Decreasing	High High
No. of locations (key threat) Trend	2 (all threats) Stable	High High
No. of subpopulations Trend	2 Stable	High High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(iii,v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented; and continuing decline observed and projected in area/extent and quality of habitat and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture has resulted in the decline and severe fragmentation of available habitat for the species. Only small remnants of the species' previously extensive grassy habitat remain, and both subpopulations are small and isolated by cleared land.
Lack of recruitment *Ongoing*	Whole	Rapid	High	Subpopulations are small and declining in the absence of recruitment. The species requires bare ground to emerge and reproduce; and seed set can drop to 25% in some years (Kahout and Coates 2010).
Inappropriate disturbance regimes and competition *Ongoing*	Whole	Rapid	High	Flowering and emergence have been positively associated with short fire intervals (Coates *et al.* 2006). However, declines are ongoing despite implementation of high frequency fire regimes since 2006 (N Reiter pers.comm. 2019). The effect of fire regimes on long-term abundance is not well-understood, although long fire-free intervals can increase competition from native plants including shrubs and grasses (N Reiter pers.comm. 2019).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Herbivores (feral and native) *Ongoing*	Whole	Slow	Medium	The species is vulnerable to defoliation by rabbits, hares and eastern grey kangaroos that are abundant in the habitat, especially after fires. Digging by rabbits has modified the habitat and destroyed individual plants (Kahout and Coates 2010).
Invasive weeds *Ongoing*	Minority	Slow	Low	Weeds can increase competition and alter fuel loads (Coates *et al.* 2006) but are not a major threat at the Munro subpopulation and a moderate threat at the Lindenow subpopulation (N Reiter pers. comm. 2019).
Land management practices *Ongoing*	Whole	Unknown	Unknown	The species occurs in small remnants surrounded by agricultural land. Fertiliser and herbicide drift may favour invasive weeds and increase competition, causing further population declines (Kahout and Coates 2010).
Low genetic diversity *Future*	Whole	Rapid	Medium	The species has declined below levels required for self-sustaining subpopulations at both sites, thus is highly vulnerable to Allee effects (N Reiter pers. comm. 2019).
Illegal collection *Future*	Whole	Slow	Low	The species is vulnerable to illegal collection and trampling by orchid enthusiasts.
Infrastructure maintenance *Future*	Whole	Rapid	Medium	Both subpopulations occur in rail easements and are vulnerable to rail maintenance activities (Kahout and Coates 2006).
Climate change *Future*	Whole	Unknown	Unknown	Climatic change may increase dry periods and alter fire regimes with implications for population abundance (Coates *et al.* 2006); projected reductions in winter-autumn rainfall will lower emergence and reproduction (N Reiter pers.comm. 2019), but may also limit competition from native species (Coates *et al.* 2006).

Current management

- Recovery actions have been identified (Kahout and Coates 2010).
- Subpopulations are not protected from grazing impacts.
- Some weed management has been undertaken although invasive weeds remain a conservation concern at one subpopulation (N Reiter pers.comm. 2019).
- There is a small representation of seed stored for conservation at the Royal Botanic Gardens Victoria (N Reiter pers.comm. 2019).
- Neither subpopulation occurs in conservation estate; both occur on rail-line easements.
- Symbiotic propagation of this species, including research into seed viability, has been optimised at Royal Botanic Gardens Victoria and Australian National University (M Freestone pers.comm. 2020). There are currently about 100 *ex situ* plants in the RBGV nursery, but no funding available to undertake translocations at present.
- Extensive targeted surveys have not located additional subpopulations.

Conservation objectives

- Monitor and maintain known subpopulations.
- Increase number of individuals and subpopulations in secure tenure by establishing an intensive *ex situ* propagation program and translocation plan.
- Increase understanding of pollinator ecology and microsite preferences.
- Improve habitat quality by threat mitigation.

Information required

Theme	Specific actions	Priority
Taxonomy	Undertake genetic work to delineate *Prasophyllum* species, many of which are genetically similar and extremely rare (H Zimmer pers.comm. 2020).	High
Population surveys	Continue targeted surveys and monitoring to determine response of species to threats and management actions.	High
Pollination ecology	Undertake research to identify pollinating species and their distribution in potential translocation sites to increase probability that translocated subpopulations will produce viable seed.	High
Microsite preferences	Determine microsite preferences to inform management of extant subpopulations, site selection for translocation and management of habitat at translocated sites.	High
Ex situ conservation/translocations	Develop a translocation plan and identify potential sites for translocation into secure tenure.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, fire ecology, population demographics, pollination and habitat suitability for translocations.	High

Management actions required

Theme	Specific actions	Priority
Ex situ conservation/translocations	Implement intensive propagation program to establish a conservation collection representing maximum range of genetic diversity and supply individuals for translocation. Implement translocation plan.	High High
Habitat protection	Ensure habitat identified for translocation sites is protected in appropriate conservation agreements.	High
Supplementary watering	Trial supplementary watering program at both subpopulations to increase flowering, seed-set and survivorship, particularly during growth/ reproductive periods and when prevailing climatic conditions are dry.	High
Inappropriate fire regimes	Monitor impacts of fire regimes on population abundance. Maintain fire intervals of <3 years in early autumn to increase the number of mature individuals and reduce competition with native flora.	High High
Habitat quality	Manage invasive weeds in vicinity of extant subpopulations and identified translocation sites. Monitor impacts of herbivory (especially rabbits) and manage as necessary.	High High
Extension and awareness	Ensure relevant stakeholders (associated with railway reserve) are informed of the subpopulation locations and appropriate management.	High

Experts consulted

Noushka Reiter, Marc Freestone and Neville Walsh.

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Prasophyllum laxum R.J.Bates [ORCHIDACEAE] Lax leek-orchid

Prasophyllum laxum inflorescence at the type locality in 2018 (image: Shane Graves).

Overview

Prasophyllum laxum is currently known from a single subpopulation. Fewer than 10 individuals have been recorded in surveys since a severe wildfire in 2017. Two previously known subpopulations are presumed extinct, and declines are ongoing in the extant subpopulation due to drought and wildfire. The species only occurs on private property that is not managed for conservation, but the nature and severity of threats are not well-understood.

Conservation status

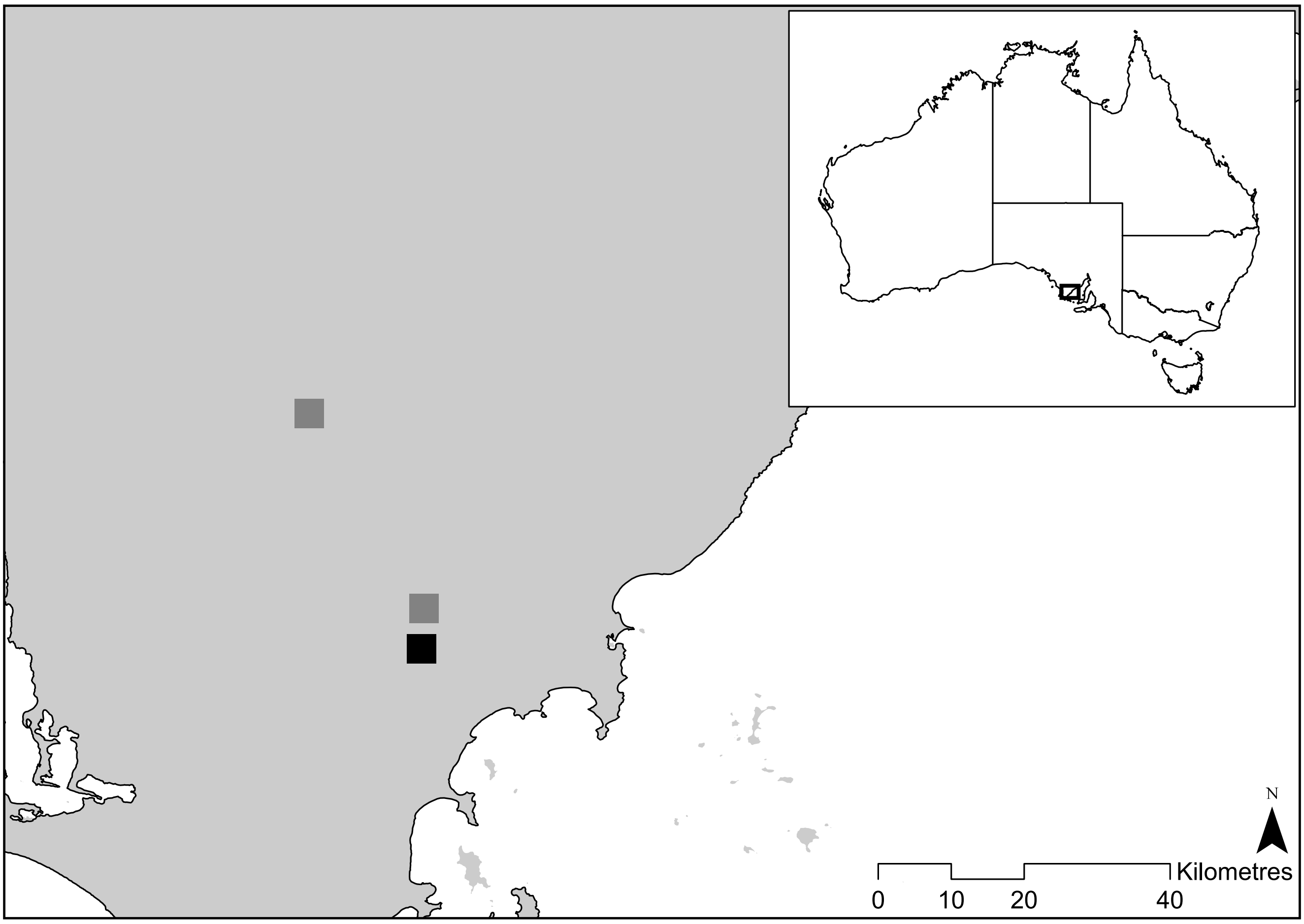
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
National Parks and Wildlife Act 1972	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Slender terrestrial orchid with a single leaf to 30 cm that tapers to a point (Bates 2008). Inflorescence of 5-20 strongly fragrant flowers to 7 mm wide are arranged in a loose, drooping spike to 6 cm long. Sepals are pale green, petals are linear with a brown stripe and the labellum is green to pink-brown with a distinct sigmoid bend. Fruit to 4 mm wide dehisce when mature. *Prasophyllum laxum* is distinguished by its 'lax' habit, pale colouring and sigmoid labellum. It co-occurs with the closely-related *P. fecnundum* and *P. goldsackii* without intermediates, indicating strong genetic isolation (Bates 2008).

Distribution

Prasophyllum laxum is known from a narrow range in the Koppio area within the Eyre York Block bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012). There is an unconfirmed record from Ungarra, ca. 20 km to the north-east.



Current (black square) and historic (grey squares) distribution of *Prasophyllum laxum* in the Eyre York Block bioregion (shaded grey) of South Australia (AVH 2020; DAWE 2012).

Population estimate and trends

Prasophyllum laxum is currently known from a single subpopulation of <50 mature individuals on private property. More than 500 plants were present here in 2004, but only three individuals were located after the Black Tuesday wildfire in 2017, declining again to seven individuals in 2018 (B Bates pers.comm. 2020). Subpopulations historically documented at Yeelanna (1913) and Hundred of Koppio (1966; AVH 2020) were presumed extinct by 2002 (Department of the Environment 2015). Given the species can persist dormant as a tuber and may be undetected in surveys, further searching is recommended (DE 2015).

Habitat and ecology

Prasophyllum laxum occurs under *Allocasuarina verticillata* amongst an isolated hill of laterite and quartz (DE 2015). The species occurs on relatively fertile red-brown loamy soils and is absent from nearby calcrete or poor soils (DE 2015). Associated species include *Eucalyptus cladocalyx* and other *Prasophyllum* spp (DE 2015).

The ecology of *P. laxum* is poorly-documented. Flowering occurs between September and October and independent of fire (DE 2015). As with other *Prasophyllum* spp., the pollination mechanism may be sexual deception (Coates *et al.* 2006). Seed are probably wind-dispersed (DE 2015) and germination may depend on mycorrhizal fungi (Coates *et al.* 2006). For other *Prasophyllum* spp., dormancy occurs annually and may be extended depending on environmental conditions (Coates *et al.* 2006). Reproductive maturity for closely related taxa is thought to be 3-5 years with species living 10-20 years (DE 2015). Generation length for *P. laxum* is therefore estimated at 10 years (DE 2015).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (<0.01 km^2) Decreasing	Medium High
Area of occupancy (actual) Trend	4 km^2 (<0.01 km^2) Decreasing	Medium High
No. of mature individuals Trend	<50 Decreasing	Medium High
No. of locations (key threat) Trend	1 (all threats) Stable	Medum High
No. of subpopulations Trend	1 Stable	Medium High
Generation length	10 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed in EOO, AOO, quality of habitat, number of locations/subpopulations and number of mature individuals.
C2a(ii)	CR: <250 mature individuals; continuing decline observed; 100% of mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Land clearing for agriculture has resulted in the decline and fragmentation of available habitat for the species. The species is considered severely fragmented as the only extant subpopulation is very small, and isolated by cleared land.
Invasive weeds *Ongoing*	Whole	Unknown	Unknown	The single subpopulation occurs on private property where invasive weeds are present (DE 2015). Invasive weeds increase competition and alter fuel loads and thus fire regimes, but the specific impacts are unknown.
Grazing/ vertebrate pests *Ongoing*	Whole	Unknown	Unknown	The single subpopulation occurs on grazed land where soil crusts are being degraded by hard-hooved domestic stock. Rabbits are also contributing to grazing pressure (DE 2015). Impacts of grazing on population dynamics are not documented.
Wildfires *Future*	Whole	Unknown	Unknown	Only three individuals were relocated following the Black Tuesday wildfires in 2017, with eight plants emerging in 2018 (B Bates pers.comm. 2020). The fire ecology of *P. laxum* is poorly-understood, and population recovery or decline may occur in the future.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Mining *Future*	Whole	Unknown	Unknown	Mining activity has been proposed in the habitat of this species.

Current management

- Recovery actions have been identified (DE 2015).
- The species only occurs on private property and is not protected in conservation estate.

Conservation objectives

- Monitor and maintain extant subpopulation by implementing recovery actions.
- Increase understanding of the species biology and ecology.
- Protect historic and current habitat in appropriate conservation agreements.
- Establish *ex situ* subpopulations of the orchid and its mychorrizal fungi.
- Increase the number of individuals and subpopulations in the wild by improving habitat quality and undertaking translocations (if feasible).

Information required

Theme	Specific actions	Priority
Population surveys	Undertake targeted surveys in historic locations and other suitable habitat to locate additional subpopulations.	High
	Monitor population to better understand threats and response to management actions.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements, mychorrizal fungi associations, disturbance ecology and habitat suitability for translocations.	High
Ex situ conservation/translocations	Undertake research to inform *ex situ* conservation and potential for translocations.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known habitat in appropriate conservation agreements, especially to ensure extant subpopulation is secure from future mining threat.	High
Ex situ conservation/translocations	Establish *ex situ* conservation collection representing maximum range of genetic diversity possible to reduce extinction risk. If feasible, collect and store seed for conservation.	High
Grazing/vertebrate pests	Exclude grazing stock from the known subpopulation and potential habitat by fencing. Control rabbit populations and/or cage individuals to protect from defoliation.	High
Invasive weeds	Manage invasive weeds to reduce competition and improve habitat quality.	High
Inappropriate fire regimes	Establish fire breaks around known subpopulation to reduce risk of future wildfires. Implement appropriate fire regime to increase habitat quality and the population abundance of *P. laxum*.	High
Extension and awareness	Raise awareness of the species with local conservation groups and stakeholders in an attempt to locate additional subpopulations.	Medium

Experts consulted

Bob Bates, Greg Kerr, Doug Bickerton, Tim Jury and Angela Duffy.

References

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Prasophyllum tunbridgense D.L.Jones [ORCHIDACEAE]
Tunbridge leek-orchid


Prasophyllum tunbridgense habitat at Tunbridge Lagoon in Tasmania (left) and inflorescence (right; images: Mark Wapstra).

Overview

Prasophyllum tunbridgense is restricted to small, degraded remnants within the agricultural region of the Tasmanian Midlands. It is only known from one or two plants at most subpopulations, and has not been located at three of these for over 20 years. Population trends are difficult to discern due to limited monitoring and seasonal fluctuations, but ongoing declines are projected due to land clearing and poor habitat quality, with limited funding available for recovery efforts.

Conservation status

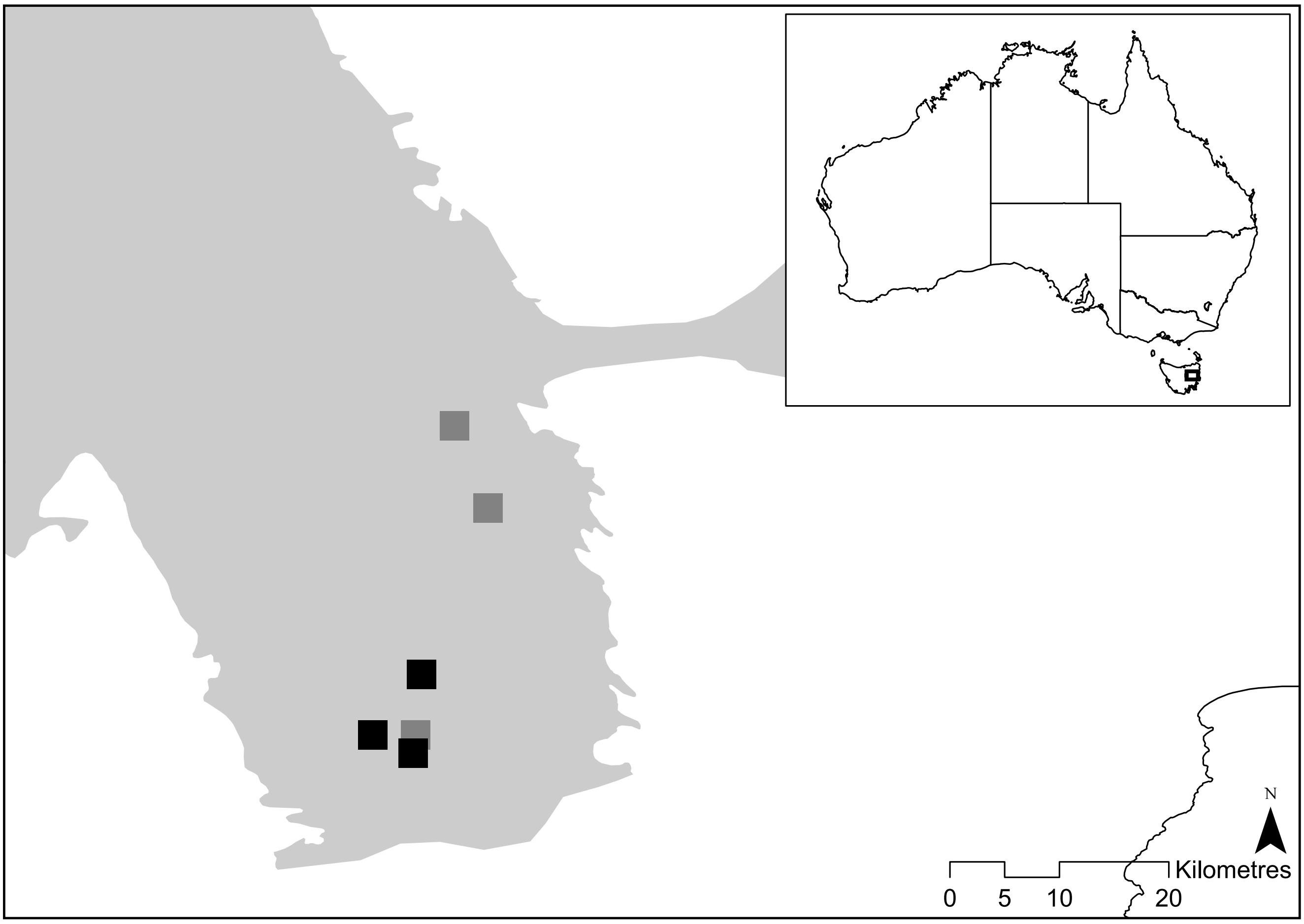
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Threatened Species Act 1995	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Deciduous, terrestrial orchid to 50 cm tall with a single bright green leaf 10-15 cm long with a red-purple base (Jones 1998). Inflorescence a spike 6-15 cm long of 10-25 fragrant flowers with prominent white petals 16-20 mm long and 17-25 mm wide (Jones 1998). The labellum has intensely crinkled margins (Jones 1998). *Prasophyllum tunbridgense* is part of the *Prasophyllum patens/truncatum* complex and could be confused with *P. milfordense* and *P. truncatum*, but is distinguished by its larger, more closely-spaced flowers, longer and wider petals with flared upper margins, and a less sharply recurved labellum (Threatened Species Section 2010).

Distribution

Prasophyllum tunbridgense is only known from the Tunbridge-Campbell Town area in the Tasmanian Northern Midlands bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Primary Industries, Parks, Water and Environment 2020).



Current distribution of *Prasophyllum tunbridgense* in the Tasmanian Northern Midlands bioregion (shaded grey) of Tasmania, including subpopulations known to be extant (black squares) and those not seen for >19 years (grey squares) that are possibly extinct (AVH 2020; DAWE 2012; DPIPWE 2020).

Population estimate and trends

Prasophyllum tunbridgense is currently known from <50 mature individuals in three subpopulations, 95% of which occur at Township Lagoon. The population has declined from <140 individuals in 2010. Regular monitoring only occurs at one subpopulation (Township Lagoon) and indicates an apparent decline (TSS 2010; Threatened Species Scientific Committee 2016). However, longer-term monitoring is required as the species can persist dormant underground, especially during dry conditions (M Wapstra pers.comm. 2020). Subpopulations may also still occur at three additional sites where it has not been detected for 31 years (Tunbridge cutting), 23 years (Campbell Town north) and 19 years (Campbell Town Golf Course; A Crane pers.comm. 2019). The habitat remains suitable at Campbell Town (north) and the species may emerge after sufficient rainfall (M Wapstra pers.comm. 2019).

Potential habitat (remnant native grassland) is widespread but severely fragmented, and almost wholly restricted to private land (M Wapstra pers.comm. 2019). Few targeted surveys have occurred, particularly on private land during the four-week flowering period (M Wapstra pers.comm. 2019). Additional subpopulations probably exist, but are almost certainly small and in degraded grazing paddocks (M Wapstra pers.comm. 2019).

Prasophyllum tunbridgense monitoring data, 1988-2018 (DPIPWE 2020; TSS 2010; TSSC 2016; A Crane, M Waptstra pers.comm. 2019)

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Township Lagoon (nature reserve and private property)	1999: 85 2007: 14 2008: 10 2009: 4 2011: 30 2018: 29	Decreasing
2 Tunbridge Tier Road (private property)	1995: 1 2001: 1	Unknown
3 Tunbridge cutting (road reserve)	1988: present 2017: 0	Possibly extinct (not detected for 31 years)
4 Tunbridge north, Wetmore (private property with conservation covenant)	1999: 45 2007: 9 2017: 2	Decreasing
5 Campbell Town Golf Course (private property with conservation covenant)	2000: 2 2017: 0	Possibly extinct (only 1-2 plants detected, and not for 19 years)

Habitat and ecology

Prasophyllum tunbridgense occurs on well-drained basaltic loams in native grassland dominated by *Themeda triandra* and *Austrostipa* spp. (TSS 2010). The species occurs in one of the driest regions of Tasmania, with 500 mm annual rainfall (TSS 2010). Several associated species are also threatened including *Dianella amoena, Leucochrysum albicans* subsp. *tricolor, Pterostylis commutata, Pultenaea prostrata, Stackhousia subterranea, Scleranthus diander, Scleranthus fasciculatus, Velleia paradoxa* and *Vittadinia* spp. (TSS 2010).

Flowering occurs in October-November, and in the absence of fire (Jones *et al.* 1999). Insects including native bees, wasps and beetles feed on the nectar and pollinate the flowers (TSS 2010). Plants persist as a dormant tuber over summer, emerging in early winter (TSS 2010). The length of time plants can persist in a dormant state is not known, but could be many years.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	65 km^2 Decreasing	Medium Medium
Area of occupancy (actual) Trend	16 km^2 (<0.02 km^2) Decreasing	Medium Medium
No. of mature individuals Trend	<50 Decreasing	Medium Medium
No. of locations (key threat) Trend	6 (3 known to be extant) (all threats) Decreasing	Medium Medum
No. of subpopulations Trend	6 (3 known to be extant) Decreasing	Medium Medium
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Inferred and projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented; and continuing decline inferred and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(i,ii)	CR: <250 mature individuals; continuing decline projected; <50 mature individuals in each subpopulation; and 90-100% (95%) of mature individuals in 1 subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and Ongoing*	Majority	Very rapid	High	Land-use change, primarily conversion of grassland to pasture, has resulted in the decline and fragmentation of available habitat. The species is now severely fragmented and extremely vulnerable to any localised activities or impacts. Small remnant patches have typically been left along fence lines, paddock corners and on rises within paddocks and these are now being actively cleared under irrigation schemes, often without threatened flora assessments (M Wapstra pers.comm. 2019),
Grazing (domestic stock) *Ongoing*	Minority	Rapid	Medium	*Prasophyllum tunbridgense* is vulnerable to grazing by domestic stock, especially sheep. Defoliation of flowering parts and leaves has been observed, and may be responsible for declines at sites on private land (TSSC 2016)
Invasive weeds *Ongoing*	Majority	Slow	Medium	Invasive weeds are present in the habitat of *P. tunbridgense*. Invasive weeds increase competition and alter fuel loads and thus fire regimes (TSS 2017).
Inappropriate fire regimes *Ongoing (?)*	Unknown	Unknown	Unknown	Fire is an important driver of abundance for many ground orchids (TSS 2017). *Prasophyllum tunbridgense* can flower in the absence of fire (TSSC 2016), but the impact of fire on long-term population trends is not well-understood (TSS 2017).
Altered hydrology *Future*	Majority	Unknown	Unknown	Irrigation is increasing within the habitat of *P. tunbridgense*, which occurs within one of the driest regions of Tasmania (M Wapstra pers.comm. 2019). Irrigation alters watertables and may impact the ecology of remnant habitat for this species.
Infrastructure maintenance *Future*	Minority	Rapid	Low	Two subpopulations occur on roadsides and are vulnerable to maintenance activities. The subpopulations are managed by the Department of State Growth, although plants have been absent at these sites for a number of years.
Climate change *Future*	Whole	Unknown	Unknown	The species has not been detected at three sites for >19 years, although it may persist as an underground tuber until favourable conditions for reproduction occur. It is not known how long this species can persist in a dormant state, and projected climatic changes may exacerbate declines (Grose *et al.* 2015).

Current management

- There is a recovery plan (Threatened Species Section 2017), Listing Statement (TSS 2010) and conservation advice (Threatened Species Scientific Committee 2016) for this species. The recovery plan clearly outlines required recovery actions and costs for conservation activities over the next 10 years, although remains unfunded.
- One subpopulation is partially protected in Township Lagoon Nature Reserve, while two subpopulations occur on land under conservation covenants (TSS 2017).
- No translocations have been undertaken although seed has been collected (TSS 2017).

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Establish *ex situ* subpopulation to spread extinction risk and supply plants for translocation if feasible.
- Increase the number of mature individuals and subpopulations in the wild.

Information required

Theme	Specific actions	Priority
Population surveys	Conduct targeted surveys in historic locations and other suitable habitat to locate additional subpopulations.	High
	Monitor subpopulations to determine trends in response to management actions and threats. Given seasonal fluctuations, time-series monitoring for a period of >50 years is probably required to accurately capture population trends (M Wapstra pers.comm. 2019).	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including mycorrhizal associations, disturbance requirements, impact of drought and habitat suitability for translocations.	High
Ex situ conservation/translocations	Investigate the viability of translocation for the species including seed germination and propagation trials. Identify areas of suitable habitat on secure tenure for translocation.	High
Inappropriate fire regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect habitat in conservation agreements. Fence known subpopulations and high value habitat to protect from grazing impacts.	High High
Invasive weeds	Continue to control invasive weeds within known subpopulations and in other high value habitat.	High
Ex situ conservation/translocations	Collect and store seed and mycorrhiza for long-term storage at the Tasmanian Seedbank Conservation Centre.	High
	Establish an *ex situ* population representing maximum range of genetic diversity in preparation for future translocations to secure tenure, and/or to augment wild subpopulations.	High
Inappropriate fire regimes	Implement suitable fire regime to habitat with extant and historic subpopulations.	High

Experts consulted

Nigel Swarts, Oberon Carter, Mark Wapstra and Andrew Crane.

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Pultenaea sp. Genowlan Point (NSW 417813) [FABACEAE]
Genowlan pultenaea

Pultenaea sp. Genowlan Point leaves and flowers (top left), plant in full flower (bottom left) and cliff habitat (right; images: David Coote).

Overview

Pultenaea sp. Genowlan Point is an undescribed species related to *P. glabra* that was first recorded in 1997. The single cliff-top population has declined dramatically due to herbivore grazing, recreational impacts and prolonged dry conditions. Abundance has increased from eight to 40 mature individuals due to fencing, although recruitment remains low. The population is also vulnerable to cliff fall associated with nearby mining activity.

Conservation status

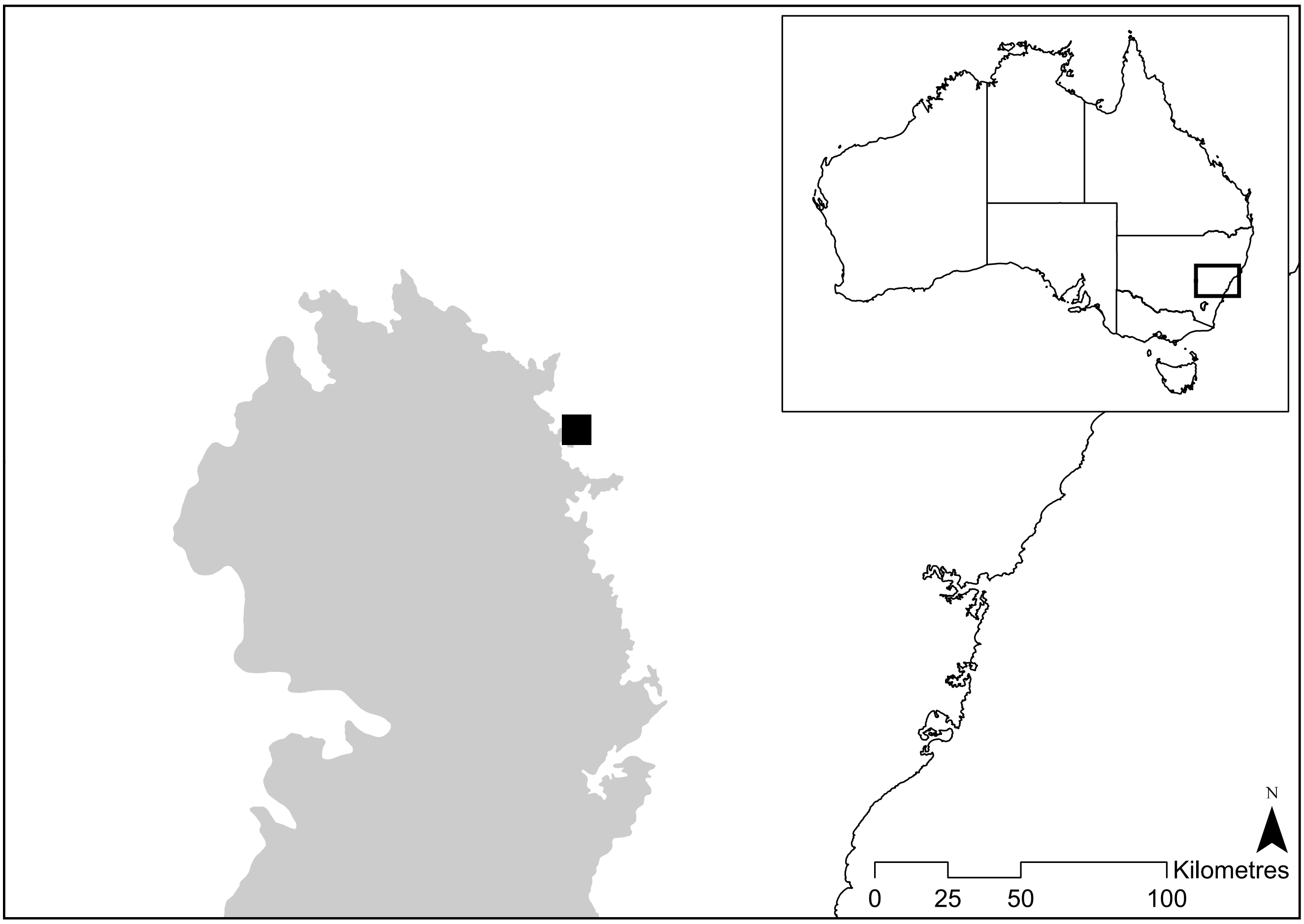
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Biodiversity Conservation Act 2016	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect shrub to 0.5 m tall with smooth stems and alternate, narrow-obovate leaves 1-2 cm long and 1-2 mm wide (Raffan and Goeth 2010). Stipules occur at the leaf bases and the leaves have pointed tips and incurved margins. Inflorescence is terminal and grows into a leafy shoot with yellow flowers that subtend the leaves. Fruit is a turgid pod to 5 mm long. It is part of the *P. glabra* complex, which is subject to ongoing research, but differs from *P. glabra* in its smaller height, deep red keel petal, and flowers that terminate in a leafy bud (Raffan and Goeth 2010).

Distribution

Pultenaea sp. Genowlan Point is known only from the Genowlan Mountain mesa in the Mugii Murum-ban State Conservation Area north of Lithgow, in the South Eastern Highlands bioregion of New South Wales (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; New South Wales Department of Planning, Industry and Environment 2020a). The species is not considered severely fragmented as it occurs in contiguous remnant habitat where dispersal can readily occur (IUCN 2019).



Current distribution (black square) of *Pultenaea* sp. Genowlan Point in the South Eastern Highlands bioregion (shaded grey) in New South Wales (AVH 2020; DAWE 2012; NSW DPIE 2020a).

Population estimate and trends

Only six individuals of *Pultenaea* sp. Genowlan Point were recorded when it was first located, however further searching in 1999 revealed 62 plants (Raffan and Goeth 2010). Annual surveys from 2002 to 2010 demonstrate the population declined from 84 to 15 mature individuals (Raffan and Goeth 2010). A slow recovery has been observed since a fence was installed in 2013, with 32 plants observed in 2014, increasing again to 40 mature individuals in 2019 (D Coote pers. comm. 2019). This slow recovery is possibly due to drought conditions, and further declines due to low recruitment are predicted regardless of fencing (D Coote pers.comm. 2019). Overall, a population reduction of >50% has been observed within 17 years, due to a combination of threats that simultaneously affect all individuals (one location). Targeted surveys have been conducted across the range of the species and it is unlikely additional subpopulations exist.

Habitat and ecology

Pultenaea sp. Genowlan Point occurs on well-drained, shallow and stony soils adjacent to a cliff edge amongst sparse montane heath (Raffan and Goeth 2010). It is associated with open *Eucalyptus sparsifolia* forest with a shrubby understorey of *Acacia obtusifolia, Astrotricha obovata, Callitris rhomboidea, Calytrix tetragona, Comesperma ericinum, Entolasia stricta, Hibbertia obtusifolia, Isopogon dawsonii, Lepidosperma urophorum, Leptospermum trinervium, L. polygalifolium, Leucopogon muticus, Monotoca scoparia, Persoonia longifolia, Philotheca myoporoides, Platysace lanceolata, Pseudanthus divaricatissimus, Xanthorrhoea johnsonii, Xanthosia pilosa* and *Zieria laevigata* (Raffan and Goeth 2010).

In the past, the ecology of *Pultenaea* sp. Genowlan Point has been inferred from closely-related species (Raffan and Goeth 2010). Current knowledge indicates the species is killed by fire, which also stimulates germination of soil-stored seed. Germination can also occur in the absence of fire (D Coote pers.comm. 2019). Further research is required to determine whether this is due to degradation of the hard seed coat over time, scarification of the seed coat or an ant-related mechanism (D Coote pers.comm. 2019). Some evidence indicates the species can also regenerate from subterranean structures after browsing (D Coote pers.comm. 2019).

Flowering occurs from August to November with fruiting until January. Flowers are likely insect pollinated and seeds are dispersed by ants. Longevity is likely to be >20 years, while the shortest juvenile period observed is four years (D Coote pers.comm. 2019). Generation length is estimated at 8 years.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.0015 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.0015 km^2) Decreasing	High High
No. of mature individuals Trend	40 Decreasing	Low High
No. locations (key threat) Trend	1 (all threats) Stable	High High
No. of subpopulations Trend	1 Stable	High High
Generation length	8 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	No	Medium
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	EN: >50% reduction observed within 3 generations (52.4% from 2002-2019); causes may not have ceased, are not well-understood and may not be reversible; based on direct observation.
B1+2ab(i-iii,v)	CR: EOO <100 km^2; AOO <10 km^2; 1 location; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Grazing *Suspended*	Majority	Rapid	Medium	In 2003, 41% of plants were defoliated by goats, and this was exacerbated with ongoing dry years in 2004 and 2005 (Raffan and Goeth 2010). Vertebrate herbivores have been successfully excluded with fencing since 2013, although breaches do occasionally occur (D Coote pers.comm. 2020).
Recreational activities *Suspended*	Majority	Rapid	Medium	Vehicle and foot traffic have damaged individuals (Raffan and Goeth 2010). In addition to exclusion fencing, mesh cages were installed around the most vulnerable individuals but recovery has been slow. Vehicle access has been stopped via progressive iterations of barrier fencing. The potential for accidental or deliberate damage to individuals remains, although evidence of this has not been observed since 2012 (D Coote pers.comm. 2019).
Inappropriate fire regimes *Ongoing*	Whole	Rapid	High	*Pultenaea* sp. Genowlan Point is probably fire sensitive and recruits from soil-stored seed after fire. Appropriately-timed fire is required for the species to reach reproductive maturity and contribute to the seedbank, and regenerate from seed following fire (Raffan and Goeth 2010). Currently, the absence of fire may be limiting recruitment as mature individuals senesce.
Extractive industry *Future*	Whole	Very rapid	Medium	An extension of mine operations by Centennial Coal under the Genowlan-Airly Mesa has been approved, which is likely to increase the risk of cliff falls in the area. Any level of cliff fall, even natural rates, threaten the population.
Stochastic events *Future*	Whole	Rapid	Medium	Due to the small population size and restricted distribution this species is vulnerable to stochastic events including cliff fall and drought, which is associated with reduced seed-set, mortality, borer infestations and beetle attack (Raffan and Goeth 2011).
Climate change *Future*	Whole	Slow	Low	Climatic drying may increase the impacts of stochastic events such as prolonged droughts or inappropriate fire regimes (Raffan and Goeth 2011).
Introduced pathogens *Future*	Whole	Unknown	Unknown	Phytophthora has not been recorded in the area and the susceptibility of the species is unknown, but infection is considered a potential threat (NSW DPIE 2020b).

Current management

- Recovery actions have been identified (Raffan and Goeth 2010; Threatened Species Scientific Committee 2004). Conservation actions have been prioritised under the New South Wales Saving our Species program (NSW DPIE 2020b) and these are being implemented; rain has interrupted plan burn trials on multiple occasions (D Coote pers.comm. 2019).
- Taxonomic research is being undertaken by Matt Renner (Royal Botanic Gardens Victoria) to better understand the *P. glabra* complex, including *P.* sp. Genowlan, *P. olinda* and *P.* sp. Wolgan Cliffs (D Coote pers.comm. 2019).
- Since 2011, the species has been protected in the Mugii Murum-ban State Conservation Area.

- In 2013, the population was fenced and larger individuals were caged to reduce impacts of herbivores and human foot traffic. Abundance initially increased and stabilised thereafter, without marked recovery. Cages are being upgraded under the Saving our Species strategy (NSW DPIE 2020b). Vehicle tracks have been progressively closed to prevent disturbance (D Coote pers.comm. 2019).
- As of 2019, the Australian Botanic Gardens (Mount Annan) hold ~2500 seeds following collections since 2012. An attempt to establish an *ex situ* subpopulation failed in 2009 (Raffan and Goeth 2010), but future translocations are planned (NSW DPIE 2020b).

Conservation objectives

- Monitor and maintain known subpopulation.
- Improve habitat quality of known subpopulation.
- Establish a sufficient *ex situ* insurance seed collection and determine potential sites for translocations on secure tenure.
- Increase the number of mature individuals and subpopulations in the wild via translocation.

Information required

Theme	Specific actions	Priority
Taxonomy	Formally describe the taxa to consolidate knowledge on the species.	High
Population monitoring	Continue monitoring to better understand population demographics and threat impacts and response to recovery actions.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Undertake research to better understand the fire ecology and seed biology of the species. Determine a suitable fire regime for the species to increase the number of mature individuals.	High
Ex situ conservation/translocations	Determine recipient sites for translocations on secure tenure.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Maintain fencing and track closures to protect population.	High
Inappropriate fire regimes	Determine and implement an appropriate fire regime to increase the population abundance in the long-term.	High
Ex situ conservation/translocations	Continue and expand *ex situ* seed collection to represent maximum range of genetic diversity possible. Ensure seed collection is sufficiently abundant for future translocations. Undertake surveys of potential recipient sites, followed by translocation to suitable sites to mitigate extinction risk.	High
Herbivory	Maintain and enhance measures (fencing/caging/culling) to exclude vertebrate browsers, especially goats, from population.	High
Introduced pathogens	Monitor for signs of phytophthora infection, and manage disease hygiene at site.	High

Experts consulted

David Coote.

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Rhodamnia maideniana C.T.WHITE [MYRTACEAE]
Smooth scrub turpentine


Healthy *Rhodamnia maideniana* flowers (left; image: Glenn Leiper) and new foliage infected with myrtle rust (right; image: Geoff Pegg).

Overview

Rhodamnia maideniana has declined rapidly since the invasion of myrtle rust *Austropuccinia psidii* in 2010, which now occurs throughout its distribution. The species is on a rapid extinction trajectory as the pathogen kills flowers, fruit and seeds, thereby limiting the capacity of the species to reproduce. *Rhodamnia maideniana* requires urgent germplasm collection to conserve genetic diversity, facilitate research and support future reintroductions.

Conservation status

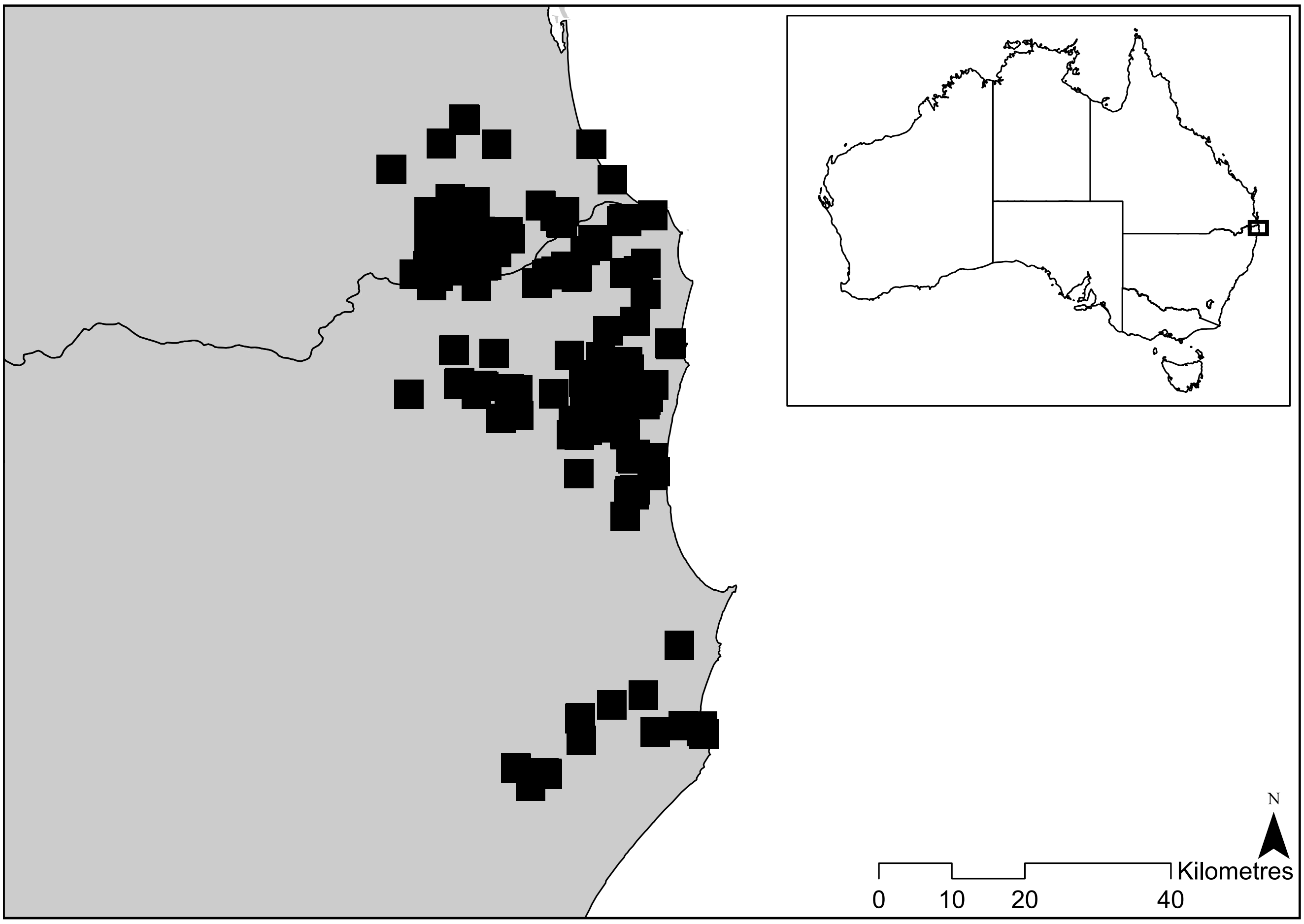
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992 (Qld)	Critically Endangered
Biodiversity Conservation Act 2016 (NSW)	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect shrub or tree to 5 m with smooth-flaky brown bark (Snow 2007). Leaves are elliptic to ovate, with a cuneate base and acuminate apex, 40-85 mm long and 13-42 mm wide (Snow 2007). Lamina is concolorous to slightly discolorous, glabrous above and sometimes hairy below along the midrib, with sparse to abundant oil glands (Snow 2007). Lateral primary veins are generally located <3 mm from the edge of the leaf margin at the midpoint of the lamina. Inflorescence of 1-3 pink-white flowers occur solitary or in pairs, and may be axillary or terminal. Fruit is a globose, hairless, purple-black berry 6.5-8.5 mm long and 6-8 mm wide, with 2-13 yellow-brown seeds 3-5 mm long (Snow 2007). *Rhodamnia maideniana* is similar to *R. glabrescens* and *R. arenaria*, but the latter two species have primary lateral veins that are usually >3 mm from the edge of the leaf margin at the midpoint of the lamina (compared with <3 mm as in *R. maideniana*). These three species also have distinct geographic ranges (Snow 2007).

Distribution

Rhodamnia maideniana occurs in sub-coastal rainforest from the Springbrook area in Queensland to Ballina in New South Wales, within the South Eastern Queensland bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Fensham *et al.* 2020; New South Wales Department of Planning, Industry and Environment 2020; Queensland Herbarium 2020a,b). *Rhodamnia maideniana* is severely fragmented as all occurrences comprise a small number of trees, while establishment and survival after any recolonisation event is hindered by myrtle rust (IUCN 2019).



Distribution of *Rhodamnia maideniana* (black squares) in the South Eastern Queensland bioregion (shaded grey) of Queensland and New South Wales (AVH 2020; DAWE 2012; Fensham *et al.* 2020; NSW DPIE 2020; QH 2020a,b). As myrtle rust occurs throughout the range of the species (Makinson 2018), the species is now absent or very unhealthy at many of these sites.

Population estimate and trends

Rhodamnia maideniana was once 'very common' in the understorey of regrowth rainforest (QH 2020; L Weber pers. comm. 2020). It remained common throughout the Tallebudgera Valley during field surveys in 2014, but has since declined rapidly due to myrtle rust (Pegg *et al.* 2017). The largest subpopulation is estimated as ca. 150 individuals in Springbrook National Park (J Radford-Smith pers.comm. 2020). The number of 'mature individuals' (IUCN 2019) is inferred to be <250 (and <50 for each subpopulation) due to reproductive suppression by myrtle rust. *Rhodamnia maideniana* reproduces sexually, and myrtle rust has caused a reduction in the abundance and density of parent plants and thus outcrossing probability, reduced flowering rates due to shoot death and flower bud infection, and reduced seed-set due to plant stress and direct infection of fruits (B Makinson pers.comm. 2020).

Habitat and ecology

Rhodamnia maideniana occurs on slopes and in gullies at 40-900 m altitude, amongst subtropical rainforest on soils derived from basalt and other volcanics, including red-brown loams and clay loams (Snow 2007). The species is a common component of rainforest understorey (Pegg *et al.* 2017), but is also found growing in disturbed fragments, along edges of simple to complex notophyll vineforest (AVH 2020). Associated species include *Davidsonia* sp., *Alphitonia petriei, Planchonella australis, Elattostachys nervosa, Endiandra globosa, Stenocarpus sinuatus, Archidendron muellerianum, Syzygium smithii* and *Elaeocarpus obovatus* (AVH 2020).

The ecology of *R. maideniana* is not well-documented. Flowering occurs from November to March, with fruiting throughout the year (Snow 2007). Like other rainforest Myrtaceae, the flowers are presumably pollinated by insects including Hymenoptera, Coleoptera and flies of the suborder Brachycera, while the fleshy fruits are predominantly dispersed by fauna including birds (Williams and Adam 2012). It is likely the species becomes reproductively mature at 4-5 years under ideal conditions, and may live for at least 50 years (P Forster pers.comm. 2020). *Rhodamnia maideniana* is a confirmed host to the introduced pathogen myrtle rust (Pegg *et al.* 2014).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	2468 km^2 (unknown) Decreasing	Low High
Area of occupancy (actual) Trend	392 km^2 (unknown) Decreasing	Low High
No. of mature individuals Trend	<250 Decreasing	Low High
No. of locations (key threat) Trend	1 (introduced pathogens) Decreasing	Medium High
No. of subpopulations Trend	Unknown Decreasing	Low High
Generation length	>20 years	Medium
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Observed and estimated	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A4e	CR: >80% reduction observed (2009-2020) and estimated (+100 years); based on decline in AOO, EOO, habitat quality; and effects of introduced pathogens.
B1ab(i-v)	EN: EOO <5000 km^2; AOO <500 km^2; severely fragmented and 1 location; continuing decline observed and estimated in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and Ongoing*	Minority	Rapid	Medium	Land clearing (for example the decimation of the Big Scrub; Parkes *et al.* 2012) has resulted in the decline and fragmentation of *R. maideniana* habitat. Land clearing for agriculture and urbanisation is ongoing (Evans 2016), although many subpopulations are protected in national park.
Introduced pathogens *Ongoing*	Whole	Very rapid	High	Myrtle rust causes dieback of young shoots and reproductive organs in *R. maideniana*, and occurs throughout the species' distribution (Makinson 2018). Only one of 100 individuals surveyed in Springbrook NP in 2020 were unaffected by the disease (J Radford-Smith pers.comm. 2020). At Tallebudgera Valley, tree mortality increased from 0% to 29.8% from 2014-2016, while canopy transparency increased from 69% to 91% (Pegg *et al.* 2017). Viable seed production has been reduced by >90% based on extensive surveys throughout the species' reproductive period (J Radford-Smith pers.comm. 2020). Similarly, a single ripe fruit was produced from 200 flowers (L Weber pers. comm. 2019); equating to a 95% reduction in seed production due to myrtle rust.
Climate change *Future*	Unknown	Unknown	Unknown	Myrtle rust infects foliage of other rainforest Myrtaceae recovering from drought-stress (J Radford-Smith, L Weber pers.comm. 2020) and fire (Fernandez Winzer *et al.* 2020). Myrtle rust infection incidence and severity is influenced by climatic conditions including temperature, rainfall and humidity (Makinson 2018). More frequent droughts, intense rainfall events, extreme temperatures and fire weather are predicted under climate change (Dowdy *et al.* 2015), but the interaction with myrtle rust is unknown.

Current management

- A National Action Plan (Makinson *et al.* 2020) has been developed through extensive consultation and provides a national expert consensus for the conservation of species affected by myrtle rust. *Rhodamnia maideniana* is listed as an 'emergency' priority species in the NAP (Makinson et al. 2020).
- The species occurs in several national parks that are managed for conservation (Lamington NP, Springbrook NP, Mooball NP and Wollumbin NP). The species also occurs in Currumbin Hill Conservation Park.
- Limited targeted surveys have been undertaken in Queensland and NSW to determine population trends in response to myrtle rust infection.
- Cuttings have been propagated from several localities in Qld and NSW and are held at the Australian Botanic Gardens Mt Annan.
- Some current research on related species and on the genomics of the myrtle rust pathogen are expected to be informative of the mechanism of resistance and susceptibility in this species (B Makinson pers.comm. 2020).

Conservation objectives

- Establish awareness, funding and leadership for a long-term and coordinated response to the impact of myrtle rust on *R. maideniana*.
- Identify feasible options for maintaining wild subpopulations of *R. maideniana.*
- Establish and maintain a viable *ex situ* collection of *R. maideniana* as an ongoing conservation resource.
- Better understand the ecology of myrtle rust as it relates to *R. maideniana* and the ecosystems within which it occurs.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake field surveys as recommend by the NAP; document myrtle rust incidence, impact, resistance among plants, demographic trends and related ecological data.	High
	Undertake rapid field surveys and also establish permanent monitoring plots to capture time-series trends and document decline rates.	High
	Monitor subpopulations in response to threat abatement actions.	High
Ex situ conservation/translocations	Undertake research to determine the most effective methods of *ex situ* germplasm capture and storage (seed, tissue culture, vegetative).	High
	Collate a national inventory of cultivated specimens (botanic gardens, private collections) that can be protected by fungicide, diversified by further sampling and used for seed production.	High
	Use *ex situ* conservation collection to undertake research (within the NAP framework where possible), including trials for more rust-tolerant genotypes that may be used as a basis for reintroduction translocations.	High
Introduced pathogens	Undertake research into biocontrol methods for myrtle rust.	Medium
	Undertake research to identify possible management actions to maintain the wild population of *R. maideniana*, such as selective fungicide application.	Medium
Life history, ecology and research	Undertake research to better understand the life history and ecology of the species to guide conservation actions.	Medium
	Investigate indirect impacts of myrtle rust on habitat of *R. maideniana*, including ecological interactions with other threatening processes such as fire, drought, invasive weeds and climate change.	Medium

Management actions required

Theme	Specific actions	Priority
Population surveys	Standardise population monitoring data methods and coordinate data storage at a national scale.	High
Ex situ conservation/translocations	Urgently secure germplasm for *ex situ* conservation efforts.	High
	Maintain and expand secure (threat-managed) and genetically representative *ex situ* collections for seed collection and to support ongoing research efforts, including identification of genotypes less-susceptible to myrtle rust for future reintroduction translocations.	High
Extension and awareness	Seek Indigenous stakeholder input and participation in conservation actions.	High
	Raise awareness of the impact of myrtle rust on the species with local landholders and other stakeholders to monitor and protect the species	High
Life history, ecology and research	Assemble botanical and ecological knowledge of the species (including seedling photographs to guide field impact surveys) in a repository to expedite research, conservation planning and rapid surveys.	Medium

Experts consulted

Bob Makinson, Geoff Pegg, Glenn Leiper, Julian Radford-Smith, Lui Weber and Rod Fensham.

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Rhodomyrtus psidioides (G.Don) Benth. [MYRTACEAE]
Native guava

Healthy fruit (bottom left) and flowers (top left) of *Rhodomyrtus psidioides* (images: Glenn Leiper) and mature trees with severe dieback due to myrtle rust (right; image: Boris Laffineur).

Overview

Once a common inhabitant of rainforest edges and coastal sand-dune communities, *Rhodomyrtus psidioides* is at risk of imminent extinction due to the introduced pathogen myrtle rust *Austropuccinia psidii*. A marked decline was first documented in 2014, shortly after the rust became naturalised in eastern Australia and no fertile fruit have been observed on wild plants during field surveys since. At most sites, the species is now locally extinct and the species requires urgent germplasm collection to conserve genetic diversity, facilitate research and support reintroductions of rust-tolerant individuals in the future.

Conservation status

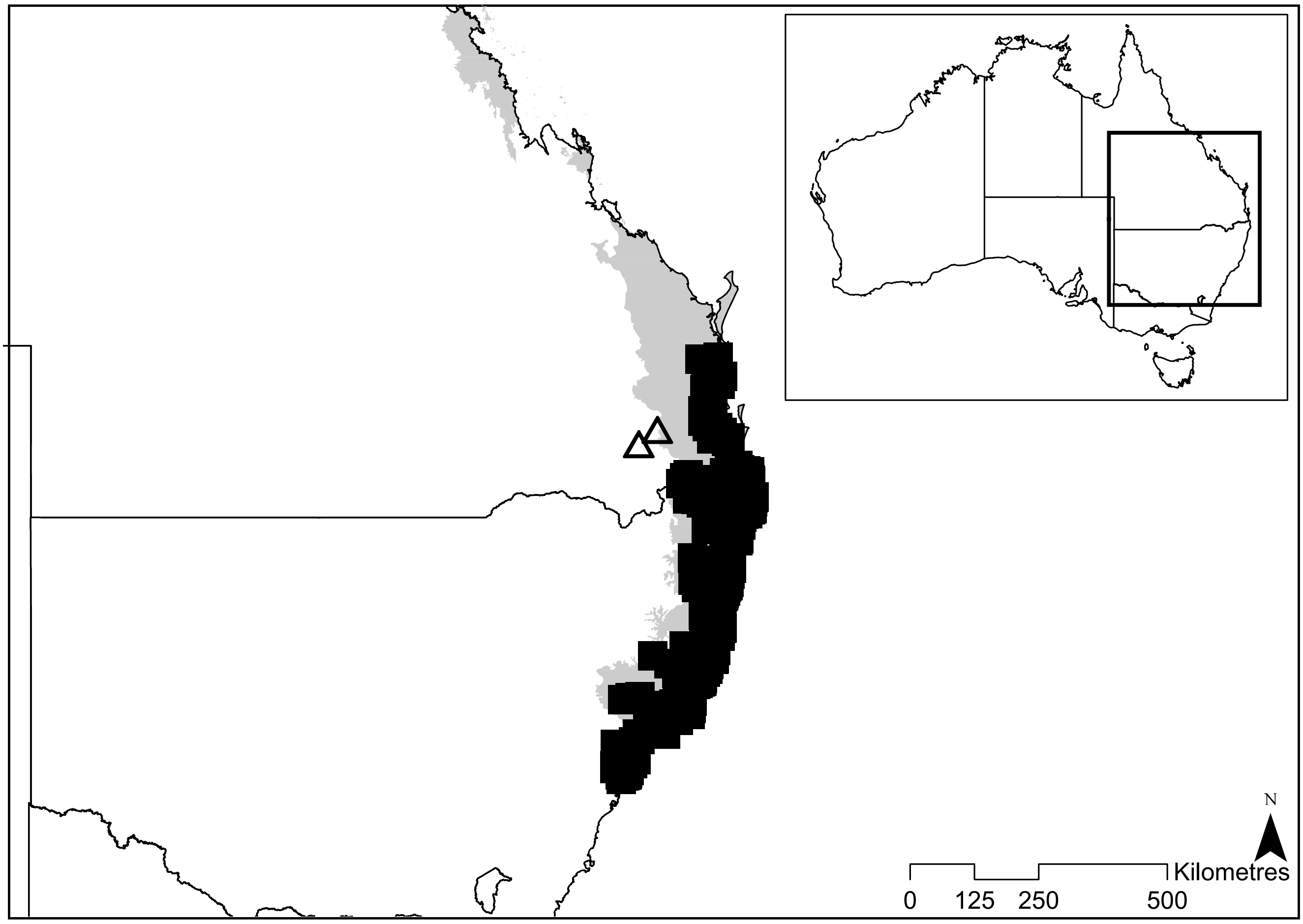
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Nature Conservation Act 1992 (Qld)	Critically Endangered
Biodiversity Conservation Act 2016 (NSW)	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Shrub or small tree to 12 m with wrinkled, flaky, light-brown bark (Scott 1978). Petiole 15-20 mm long and lamina 5-20 cm long and 2.5-6.5 wide (Scott 1978). Leaves ovate-elliptic, ovate-lanceolate or oblong, with an acuminate apex, cuneate base, 7-11 pinnate nerves and lacking an intramarginal vein (Scott 1978). Upper leaf surface glossy dark brown to green, lower surface glabrous or sparsely hairy (Scott 1978). Inflorescence hairy and axillary, with single or branched clusters of 3-5 white flowers that form a 9-flowered raceme up to 6 cm long (Scott 1978). Fruit is a yellow globular berry, 15-25 mm long and 10-15 mm wide, flattened at the apex and hairy, with numerous compressed-reniform seeds 3 mm wide separated by a false septa (Scott 1978).

Distribution

Rhodomyrtus psidioides is known from a widespread distribution along the east coast of Australia from Broken Bay (north of Sydney) in New South Wales to north of Gympie in Queensland. The species occurs in the South Eastern Queensland, NSW North Coast and Sydney Basin bioregions (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Fensham *et al.* 2020b; New South Wales Department of Planning, Industry and Environment 2020a). Given the widespread dieback throughout its range, *R. psidioides* is now severely fragmented, as all subpopulations are small and isolated by large distances, and recolonisation is hindered by habitat change and myrtle rust (IUCN 2019).



Rhodomyrtus psidioides (black squares) has exhibited severe dieback at all of the many sites surveyed across its distribution in the South Eastern Queensland, NSW North Coast and Sydney Basin bioregions (shaded grey) of eastern Australia (AVH 2020; DAWE 2012; Fensham *et al.* 2020b; NSW DPIE 2020a). The species has been translocated outside its natural range although these subpopulations are not yet self-sustaining (hollow triangles).

Population estimate and trends

Rhodomyrtus psidioides was a very common tree of open rainforest edges, but has undergone a rapid decline due to myrtle rust since 2010 (Pegg *et al.* 2017). In 2014, Carnegie *et al.* (2016) assessed 18 sites from Wambina Nature Reserve (NSW) to Tallebudgera Valley (Qld). Myrtle rust was present at every site, and all but three sites had very high levels of tree mortality. Four sites had 50–75 % mortality, two sites had 95 % mortality, and two sites had 100% mortality (Carnegie et al. 2016). Myrtle rust was only likely to have established in these areas 3 years prior to these measurements. A subsequent survey of 66 subpopulations in 2018 failed to locate the species at 23% of sites, 66% were reduced to root suckers, with only 3% having <10% dieback (Fensham *et al.* 2020a). Following this widespread dieback, surveys during 2019-2020 identified several locations where the species persists in NSW; 75% of these were as suckers <1 m tall and the remaining 15% were as mature trees up to 8 m tall (C Stehn pers.comm. 2020). Some of these have produced flowers and fruit, although the viability of seed is unconfirmed (C Stehn pers.comm. 2020).

The number of 'mature individuals' (IUCN 2019) is inferred to be <250 due to reproductive suppression by myrtle rust. *Rhodomyrtus psidioides* reproduces sexually and also asexually via root suckering. Myrtle rust has caused a reduction in the abundance and density of parent plants and thus outcrossing probability, reduced flowering rates due to shoot death and flower bud infection, and reduced seed-set due to plant stress and direct infection of fruits (B Makinson pers.comm. 2020). Myrtle rust has also killed a very large proportion of mature adult stems, and although root suckering can be prolific, the likelihood of suckers reaching reproductive maturity is low; while some survive their first growth season, survival into their third year is very rare (B Makinson pers.comm. 2020).

Two subpopulations were introduced outside the natural range of *R. psidioides* in 2018, where myrtle rust infection was predicted to be less severe. Thirty-seven of 40 plants survived at Highfields (north of Toowoomba) in 2019 (T Collingwood pers.comm. 2020), but have now have heavy myrtle rust infection (R Fensham pers.comm. 2020). Thirty-one of 40 plants survived at Pittsworth in 2019 (T Collingwood pers.comm. 2020), but the long-term survival of the species here is uncertain.

Habitat and ecology

Rhodomyrtus psidioides occurs in a variety of soils and rainforest habitats up to 910 m altitude, but favours open or disturbed rainforest margins (Scott 1978; ALA 2020). It is listed as a characteristic species in the 'Littoral rainforest in the NSW North Coast, Sydney Basin and South Easter Corner' bioregions.

Flowering occurs synchronously and often *en masse*, but the species may not flower in years when conditions are unfavourable (Williams and Adam 2012). Flowers have an average life-span of 5 to 7 days, are self-incompatible and pollinated by insects including native bees (*Leioproctus, Amphylaeus, Heterapoides, Homalictus*), beetles (Mordelliae), mirid bugs (Miridae), true bugs (Hemiptera), nocturnally active Nematocera (Scatopsidae, Trickoceridae) and thrips (William and Adams 2010). However, visitation is infrequent and the flowers produce little nectar, and it is possible that the flowers are also wind-pollinated, as the stigma is relatively broad and long, and positioned above the anthers (William and Adams 2010). The fleshy fruits are predominantly dispersed by fauna including birds (Williams and Adam 2012).

Rhodomyrtus psidioides is a pioneer species and can reproduce asexually via coppice growth or root suckers. It becomes reproductively mature within 4-5 years under ideal conditions, and as the species can sucker profusely after disturbance, it may live indefinitely (P Forster pers.comm. 2020). *Rhodomyrtus psidioides* is a confirmed host to the introduced pathogen myrtle rust (Pegg *et al.* 2014).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	90 140 km^2 (unknown) Decreasing	Low High
Area of occupancy (actual) Trend	1552 km^2 (unknown) Decreasing	Low High
No. of mature individuals Trend	<250 Decreasing	Low High
No. locations (key threat) Trend	1 (introduced pathogens) Decreasing	Medium High
No. of subpopulations Trend	Unknown Decreasing	Low High
Generation length	>40 years	Low
Extreme fluctuations	No	High
Severely fragmented	Yes	High
Continuing decline	Observed and estimated	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A4e	CR: >80% reduction observed (2009-2020) and estimated (+100 years); based on decline in AOO, EOO, habitat quality; and effects of introduced pathogens.
B2ab(i-v)	VU: AOO <2000 km^2; severely fragmented and 1 location; continuing decline observed and estimated in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and ongoing*	Minority	Rapid	Medium	The distribution of *R. psidioides* coincides with one of the most densely populated regions of Australia. Land clearing (for example the decimation of the Big Scrub (Parkes *et al.* 2012) has resulted in the decline and fragmentation of available habitat. Many subpopulations occur on the edges of small rainforest remnants. Land clearing for agriculture and urbanisation is ongoing throughout the region (Evans 2016), but many remnant plants occur on protected land.
Introduced pathogens *Ongoing*	Whole	Very rapid	High	*Rhodomyrtus psidioides* is 'extremely susceptible' to myrtle rust, which kills young and regenerating foliage of adult plants, entire seedlings and fertile organs (Fernandez Winter 2019; Makinson 2018). Within 3 years of myrtle rust invasion, 50-100% of *R. psidioides* trees in stands were dead (Carnegie *et al.* 2016) and by 2017, entire stands could not be relocated (Pegg *et al.* 2017). Some flowers and fruit have been recently located, although viability is unknown (C Stehn pers.comm. 2020).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Invasive weeds/ burn incursion *Ongoing*	Majority	Unknown	Unknown	*Rhodomyrtus psidioides* occurs on rainforest edges and has been replaced by invasive weeds including lantana after dieback (Fernandez Winzer *et al.* 2020a; Pegg *et al.* 2017). This competition may reduce re-establishment opportunities, while altering habitat structure and flammability during dry periods (Pegg *et al.* 2017; Fernandez-Winzer *et al.* 2020a,b)
Climate change *Future*	Unknown	Unknown	Unknown	Myrtle rust infection severity is influenced by climatic conditions including temperature, rainfall and humidity (Makinson 2018). More frequent droughts, intense rainfall events, extreme temperatures and fire weather are predicted under climate change (Dowdy *et al.* 2015), but the interaction with myrtle rust is unknown.

Current management

- A National Action Plan (Makinson *et al.* 2020) has been developed through extensive consultation and provides a national expert consensus for the conservation of species affected by myrtle rust. *Rhodomyrtus psidioides* is listed as an 'emergency' priority species in the NAP (Makinson *et al.* 2020).
- Current research on related species and on the genomics of the myrtle rust pathogen are expected to be informative about the mechanism of resistance and susceptibility in this species (B Makinson pers.comm. 2020).
- A Saving our Species Strategy has been developed and is being implemented (NSW DPIE 2020b). Extensive monitoring and recovery work has been undertaken in NSW (2018-2020) by Angus Carnegie, NSW DPIE, the Australian Botanic Gardens Mt Annan and the Royal Botanic Gardens Sydney (C Stehn pers.comm. 2020). An *ex situ* collection has been established at ABG (Mt Annan) from cuttings, excavated suckers and DNA, representing 80 individuals from 15 sites between Sydney and the NSW/Queensland border. A seed orchard has also been established at ABG (Mt Annan) (Viler and Offord 2020). Germplasm collection is ongoing and dispersed collection arrangements are being investigated. Maurizio Rossetto from the RBGS is leading genetic research. Monitoring of flowering individuals, subsequent fruit set and seed viability will be undertaken in 2020-2021 (C Stehn pers.comm. 2020).
- In Queensland, targeted surveys have been undertaken to determine population trends in response to myrtle rust infection (Fensham *et al.* 2020). Eighty plants grown from rootstock (possibly two genetic clones) were translocated in 2018; with 36 of 40 plants surviving at Highfields and 31 of 40 plants surviving at Pittsworth in 2019 (T Collingwood pers.comm. 2020b). In 2020, myrtle rust had damaged all the growing shoots at Highfields while the disease was not evident at Pittsworth (R Fensham, B Laffineur pers.comm. 2020). Both sites are beyond the natural aridity limit for the species (around 920 mm mean annual rainfall), although significant levels of myrtle rust have been recorded in Highfields under normal rainfall conditions (G Pegg pers.comm. 2020).

Conservation objectives

- Establish awareness, funding and leadership for a long-term and coordinated response to the impact of myrtle rust on *R. psidioides*.
- Identify feasible options for maintaining wild subpopulations of *R. psidioides*.
- Establish and maintain a viable *ex situ* collection of *R. psidioides* as an ongoing conservation resource.
- Better understand the ecology of myrtle rust as it relates to *R. psidioides* and the ecosystems within which it occurs.

Information required

Theme	Specific actions	Priority
Population surveys	Undertake field surveys as recommend by the NAP; document myrtle rust incidence, impact, resistance among plants, demographic trends and related ecological data.	High
	Continue monitoring in permanent plots to document time-series trends.	High
	Monitor subpopulations in response to threat abatement actions.	High
Ex situ conservation/translocations	Undertake research to determine the most effective methods of *ex situ* germplasm capture and storage (seed, tissue culture, vegetative).	High
	Collate a national inventory of cultivated specimens (botanic gardens, private collections) that can be protected by fungicide, diversified by further sampling and used for seed production.	High
	Use *ex situ* conservation collection to undertake research (within the NAP framework where possible), including trials for more rust-tolerant genotypes that may be used as a basis for reintroduction translocations.	High
Introduced pathogens	Undertake research into biocontrol methods for myrtle rust.	Medium
	Undertake research to identify possible management actions to maintain the wild population of *R. psidioides*, such as selective fungicide application.	Medium
Life history, ecology and research	Undertake research to better understand the life history and ecology of the species to guide conservation actions.	Medium
	Continue to document indirect impacts of myrtle rust on habitat of *R. psidioides*, including ecological interactions with other threatening processes such as fire, drought, invasive weeds and climate change.	Medium

Management actions required

Theme	Specific actions	Priority
Population surveys	Standardise population monitoring data methods and coordinate data storage at a national scale.	High
Ex situ conservation/translocations	Urgently secure germplasm for *ex situ* conservation efforts.	High
	Maintain and expand secure (threat-managed) and genetically representative *ex situ* collections for seed collection and to support ongoing research efforts, including identification of genotypes less-susceptible to myrtle rust for future reintroduction translocations.	High
	Monitor and maintain translocated subpopulations via weeding, watering, mulching, staking of young plants.	High
Extension and awareness	Seek Indigenous stakeholder input and participation in conservation actions.	High
	Raise awareness of the impact of myrtle rust on the species with local landholders and other stakeholders to monitor and protect the species	High
Life history, ecology and research	Assemble fragmented botanical and ecological knowledge of the species (including seedling photographs to guide field impact surveys) in a repository to expedite research, conservation planning and rapid surveys.	Medium

Experts consulted

Bob Makinson, Geoff Pegg, Craig Stehn, Lui Weber, Glenn Leiper, Rod Fensham, Boris Laffineur, Julian-Radford Smith and Teghan Collingwood.

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Senecio behrianus Sond. & F.Muell. ex Sond. [ASTERACEAE]
Stiff groundsel

Senecio behrianus (clockwise from left) leaves and flowerhead, swampy woodland habitat on private property near Corop, and a translocated plant flowering and spreading via rhizomes at a wetland under a conservation covenant (private property) that receives regular environmental water (images: Damien Cook).

Overview

Senecio behrianus once occurred widely across floodplains and wetlands of south-eastern Australia but was presumed extinct until it was relocated in 1991. It is currently known from seven small wild subpopulations in Victoria. Its habitat has been extensively cleared and altered hydrologically for agriculture, and remnant subpopulations are very small and mostly occur on insecure tenure with ongoing threats. Translocations have been recently implemented to wetlands on secure tenure that receive environmental water, and at several sites plants have established, are flowering profusely and spreading vegetatively.

Conservation status

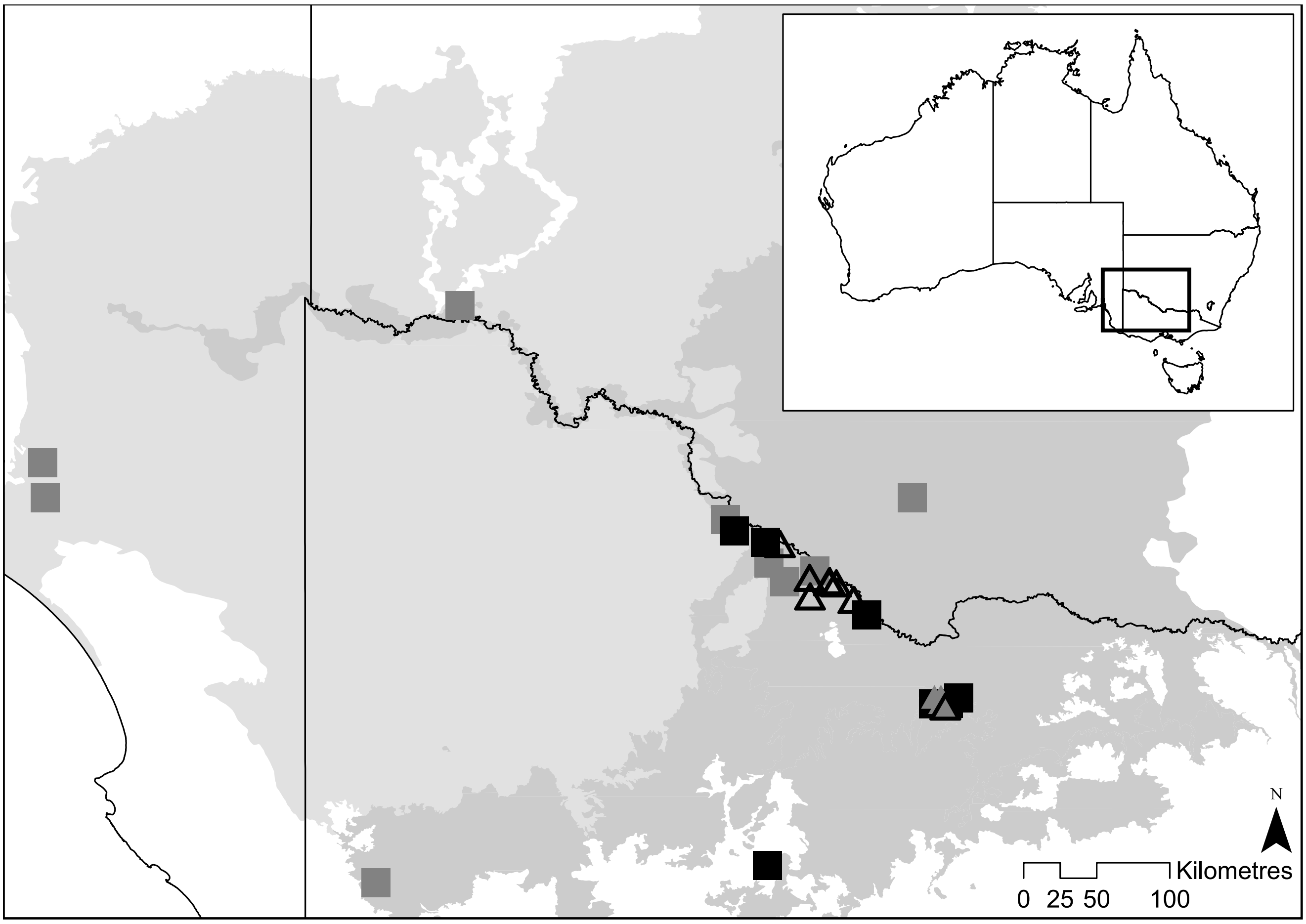
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Flora and Fauna Guarantee Act 1988 (Vic)	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Endangered
National Parks and Wildlife Act 1972 (SA)	Endangered
Biodiversity Conservation Act 2016 (NSW)	Extinct
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect, woolly perennial herb to 1 m tall forming extensive rhizomatous clumps. Leaves are grey-green, linear, 2-8 cm long and 1-5 mm wide. Lamina usually has recurved margins and is initially whiteish-pubescent before becoming glabrous, although the lower surface may remain mealy (Walsh 1999). Small yellow inflorescences are borne in loose clusters at the ends of the stems, each comprised of 6 ray florets and 13-15 disc florets (Walsh 1999). Achenes are dark brown, flattened and 2-2.5 mm long (Walsh 1999).

Distribution

Senecio behrianus was formerly known from a widespread distribution on the floodplains of the Murray Darling river system. It occurred in South Australia, New South Wales and Victoria in the Riverina, Murray Darling Depression and Victorian Midlands bioregions (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012). The species is now presumed extinct in NSW and SA, and currently persists in a restricted area around Corop, Ballarat, Gunbower and Kerang in Victoria in the Riverina and Victorian Midlands bioregions (AVH 2020). Translocations have been undertaken at Gunbower Forest, around Corop and at several locations around Kerang (D Cook pers.comm. 2020).



Current (black squares) and historic (grey squares) distribution of *Senecio behrianus* in the Victorian Midlands and Riverina bioregions (shaded dark grey) and the Murray Darling Depression bioregion (shaded light grey). At least 12 introduction translocations have been undertaken. Some have failed (grey triangles), but at several sites the species appears to have established and is reproducing clonally via rhizomes (hollow triangles). These are not yet included as self-sustaining subpopulations because plants have been in the ground for <5 years (IUCN 2019).

Population estimate and trends

Senecio behrianus is currently known from seven wild subpopulations and seven translocated subpopulations. The species was presumed extinct until it was relocated in 1991 at Corop in Victoria. Counts were undertaken in 2015 at all subpopulations, however accurately estimating the number of mature individuals (IUCN 2019) is difficult as the species forms rhizomatous 'patches' of interconnected plants (D Cook pers.comm. 2020). All subpopulations occupy <0.25 ha in extent, and total population size is likely to be <250 individuals (D Cook pers.comm. 2020). A total of 31 patches were recorded in 2015. Two subpopulations are have recently become extinct (Nevill and Camelleri 2010; Cook 2015), and two others are suspected to be declining due to a range of threats. Further surveys are required to assess trends in the remaining wild subpopulations (D Cook pers.comm. 2020).

At least 12 translocations have been undertaken, and some plants survive at seven sites, with vegetative recruitment occurring at five. These sites are not yet considered self-sustaining as they have been in the ground for <5 years (IUCN 2019; Silcock *et al.* 2019).

Targeted surveys have been conducted in suitable habitat across the species' range on public land, however additional small subpopulations may exist, particularly on private land in the Kerang and Corop regions (D Cook pers.comm. 2020).

Senecio behrianus monitoring data, 1993-2020 (Cook 2015; Nevill and Camelleri 2010; Silcock *et al.* 2019, D Cook pers. comm. 2020)

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Miners Rest, Ballarat (Wetland Reserve)	2015: 5 patches over 2000 m^2	Unknown
2 Gilmour Road, Corop (Shire roadside/private property)	2015: 6 patches over 100 m^2	Unknown
3 Grinter Road S, Corop (Shire roadside/private property)	2015: 10 patches over 200 m^2	Unknown
4 Grinter Road N, Corop (Shire roadside/private property)	2015: 2 patches over 10 m^2	Decreasing
5 Wallenjoe Road, Corop (private property)	2015: 0	Presumed extinct
6 McGillivray Road, Gunbower (Shire roadside)	2015: 3 patches over 10 m^2	Decreasing
7 North-west of Lake Boga (private property)	2015: 10 patches over 20 m^2	Unknown
8 Winlaton (private property)	2020: 20-30 plants (estimated)	Unknown
9 (T) Between Reedy Lagoon and Black Swamp, Gunbower Forest (National Park)	2016: 50T 2017: 25T 2020: 9T	9 plants now well established and spreading via rhizomes
10 (T) Gravel Pit Track, Gunbower Forest (National Park)	2016: 20T 2017: 3T	Low survival
11 (T) Greens Lake, Corop (wildlife reserve)	1993: unknown number planted 2010: 0	Failed
12 (T) Hudson Track, Gunbower Forest (National Park)	2016: 7 planted 2017: 7 planted 2020: 2T	2 plants now well established and spreading via rhizomes
13 (T) Koondrook Track, Gunbower Forest (National Park)	2014: 16 plants over 20 m2 2016: (12 planted) 2017: 1T	Low survival
14 (T) Mansfield Swamp, Corop (wildlife reserve)	1990s: unknown number planted 2010: 0	Failed
15 (T) Spur Creek, Gunbower Forest (National Park)	2016: 80T 2017: 40T	Unknown

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
16 (T) Two Tree Swamp, Corop (wildlife reserve)*	2003 and 2005: 200T 2015: 100T over 100 m^2	Stable
17 (T) Wallenjoe Swamp, Corop (wildlife reserve)	1993: 50 planted 2015: very few alive	Failed
18 (T) Wirralo Wetlands, Murrabit West (covenanted private property)	2016-2020: 75 planted	Some plants well- established and spreading via rhizomes
19 (T) Johnson Swamp Wildlife Reserve (State Game Reserve)	2018: 40T planted	Some plants well- established and spreading via rhizomes
20 (T) McDonalds Swamp Wildlife Reserve (State Game Reserve)	2016-2018: 40T planted	Some plants well- established and spreading via rhizomes

Translocated individuals/subpopulation (T). *An earlier translocation (1994) of >50 plants at this site failed and is not shown here.

Habitat and ecology

Senecio behrianus grows in grey, poorly-drained sedimentary and basaltic clays, often in depressions that are periodically inundated (Nevill and Camilleri 2010). It grows in swampy areas, amongst open riverine woodlands, grassy wetlands and dense reed beds (Neville and Camilleri 2010). At three sites it also occurs on artificial levees and channel embankments (D Cook pers.comm. 2020). Associated species include *Eucalyptus camaldulensis, Muehlenbeckia florulenta, Marsilea drummondii, Rytidosperma duttonianum, Rytidosperma caespitosum, Eragrostis infecunda, Amphibromus nervosus, Carex tereticaulis, Teucrium racemosum* and *Marsilea drummondii* (Nevill and Camilleri 2010; D Cook unpublished data).

The hydrological regime is an important habitat requirement for *S. behrianus*. The species appears to depend on periodic inundation, as individuals will die if they become too dry or are flooded for too long (Nevill and Camilleri 2010). Growth is more vigorous in areas flooded to a depth of >30 cm, possibly due to reduced competition, although the species can also grow on slightly raised areas rather than in the bottom of depressions (Nevill and Camilleri 2010). Plants recently introduced to wetlands in the Kerang region that are regularly inundated (every 1-3 years) by environmental water are growing vigorously, flowering profusely and producing copious quantities of seed (D Cook pers.comm. 2020). By contrast, nearby wild subpopulations that did not receive regular water over the same period have remained stable or declined, produced few flowers and few seed (D Cook pers.comm. 2020).

Senecio behrianus can re-sprout after disturbances including fire, grazing and drought, and extreme fluctuations are unlikely. Recruitment from seed has not been observed in the wild despite high rates of germination under experimental conditions (Nevill and Camilleroi 2010). Given most individuals are connected by woody rhizomes, genetic diversity may be low (Nevill and Camilleri 2010).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	14 021 km^2 Stable	Medium High
Area of occupancy (actual) Trend	24 km^2 (<00.1 km^2) Stable	Medium High
No. of mature individuals Trend	<250 Decreasing	Medium Medium
No. locations (key threat) Trend	5 (+7T) (altered hydrology) Decreasing	Medium High
No. of subpopulations Trend	8 (+7T) Decreasing	Medium High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B2ab(iii-v)	EN: AOO <500 km^2; severely fragmented; and continuing decline observed in area/extent and quality of habitat, number of locations and subpopulations, number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and <50 mature individuals in each subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Grazing and trampling (livestock) *Suspended*	Majority	Slow	Low	Defoliation and trampling damage plants. Known subpopulations have been fenced to exclude stock (Nevill and Camilleri 2010).
Altered hydrology *Ongoing*	Whole	Rapid	High	Hydrological regimes are an important habitat requirement of the species, and these have been extensively modified in the region. Plants recently introduced to wetlands that are regularly inundated by environmental water are growing and seeding vigorously and reproducing via rhizomes, in contrast to natural subpopulations that do not receive this water that have declined or remained stable over the same time period (D Cook pers.comm. 2020). Four of the eight subpopulations occur in close proximity to each other on the same drainage system, so the species occurs at five locations when assessed against this threat.
Habitat loss *Past and ongoing*	Majority	Very rapid	High	Land clearing for agriculture has resulted in the decline and severe fragmentation of habitat. This threat is ongoing at some locations, with one landholder recently clearing trees and applying herbicide near one subpopulation.
Infrastructure maintenance *Ongoing*	Majority	Rapid	Medium	Many subpopulations occur on roadsides and irrigation channels and are vulnerable to slashing, channel maintenance and other earthworks, herbicide application and other maintenance activities.
Invasive weeds *Ongoing*	Whole	Slow	Medium	Invasive perennial grasses, mat-forming herbs and woody weeds occur at all sites and can outcompete native species (Nevill and Camilleri 2010; D Cook pers.comm. 2020).
Genetic diversity *Ongoing*	Whole	Unknown	Unknown	Recruitment from seed has not been observed and plants are connected by rhizomes, therefore the number of distinct genetic individuals may be low (Nevill and Camilleri 2010).
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	*Senecio behrianus* re-sprouts readily after fire and this may be important in its life cycle (Nevill and Camilleri 2010). Fire regimes have changed with large scale habitat conversion, although direct impacts on the species are not documented.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat change *Ongoing*	Majority	Unknown	Unknown	There is dense river red gum regeneration at some sites, and this may impact the suitability of the habitat in the long-term (D Cook pers.comm. 2017).
Climate change *Future*	Whole	Unknown	Unknown	Climate change will result in drier winters and alter hydrology that the species depends upon (Timbal *et al.* 2015).

Current management

- Recovery actions have been identified and implemented (Nevill and Camilleri 2010).
- The species occurs in a wetland reserve at Miners Rest, but other naturally occurring subpopulations are on private land or roadsides.
- Twelve translocations have been undertaken since the early 1990s using seedlings and cuttings at sites in Gunbower Forest north-west of Echuca, around Corop and Kerang, and plants remain at nine of these.
- The species is presumed extinct in NSW and there are no active recovery actions for the species in this jurisdiction (Office of Environment and Heritage 2017). Similarly, there are no recent records of the species in South Australia, although plants have been grown *ex situ* by the South Australian Seed Conservation Centre.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Increase the number of mature individuals and subpopulations in the wild by maintaining and expanding translocation program.

Information required

Theme	Specific actions	Priority
Population surveys	Continue targeted surveys in historic locations and other suitable habitat to locate additional subpopulations.	High
	Monitor population response to recovery actions. Revisit all wild subpopulations to assess trends and threats.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including hydrological requirements, fire ecology, conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Ex situ conservation/translocations	Identify potential habitat for further translocations and secure in appropriate conservation agreements.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known subpopulations and other suitable habitat in appropriate conservation agreements.	High
Habitat quality	Increase habitat quality for subpopulations occurring on roadside remnants via revegetation, invasive weed control, exclusion of grazing stock and allocation of environmental water to translocated and naturally-occurring subpopulations.	High
Inappropriate fire regimes	Implement appropriate fire regime at all sites to increase the number of mature individuals and improve habitat quality.	High
Ex situ conservation/translocations	Maintain and expand *ex situ* subpopulation to represent maximum range of genetic diversity; continue translocation attempts.	High
	Maintain translocated subpopulations with ongoing management actions as required.	High

Experts consulted

Damien Cook.

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Solanum orgadophilum A.R.Bean [Solanaceae]
Capella potato bush

Solanum orgadophilum flower (top left), roadside habitat adjacent to cropping land at Clermont (right) and plant showing cordate leaf base amongst remnant grassland at Capella (bottom left; images: Teghan Collingwood).

Overview

Solanum orgadophilum occurs on fertile soils in central Queensland. Clearing for agriculture has been extensive in this habitat and is ongoing for mining and urban development. All three subpopulations are in disturbed areas that are threatened by human activities, including a narrow road verge and two urban properties; one is a grazing paddock and the other is zoned for development. Habitat security is essential for the persistence of this species, and a better understanding of its biology and disturbance ecology is required to inform land management and translocations.

Conservation status

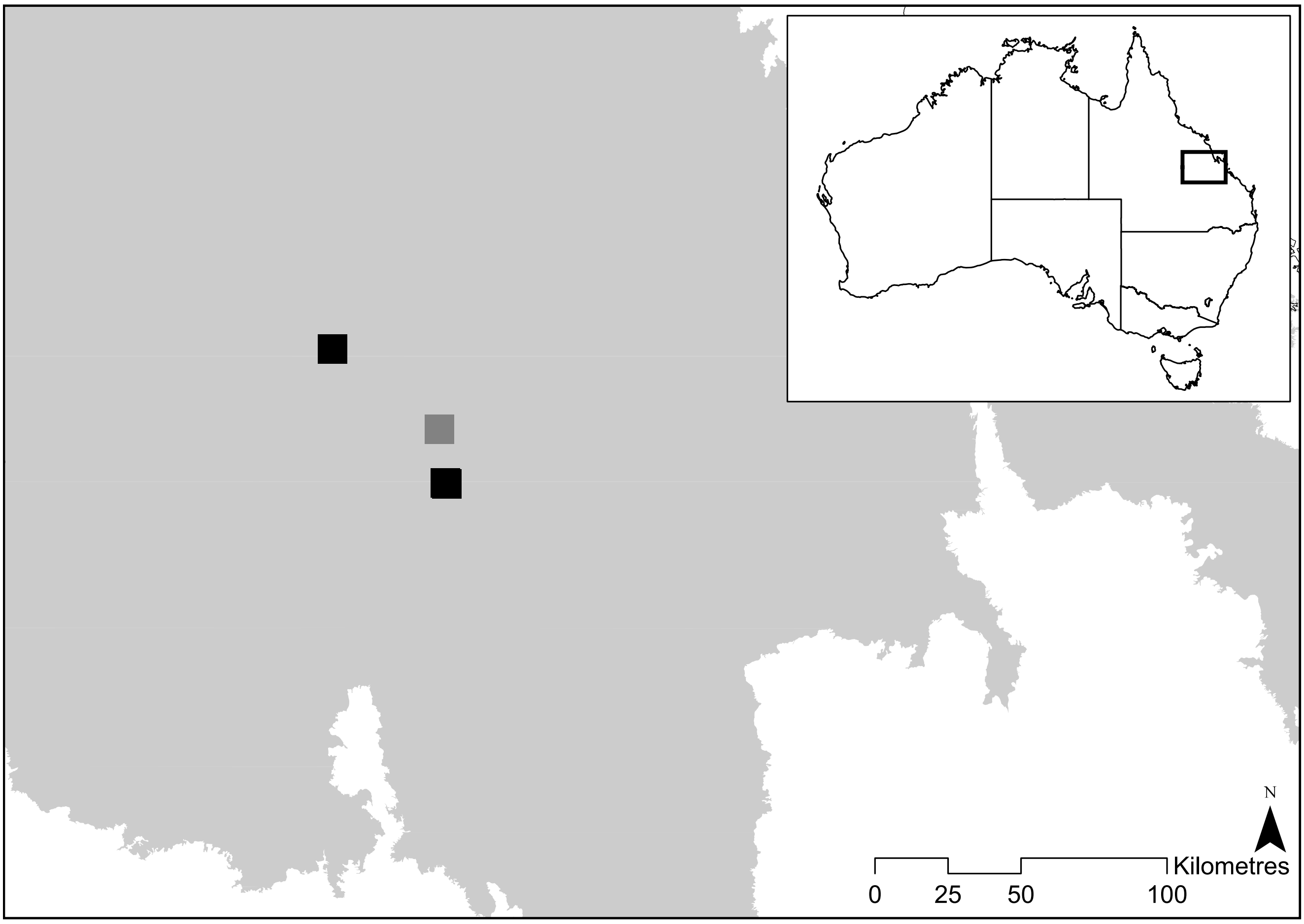
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992	Critically Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect perennial herb to 40 cm tall that grows from underground rhizomes (Bean 2010). Branches are white-grey to brown and covered in sparse prickles and stellate hairs. Leaves are hairy and ovate with entire, often undulating margins 6.5-20 cm long and 3.8-11.7 cm wide, usually with a cordate base. The inflorescence has 3-6 purple flowers 13-14 mm wide (Bean 2010). Immature fruit have been rarely observed. *Solanum orgadophilum* is distinct within the genus (Bean 2010).

Distribution

Solanum orgadophilum is known from a very narrow range near Capella and Clermont in the Brigalow Belt North bioregion of Queensland (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Queensland Herbarium 2020).



Current (black squares) and historic (grey square) distribution of *Solanum orgadophilum* in the Brigalow Belt North bioregion (shaded grey) of Queensland (AVH 2020; DAWE 2012; QH 2020). Note that the southern square represents two close but separate extant subpopulations at Capella.

Population estimate and trends

The first collections of *S. orgadophilum* were from Peak Downs in 1951 and 1954, when the species was 'very common' and a 'serious weed' (Queensland Herbarium 2020). The species appears to have undergone a severe decline since, with only four subsequent collections, in 2006, 2010, 2014 and 2019 (Queensland Herbarium 2020). The species is currently known from three sites, where it forms patches of stems, with each patch probably a single cloning individual (Bean 2010). At Gordon Street (Capella), there were 100 plants observed in 2014. In 2019, there were ca. 50-100 patches of 30-40 stems, equating to 1500-4000 individuals. At Kettle Street (Capella), >30 plants were recorded in a grazing paddock in 2010, but the species was not detected here in 2014 or 2019. At Clermont, the species occurred in 'two small patches' (2-3 m^2) of up to 500 stems (Queensland Herbarium 2020; Bean 2010), was absent in 2008 and <500 stems were present in 2019. A future population reduction of >80% is projected due to habitat conversion at Gordon Street combined with the apparent loss of the Kettle Street subpopulation in Capella.

Despite extensive surveys, the species has not been located elsewhere in the region (Fensham 1999). However, the species may go undetected as it can persist underground as rhizomes. Further opportunistic surveys are warranted, although survey effort to date indicates the species is very rare (Fensham 1999; R Fensham and T Collingwood unpublished data).

Habitat and ecology

Solanum orgadophilum grows in clay soils on flat to undulating terrain in grasslands or open eucalypt woodlands (Bean 2010). Flowering has been recorded in January and May, and immature fruit have been observed in May. Flowers are often infertile indicating reproduction and dispersal is predominantly asexual via rhizomes, although further research is required. Although fluctuations in abundance have been observed, *S. orgadophilum* can persist underground and re-sprout from rhizomes after disturbance (Bean 2010), indicating extreme fluctuations are unlikely (IUCN 2019). The generation length is not known.

Solanum orgadophilum appears to prosper with some disturbance. It has been observed growing in association with mechanical disturbance at both Clermont and Capella. Open vegetation structure may be an important habitat requirement, as the Clermont subpopulation was not detected in previous years when grass cover was dense. Although plants appeared to be ungrazed at Clermont in 2019, prolonged grazing may lead to declines, as the species is now absent from grazing paddocks including Kettle Street (Capella).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	8 km^2 (0.01 km^2) Decreasing	High High
Area of occupancy (actual) Trend	8 km^2 (<0.01 km^2) Decreasing	High High
No. locations (key threat) Trend	3 (habitat loss) Decreasing	High High
No. of subpopulations Trend	3 Decreasing	High High
No. of mature individuals Trend	<5000 Decreasing	Medium High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A3c	CR: >80% population reduction projected within 10 years (generation length unknown so minimum threshold applied) based on decline in AOO and EOO.
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and continuing decline projected in AOO, EOO, number of locations and number of mature individuals; and continuing decline observed in quality of habitat.
C1	VU: <10 000 mature individuals; projected decline of >10% within 10 years.
D	Not eligible.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and ongoing*	Whole	Very rapid	High	More than 67% of grasslands in central Queensland have been converted to crops or pasture (Butler 2006). All subpopulations of *S. orgadophilum* occur in small, isolated patches surrounded by farmland, mines or housing and are severely fragmented amongst a heavily cleared landscape. The species occurs at three locations when assessed against the range of threats associated with habitat loss, which can be managed at the land tenure/ subpopulation scale.
Infrastructure development/ roadside threats *Ongoing*	Whole	Very rapid	High	At Clermont, the subpopulation occurs on a road verge. The species is vulnerable to management activities such as grading (observed), road realignment and herbicide drift from adjacent cropping properties.
Inappropriate disturbance regimes *Ongoing*	Whole	Rapid	High	No plants were seen at the Clermont subpopulation in 2008 when dense grass covered the site (Bean 2010) but was relocated in a recently disturbed area in 2019. At Gordon Street, the species forms patches in open areas of grassland and in recently disturbed soil. Prolonged grazing may be responsible for the absence of the species at Kettle Street.
Grazing (domestic stock) *Ongoing*	Whole	Slow	Medium	The subpopulation at Clermont occurs on a road verge periodically used for cattle grazing. The optimal grazing/ disturbance regime is not understood. At Capella, the species has not been detected since 2010 in a paddock that is continuously grazed.
Invasive weeds/ competition with native species *Ongoing*	Whole	Slow	Medium	Invasive weeds (especially parthenium) are present in the species' habitat (Bean 2010). Invasive weeds degrade habitat and encourage conversion of grazing paddocks to croplands (Butler 2006; Fensham 1999). The species was absent at Clermont when perennial grass cover was dense, possibly due to competition (Bean 2010).
Human activities *Ongoing*	Minority	Very rapid	Medium	The subpopulation at Kettle Street (Capella) has been subject to active removal and slashing (A Bean pers.comm. 2019; Bean 2010).
Insect herbivory *Future*	Majority	Unknown	Unknown	Insect herbivory was evident on leaves of all individuals at the Clermont subpopulation in 2019, but the specific impact is not known (T Collingwood pers.obs. 2019).

Current management

- There is no recovery plan for this species.
- This species does not occur in any conservation reserves.
- Surveys of suitable habitat undertaken since the mid-1990s, including the extensive environmental impact assessments of the coal-mining boom in the early 2000s, have confirmed the rarity of the species (R Fensham pers.comm. 2020).

Conservation objectives

- Establish conservation covenants over existing subpopulations.
- Increase understanding of the species' biology and ecology to guide management actions.
- Establish genetically representative *ex situ* collection to reduce extinction risk and support introduction of species to secure tenure.
- Detect more subpopulations via opportunistic surveys.

Information required

Theme	Specific actions	Priority
Life history and ecology	Undertake research to better understand the biology and ecology of the species including disturbance ecology and reproductive strategy.	High
Ex situ conservation/translocations	Undertake research to determine effective methods for propagating species *ex situ*.	High
	Identify areas of suitable habitat on secure tenure for future translocations, if feasible.	High
Population surveys	Monitor response of known subpopulations to management actions and threats.	High
	Opportunistic surveys in historic locations and other suitable habitat to locate additional subpopulations, particularly after disturbance.	Medium

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect known habitat of species at Capella and Clermont in appropriate conservation agreements. If possible, acquire land at Gordon Street and gazette as a conservation reserve. Ensure habitat at Gordon Street is not converted to urban land use.	High
	Protect additional suitable habitat (if present) in conservation agreements with view to establish additional subpopulations via translocation	High
Inappropriate disturbance regimes	Implement disturbance (i.e. fire/ periodic grazing) at subpopulations when required to maintain/increase population abundance.	High
Extension and awareness	Raise awareness of the species with relevant stakeholders in an attempt to locate additional subpopulations.	High
Ex situ conservation/translocations	Establish *ex situ* collection representing maximum range of genetic diversity possible. Increase the number of wild subpopulations via introductions to secure tenure.	High

Experts consulted

Tony Bean, Rod Fensham and Teghan Collingwood.

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Sphaerolobium acanthos Crisp [FABACEAE]
Grampians globe-pea

Sphaerolobium acanthos flowers (image: Neville Walsh, State Botanical Collection, Royal Botanic Gardens Victoria).

Overview

Sphaerolobium acanthos is endemic to Gariwerd (Grampians National Park) in western Victoria. Herbarium records indicate it once occurred at up to 15 sites, but is now present at only four of these due to a combination of threats including vertebrate pest browsing, urbanisation, infrastructure maintenance and recreational activities. Recovery actions including fencing, phytophthora management and regular monitoring are required to secure this species.

Conservation status

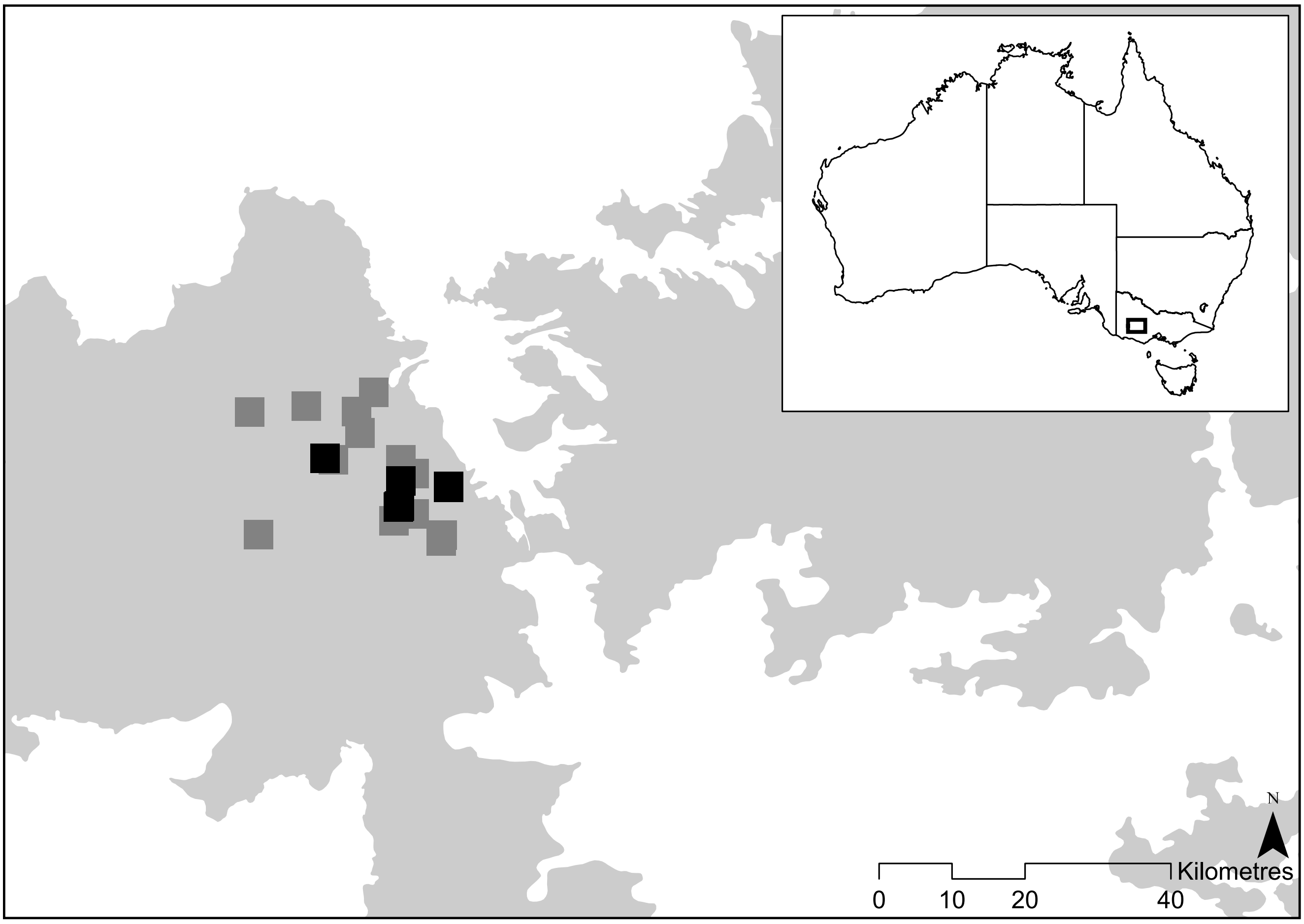
Environment Protection and Biodiversity Conservation Act 1999	Critically Endangered
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Rare
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Erect, perennial shrub to 1 m with long rigid branches (Crisp 1994). Branchlets are divaricate and often 3-5-forked at the tips. Leaves are scattered to sub-whorled and 2-3 mm long. Flowers are mostly orange with a yellow flare at the base of the standard. Fruit is a plump, ovoid pod 4.5 mm long and 2.5 mm wide with broad-ovoid seed (Crisp 1994). *Sphaerolobium acanthos* has been confused with *S. daviesioides* that only occurs in Western Australia and has different branchlet morphology, and no stigma hairs (Crisp 1994).

Distribution

Sphaerolobium acanthos is known from a restricted distribution in Gariwerd (Grampians National Park) within the Victorian Midlands bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012; Department of Environment, Land, Water and Planning 2020). Although the habitat of *S. acanthos* is relatively intact, the species is considered severely fragmented (IUCN 2019) as some past habitat loss has occurred and recolonisation of areas following local extinction is unlikely (IUCN 2019).



Current (black squares) and historic (grey squares) distribution of *Sphaerolobium acanthos* in the Victorian Midlands bioregion (shaded grey) of Victoria (AVH 2020; DAWE 2012; DELWP 2020).

Population estimate and trends

Sphaerolobium acanthos is currently known from four subpopulations with approximately 70 mature individuals. The majority of individuals occur at Duwil (Mt William). Herbarium records indicate the species previously occurred at up to 15 sites throughout the park (AVH 2020). Many of these subpopulations are presumed to have been destroyed during roadworks, housing development, the construction of Lake Bellfield and walking track widening (N Reiter pers. comm. 2019). Targeted surveys of suitable habitat in 2015 failed to locate additional subpopulations.

Sphaerolobium acanthos monitoring data, 2011-2017 (N Reiter pers.comm. 2019; TSSC 2016).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Duwil (Mt William) (national park)	2011: <20 2017: ca. 60	Unknown
2 Firebreak (national park)	2011: <20 2015: <5 2017: <5	Decrreasing
3 Calectasia Falls (national park)	2013: <10	Unknown
4 Redmans Track (national park)	2015: <5 2017: <3	Decreasing

Habitat and ecology

Sphaerolobium acanthos occurs in sclerophyll forests, woodland and heath. The largest subpopulation is situated amongst high altitude heathland on the slopes of Duwil (Mt William; N Reiter pers.comm. 2019). The species also occurs on lower slopes, gullies and near streams (Crisp 1994). Associated species include *Eucalyptus baxteri, Acacia myrtifolia, Allocasuarina grampiana, Leucochrysum albicans, Kunzea ericoides, Leptospermum continentale, Isopogon ceratophyllus, Grevillea alpina, Ixodia achillaeoides, Cassytha glabella, Hakea nodosa, Banksia marginata* and *Correa reflexa* (AVH 2020).

Flowering occurs from late November to January, with fruit produced until February (Crisp 1994). As with other species in the genus, pollination is probably by insects especially native bees (Hymenoptera; TSSC 2016). Naturally occurring plants appear to be slow-growing, although the growth rate of cultivated plants is comparable to other native pea shrubs (N Walsh pers.comm. 2019).

Sphaerolobium acanthos is probably an obligate-seeder (TSSC 2016). Mature individuals are killed by fire and there have been no observations of re-sprouting. Fire may stimulate germination of soil-stored seed, as a recently located subpopulation occurs in a previously burnt area. Due to this apparently persistent seedbank, extreme fluctuations are considered unlikely (IUCN 2019), but further knowledge of seed biology is required. No recruitment was observed at two subpopulations during surveys in 2011, 2013 and 2015.

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	30 km^2 Decreasing	Medium High
Area of occupancy (actual) Trend	16 km^2 (<1 km^2) Decreasing	Medium High
No. of mature individuals Trend	<70 Decreasing	Medium High
No. of locations (key threat) Trend	4 (vertebrate pests) Decreasing	Medium High
No. of subpopulations Trend	4 Decreasing	Medium High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Low
Severely fragmented	Yes	High
Continuing decline	Observed	Medium

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	EN: EOO <100 km^2; <5 locations; and continuing decline observed in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed; and <50 mature individuals in each subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Urban development *Past*	n/a	n/a	n/a	The Halls Gap housing development was constructed at the location of a historic collection where the species has not been relocated (N Reiter pers.comm. 2019).
Vertebrate pests *Ongoing*	Whole	Rapid	High	All subpopulations, but especially Firebreak, are affected by feral goat and deer. Some plants have been severely browsed with no fruit set occurring (TSSC 2016), causing depletion of the soil seedbank and mortality of mature plants. Swamp wallabies may be adding to herbivore pressure due to increased numbers (TSSC 2016). As this threat can be managed at the subpopulation scale via fencing, the species occurs at four locations.
Infrastructure construction/ maintenance *Past and ongoing*	Majority	Rapid	High	Lake Bellfield was constructed at the location of a historic collection (N Reiter pers.comm. 2019). Some individuals were removed for the Redmans Track in 2016, and several other historic collections may have been lost to road maintenance (N Reiter pers.comm. 2019). Part of the Duwil (Mt William) subpopulation was removed during walking track construction (N Reiter pers.comm. 2019).
Introduced pathogens *Ongoing*	Whole	Slow	Medium	*Sphaerolobium acanthos* is susceptible to phytophthora infection as plants turn black with impaired leaf /branch growth. Extinction risk due to this threat is low-moderate (Reiter *et al.* 2004)
Human activities (recreation) *Ongoing*	Minority	Slow	Low	The Firebreak subpopulation is vulnerable to recreation activities, with individuals found trampled and damaged by vehicles (N Reiter pers.comm. 2019).
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	As an obligate-seeder, too-frequent fire can exhaust the seedbank, but fire may be required for recruitment. One subpopulation was recently located in a bunt area, although there are no pre-fire surveys to confirm whether fire stimulated recruitment (N Reiter pers.comm. 2019).

Current management

- Recovery actions have been identified (TSSC 2016).
- Seed has been collected and an *ex situ* subpopulation established at the Royal Botanic Gardens Victoria. Germination and propagation research is ongoing, and translocations have been undertaken.
- This species occurs only within Gariwerd (Grampians National Park), which is managed for conservation.

Conservation objectives

- Reduce the collective impact of threatening processes on the species.
- Establish a genetically representative *ex situ* collection of the species for conservation and future translocation attempts. Only individuals from Calactasia Falls and Duwil (Mt William) are currently represented in the *ex situ* collection.
- Increase the number of mature individuals and subpopulations in the wild.

Information required

Theme	Specific actions	Priority
Population surveys	Targeted surveys in historic locations and other suitable habitat to locate additional subpopulations, particularly after fire.	High
	Undertake regular monitoring to understand population trends in relation to threats and recovery actions.	High
Ex situ conservation/translocations	Identify seed germination cues/requirements to maximise genetic diversity within *ex situ* propagation program and increase recruitment in wild subpopulations.	High
Fire ecology	Undertake research to determine the post-fire response of the species and determine a suitable fire regime to ensure population persistence.	High
Pollination ecology	As many Fabaceae species have specific pollinators, undertake pollinator studies to determine the identity and distribution of the pollinators to guide selection of possible translocation sites.	Medium
Habitat requirements	Undertake research to determine appropriate sites for translocations. Identify the specific habitat requirements of the species.	Medium

Management actions required

Theme	Specific actions	Priority
Introduced pathogens	Implement hygiene measures to minimise spread of phytophthora, monitor subpopulations for infestation and apply phosphonate treatments as necessary.	High
Vertebrate pests/grazing	Reduce herbivory pressure via vertebrate pest control (culling) and/or fencing (if appropriate), particularly during dry periods.	High
Infrastructure maintenance	Ensure subpopulations vulnerable to infrastructure maintenance are protected via fencing, markers and/or liaison with appropriate stakeholders.	High
Ex situ conservation/translocations	Ensure *ex situ* collection represents the maximum range of genetic diversity possible.	Medium
	Establish seed orchard. Undertake intensive propagation program from seed orchard to augment wild subpopulations and re/introduce species to historic/new sites.	Medium
Human activities	Ensure subpopulations vulnerable to impacts associated with recreational activities are protected via closure of four wheel drive tracks, fencing or other appropriate management actions.	Medium
Inappropriate fire regimes	Manage fire intervals to increase the soil seedbank, number of mature individuals and populations in the long-term.	Medium

Experts consulted

Neville Walsh, Noushka Reiter and Wendy Bedggood.

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Spyridium fontis-woodii Kellermann & W.R.Barker [RHAMNACEAE]
Woods Well spyridium


Spyridium fontis-woodii flowers (left) and roadside habitat (right; images: Daniel Duval, South Australian Seed Conservation Centre).

Overview

Spyridium fontis-woodii was described in 2012 and is known from a single roadside population in an agricultural region of South Australia. A recent decline from 35 to 13 mature individuals has been observed, apparently due to a lack of disturbance to promote germination and possibly rabbit browsing. Research into the disturbance ecology and threats is urgently required, alongside translocation to secure tenure.

Conservation status

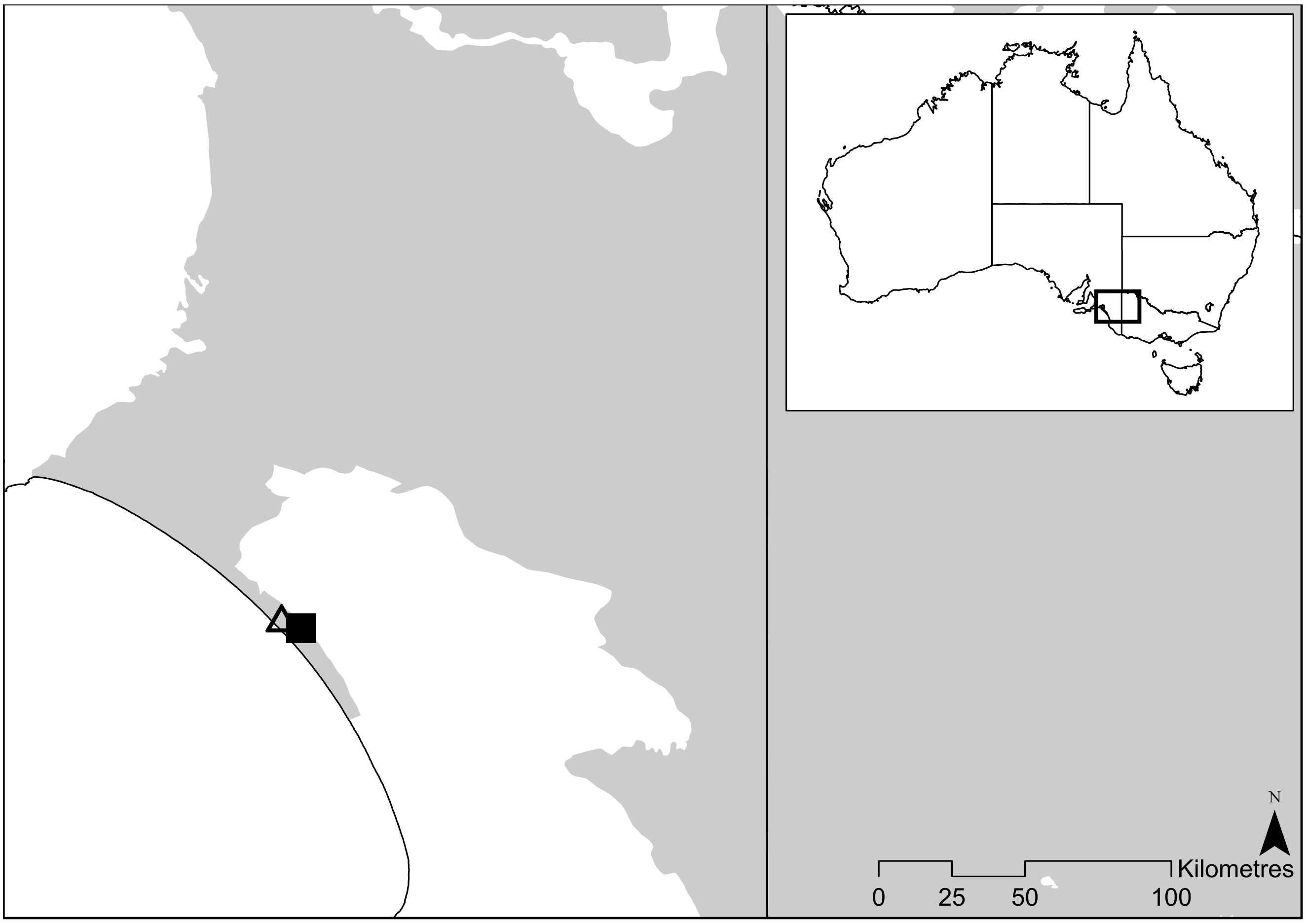
Environment Protection and Biodiversity Conservation Act 1999	Not listed
National Parks and Wildlife Act 1972	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Slender shrub to 1.8 m tall with densely hairy stems (Kellermann and Barker 2012). Leaves 4-8.8 mm long and 3.5-6.5 mm wide with recurved margins, broadly obovate or obcordate and mostly glabrous but with a hairy petiole 1-2 mm long. Inflorescence of densely clustered, funnel-shaped, white-cream flowers that are approximately 3 mm long. Fruit are dark brown, papery and ellipsoid to obovoid, 2-2.2 mm long and 1.2-1.8 mm wide. Seeds are brown and spotted, with a small aril that is easily detached. Although similar to *S. halmaturinum, S. furculentum* and *S. coactilifolium, S. fontis-woodii* is differentiated by its leaf shape, size and indumentum type (Kellermann and Barker 2012).

Distribution

Spyridium fontis-woodii is known a single site near Woods Well in the Murray Darling Depression bioregion of South Australia (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and the Environment 2012).



Current distribution (black square) of *Spyridium fontis-woodii*, including a translocated subpopulation 5 km away that is not self-sustaining, in the Murray Darling Depression bioregion (shaded grey) of South Australia (AVH 2020; DPAW 2012).

Population estimate and trends

Spyridium fontis-woodii was first collected in 1973 and remains known from this single population, occupying an area of ~100 m^2 in a narrow roadside remnant (D Duval pers.comm. 2018). In 1995 and 2012, 35 mature individuals were recorded, and there were >50 in 2006. By 2018, the subpopulation had declined to 13 plants (D Duval pers.comm. 2020), an overall population reduction of 63% within 23 years.

Potential habitat is rare in the area and typically occurs as small and disturbed roadside remnants (Department for Environment and Water 2020). Although extensive searches have been undertaken, more are recommended in Messent Conservation Park and potentially suitable habitat on private land in the area, particularly after fire (DEW 2020).

Habitat and ecology

Spyridium fontis-woodii is an understorey shrub that grows amongst open shrubland dominated by *Eucalyptus diversifolia* with a diverse understorey. Soils are light brown sands over calcrete (Kellermann and Barker 2012). Flowers and fruit have been collected in October (Kellermann and Barker 2012).

As with other species in the genus, pollination is probably via insects and seed are dispersed limited distances by ants (Carter and Downe 2006). Seed has a hard coat, and is presumably stored in the soil until disturbance breaks this physical dormancy. The known subpopulation comprises a single-aged cohort, indicating germination was triggered by a disturbance event (D Duval pers.comm. 2018). Fire probably kills mature individuals while stimulating germination of soil-stored seed, although further research is required. Other species in the genus are reproductively mature at 1-4 years and can live for at least 45 years (Coates 1996; D Duval pers.comm. 2018). Generation length is estimated as 10-30 years (DEW 2020).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence (actual) Trend	4 km^2 (0.0001 km^2) Decreasing	High High
Area of occupancy (actual) Trend	4 km^2 (0.0001 km^2) Decreasing	High High
No. of mature individuals Trend	13 Decreasing	High High
No. of locations (key threat) Trend	1 (lack of recruitment) Stable	High High
No. of subpopulations Trend	1 Stable	High High
Generation length	10-30 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A2a	EN: >50% reduction observed within 3 generations (63% from 1995-2019); causes may not have ceased, are not well-understood and may not be reversible; based on direct observation (see also DEW 2020).
B1+2ab(i-v)	CR: EOO <100 km^2; AOO <10 km^2; severely fragmented and 1 location; and continuing decline observed and projected in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, number of mature individuals.
C1+2a(i,ii)	CR: <250 mature individuals; continuing decline observed and projected; <50 mature individuals in each subpopulation; 90-100% (100%) of mature individuals in one subpopulation.
D	CR: <50 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past*	n/a	n/a	n/a	Eighty-one percent of vegetation within the region has been cleared for agriculture (DEW 2020). Potentially suitable habitat for the species now occurs as small, isolated and often disturbed roadside remnants and the species is considered severely fragmented (DEW 2020).
Lack of disturbance/ recruitment *Ongoing*	Whole	Rapid	High	Recruitment of *S. fontis-woodii* has never been observed and the even-aged cohort indicates seeds germinated following disturbance. Disturbance is thought to break physical dormancy of soil-stored seed, as well maintain an open vegetation structure. Most remnant vegetation in the area occurs in small patches along roadsides that are rarely burnt, as fire frequency has decreased since colonisation (DEW 2020). Senescence is projected in the absence of managed disturbance.

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Invasive weeds *Ongoing*	Whole	Unknown	Unknown	Invasive weeds including bridal creeper and veldt-grass are present and may impact the species by increasing competition and altering fuel loads and thus fire regimes.
Grazing (feral) *Ongoing*	Whole	Unknown	Unknown	Rabbits and hares are present and may browse plants and seedlings. In 2018, all individuals were growing among other plants, which may have been protecting them from browsing impacts (D Duval pers.comm. 2019).
Infrastructure maintenance *Future*	Whole	Rapid	Medium	The only known subpopulation occurs on a roadside and is vulnerable to future maintenance activities.
Genetic diversity *Future*	Whole	Unknown	Unknown	Given the small population size the species may be vulnerable to genetic effects including inbreeding depression.

Current management

- There is no recovery plan for this species.
- This species is only known from a roadside that is not managed for conservation.
- Seed was collected from the population in 2006 and 2013 for storage at the Millennium Seed Bank and the SA Seed Conservation Centre (DEW 2020).
- A number of plants have been propagated by the SA Seed Conservation Centre, and 20-30 now are now growing in a seed orchard, from which additional seed has been collected (D Duval pers.comm. 2020). A small-scale translocation of >20 plants including some seedlings has occurred ca. 5 km from the natural subpopulation (D Duval pers.comm. 2020).
- A local school has been engaged in conservation activities including plant propagation, establishment of a seed orchard, plantings on their property and targeted surveys (Botanic Gardens of South Australia 2016).

Conservation objectives

- Monitor and maintain known subpopulation.
- Increase the number of self-sustaining wild subpopulations via translocation to other suitable habitat on secure tenure and surveys of additional habitat.
- Better understand the germination requirements of the species.
- Establish a large *ex situ* population for future translocation efforts.

Information required

Theme	Specific actions	Priority
Population surveys	Continue population monitoring to understand response to conservation actions and threats.	High
	Undertake further surveys to determine whether additional subpopulations exist, particularly after disturbance events.	High
Inappropriate disturbance regimes	Undertaken research to better understand the disturbance ecology of the species particularly in relation to germination.	High
Ex situ conservation/translocations	Determine habitat requirements and potential sites for translocation on secure tenure.	High
	Investigate feasibility of translocation and develop translocation plan.	High
Herbivory	Trial caging/fencing to examine the role of herbivory in limiting recruitment.	High

Management actions required

Theme	Specific actions	Priority
Infrastructure maintenance	Install markers to caution contractors working in the area of the species' presence.	High
Ex situ conservation/translocations	Maintain and expand the *ex situ* collection to represent the maximum range of genetic diversity possible.	High
	Propagate large numbers of individuals for future translocation attempts.	High
	Continue to implement translocation at Crawford site.	High
Habitat quality	Control invasive weeds within the subpopulation.	High
	Control vertebrate pests to minimise browsing impacts as required.	High
Extension and awareness	Ensure the Coorong District Council who manage the roadside is aware of the species' presence and their conservation obligations.	High
	Raise awareness with relevant stakeholders in attempt to locate additional subpopulations	Medium

Experts consulted

Daniel Duval and Angela Duffy.

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Spyridium furculentum W.R.Barker & Kellerman [RHAMNACEAE]
Forked spyridium

Spyridium furculentum growing at the Royal Botanic Gardens Victoria (image: Jo Lynch).

Overview

Spyridium furculentum occurs amongst a heavily cleared landscape and is not protected in the conservation estate. Two roadside subpopulations are presumed extinct, and others on private property are declining in association with phytophthora *Phytophthora cinnamomi* and drought. Long-term survival may depend on translocating the species to secure tenure, with an introduction that commenced in 2017 showing early signs of success.

Conservation status

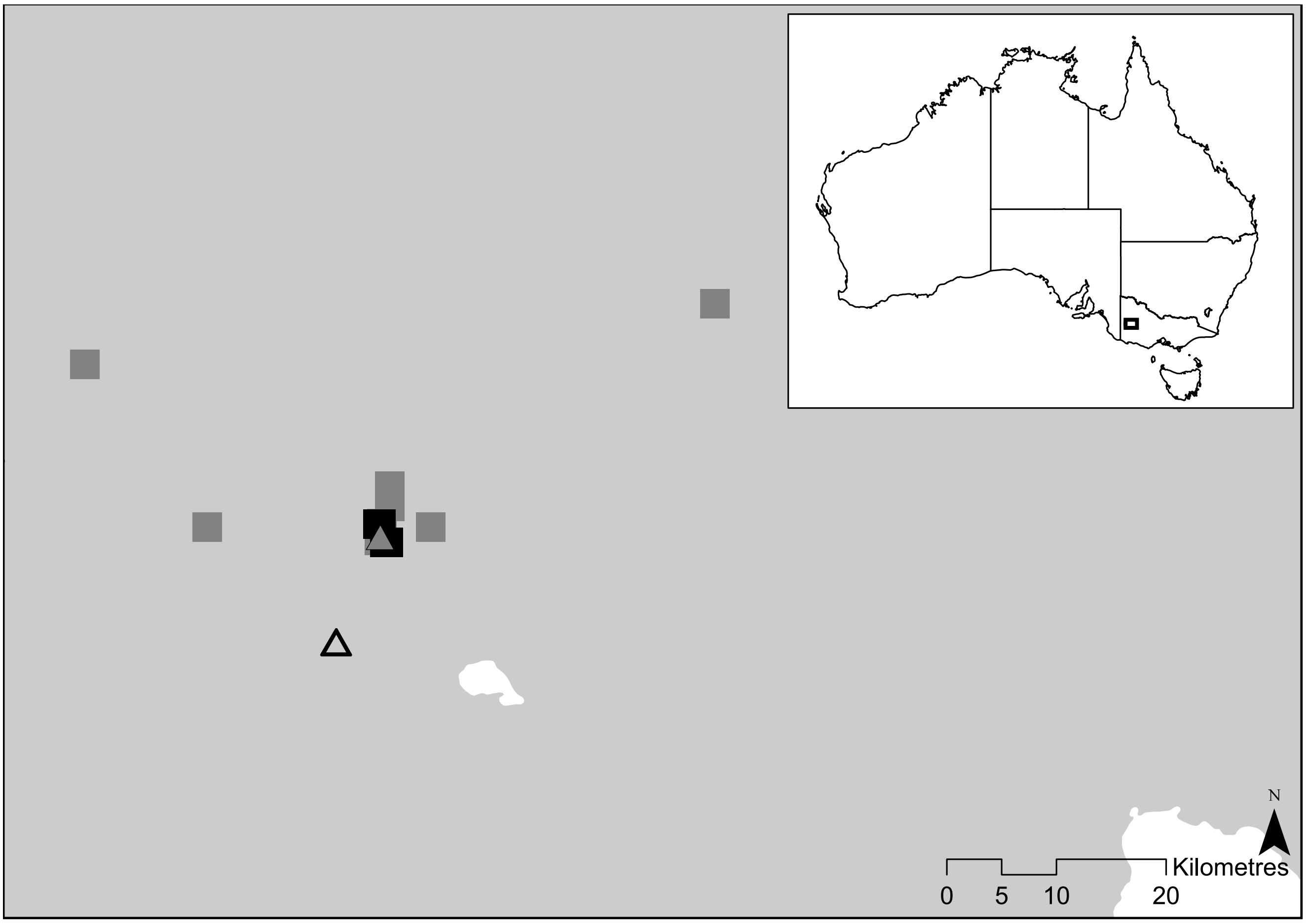
Environment Protection and Biodiversity Conservation Act 1999	Endangered
Flora and Fauna Guarantee Act 1988	Threatened
Advisory List of Rare or Threatened Plants in Victoria	Endangered
IUCN Red List (eligible)	Not listed (Critically Endangered)

Brief description

Shrub to 1.6 m high, young branchlets densely pubescent with stellate hairs that are initially rusty and become greyish (Walsh and Entwisle 1999; Kellermann and Barker 2012). Leaves are dark grey-green and Y-shaped with red-brown stipules at the base. Inflorescence a cluster of small, white-cream flowers to 10 mm wide surrounded by 2-5 densely hairy, pale-green white floral leaves. Fruit dark brown and ovoid, 2-2.5 mm long and 1.4-1.6 mm wide. Each fruit comprises three papery fruitlets with brown-black seeds to 1.9 mm long and 1.1 mm wide. *Spyridium furculentum* is similar to *S. halmaturinum* and *S. fontis-woodii* and distinguished by deeply emarginate, bifid or Y-shaped leaves and its upper leaf surface becoming glabrous (Kellermann and Barker 2012).

Distribution

Spyridium furculentum is known from a very restricted distribution near the southern boundary of the Little Desert, between Goroke and Dimboola in the Murray Darling Depression bioregion of Victoria (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and Environment 2012; Department of Environment, Land, Water and Planning 2020).



Current (black squares) and historic (grey squares) distribution of *Spyridium furculentum* in the Murray Darling Depression bioregion (shaded grey) of western Victoria (AVH 2020; DAWE 2012; DELWP 2020). Two translocations have occurred including an introduction that is not yet self-sustaining (hollow triangle) and an augmentation (grey triangle) with no surviving plants (Silcock *et al.* 2019).

Population estimate and trends

Spyridium furculentum was first collected from Cooack Parish at the southern border of the Little Desert in 1894 (AVH 2020). In 2008, there were 500 individuals across five subpopulations (Threatened Species Scientific Committee 2008), which declined to a single plant on a roadside and 200 individuals across three subpopulations on private property by 2017 (N Walsh pers.comm. 2020). Currently, there are three extant subpopulations with <250 mature individuals. Seedlings and juveniles have been observed but are rare (P Rudolph pers.comm. 2020).

In 2017, a translocated subpopulation was established on private property, but it is not yet self-sustaining. A small augmentation of a roadside subpopulation occurred in 1992, although no plants survived (Silcock *et al.* 2019). Despite the limited remaining habitat, three subpopulations were located during targeted surveys from 2006-2017, indicating additional small subpopulations may be located in the future (N Walsh pers.comm. 2020). Given declines are simultaneously affecting all individuals/subpopulations, which occur in close proximity, the species is considered to occur at one location (IUCN 2019).

Spyridium furculentum monitoring data, 2006-2018 (Carter and Downe 2006; TSSC 2018; N Walsh pers.comm. 2017).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Cooack Fire Access Road (roadside)	2006: 9 2008: 9 2018: 0	Presumed extinct
2 Cooack Settlement Road (roadside)	2006: 120 2008: 120 2016: 1 2018: 0	Presumed extinct
3 Cooack (private property 1)	2006: 35 2008: 35 2016: 0 (some dead plants)	Decreasing
4 Cooack (private property 2)	2008: 380+ 2016: ca. 200	Decreasing
5 Cooack (private property 3)	2008: 50+	Unknown
6 (T) Greening Australia property (private property managed for conservation)	2017: 174T 2018: 110T 2019: 95T	Not self-sustaining

Translocated individuals/subpopulation (T).

Habitat and ecology

Spyridium furculentum occurs on aeolian deep brown-white sandy rises amongst heathy mallee woodland (Carter and Downe 2006). Dominant species include *Eucalyptus arenacea, Callitris rhomboidea, Allocasuarina muelleriana* and *E. incrassata.* Associated heath species include *Astroloma conostephioides, Brachyloma daphnoides, Calytrix alpestris, C. tetragona, Hibbertia sericea, Leucopogon ericoides, Leptospermum myrsinoides, Correa reflexa, Phebalium stenophyllum* and *Persoonia juniperina* (AVH 2020; Carter and Downe 2006).

As with other species in the genus, *S. furculentum* is probably an obligate-seeder, with mature individuals killed by fire that also stimulates germination of soil-stored seed (Coates and Kirkpatrick 1999). Recruitment has also been observed after roadworks, indicating the species may respond to other disturbance mechanisms (Carter and Downe 2006). Seed dispersal is thought to be poor and *Spyridium* spp. cannot regenerate vegetatively (Coates and Kirkpatrick 1999; Carter and Downe 2006). Due to the apparently persistent seedbank, extreme fluctuations are not considered likely (IUCN 2019).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	12 km^2 Decreasing	Medium High
Area of occupancy (actual) Trend	12 km^2 (<0.1 km^2) Decreasing	Medium High
No. of mature individuals Trend	<250 Decreasing	Medium High
No. of locations (key threat) Trend	1 (all threats) Decreasing	Medium High
No. of subpopulations Trend	3 Decreasing	Medium High
Generation length	Unknown	Low
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A	DD: insufficient data available to reliably estimate population reduction relative to generation length.
B1ab(i-v)	CR: EOO <100 km^2; severely fragmented and 1 location; and continuing decline observed in EOO, AOO, area/extent and quality of habitat, number of locations and subpopulations, and number of mature individuals.
C2a(i)	CR: <250 mature individuals; continuing decline observed and projected; and 90-100% of mature individuals in one subpopulation.
D	EN: <250 mature individuals.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and ongoing*	Whole	Rapid	High	Land clearing has reduced and fragmented the available habitat of the species. The species is now severely fragmented as all subpopulations are small and isolated by cleared land. As all subpopulations are on roadsides or private property, further habitat loss may occur in the future. Roadworks to accommodate larger farm machinery frequently result in damage and local destruction of remnant roadside vegetation in the area (N Walsh pers. comm. 2020).
Introduced pathogens *Ongoing*	Whole	Rapid	High	*Spyridium furculentum* is susceptible to phytophthora *Phytophthora cinnamomi*, which has been documented at all subpopulations. Phytophthora is thought to be the primary threat causing current population declines (N Walsh pers.comm. 2020).
Drought/climate change *Ongoing and future*	Whole	Rapid	High	Recent declines coincide with a period of drought. Drought-induced deaths have been exacerbated due to the presence of phytophthora (N Walsh and P Rudolph pers.comm. 2020). Longer dry periods and hotter summers are predicted under climate change with medium confidence (Timbal *et al.* 2015).
Grazing (feral) *Ongoing*	Majority	Rapid	Medium	Rabbits are abundant at some subpopulations and are known to target seedlings (N Walsh pers. comm. 2020).
Infrastructure maintenance *Ongoing*	Minority	Rapid	Medium	Roadside subpopulations are vulnerable to road widening, grading, drainage channel construction, slashing and herbicide application; both known roadside subpopulations are signed but presumed extinct (see habitat loss).
Inappropriate fire regimes *Ongoing*	Whole	Unknown	Unknown	Fire or disturbance is probably required for recruitment. The absence of fires to stimulate seed germination may cause population declines (Carter and Downe 2006).
Grazing (domestic) *Ongoing*	Majority	Negligible	Negligible	Three subpopulations occur on private grazing property. No recent evidence of damage to the subpopulations has been observed, and cattle mostly graze on adjacent pasture (N Walsh pers. comm. 2020).

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Invasive weeds *Ongoing*	Whole	Negligible	Negligible	Sites where the species occurs are largely native vegetation; some weeds are present but effects on the species have not been documented.
Human activities *Future*	Majority	Slow	Low	Apiarists collect honey from beehives amongst subpopulations of *S. furculentum* and could trample seedlings. Broombush is harvested from the roadside habitats and trampling may occur during this process.

Current management

- Recovery actions have been identified (Carter and Downe 2006; TSSC 2016).
- Three additional subpopulations were located during targeted surveys of nearby roadsides and private property from 2006-2017 (N Walsh pers.comm. 2020).
- In 1992, a re-introduction attempt of eight plants to a roadside remnant failed (N Walsh pers.comm. 2017).
- Seed have been collected (funded by DELWP), stored and propagated at the Royal Botanic Gardens Victoria, with 174 individuals translocated to a Greening Australia property in 2017. Early signs of success have been observed, with 95 plants (55%) alive in 2019 including 89 that were flowering (P Rudolph pers.comm. 2020).
- All subpopulations occur on roadsides or private property that are not managed for conservation.

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Increase the number of mature individuals and subpopulations in the wild via improving habitat quality and translocating the species to secure tenure.

Information required

Theme	Specific actions	Priority
Population surveys	Regularly monitor subpopulations to understand population demographics, trends in response to management activities and impacts of threats.	High
Life history and ecology	Undertake research to better understand the life history and ecology of the species including conservation genetics, pollination, seed production and viability, germination requirements and habitat suitability for translocations.	High
Inappropriate fire regimes	Determine a suitable fire regime for the species to increase the number of mature individuals.	High
Introduced pathogens	Investigate impacts of phytophthora in the field to better understand impacts and management actions.	High

Management actions required

Theme	Specific actions	Priority
Introduced pathogens	Implement and maintain disease hygiene measures at all subpopulations to reduce impact of phytophthora.	High
Habitat protection	Protect known habitat of species in appropriate conservation agreements.	High
Infrastructure maintenance/ recreation/human activities	Fence and mark any subpopulations found on roadsides to protect from road maintenance activities and minimise damage from apiarists and commercial plant harvesters.	High
Ex situ conservation/translocations	Continue implementing translocation and identify potential sites for future translocation that occur on secure tenure.	High
	Maintain and expand *ex situ* propagation program, including seed-banking RBGV.	High
Grazing	Fence known subpopulations on private land to minimise impacts of grazing.	Medium
Extension and awareness	Raise awareness of the species with local landholders and other stakeholders (apiarists, road maintenance workers, commercial plant harvesters) to protect the species.	Medium

Experts consulted

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Zieria exsul Duretto & P.I.Forst. [RUTACEAE]
Banished stinkbush


Zieria exsul flowers and foliage (left; image: Glenn Leiper) and straggly plant habit in heath habitat (right; image: Jen Silcock).

Overview

Zieria exsul occurs on the Sunshine Coast in south-eastern Queensland and its habitat has been extensively cleared for agriculture, housing and infrastructure. The four known subpopulations occur in small remnants that are subject to a variety of threats associated with ongoing urbanisation. The largest subpopulation contains 95% of known mature individuals and occurs along a proposed transport corridor. No reserves are actively managed for this species, whose life history and disturbance requirements are poorly understood.

Conservation status

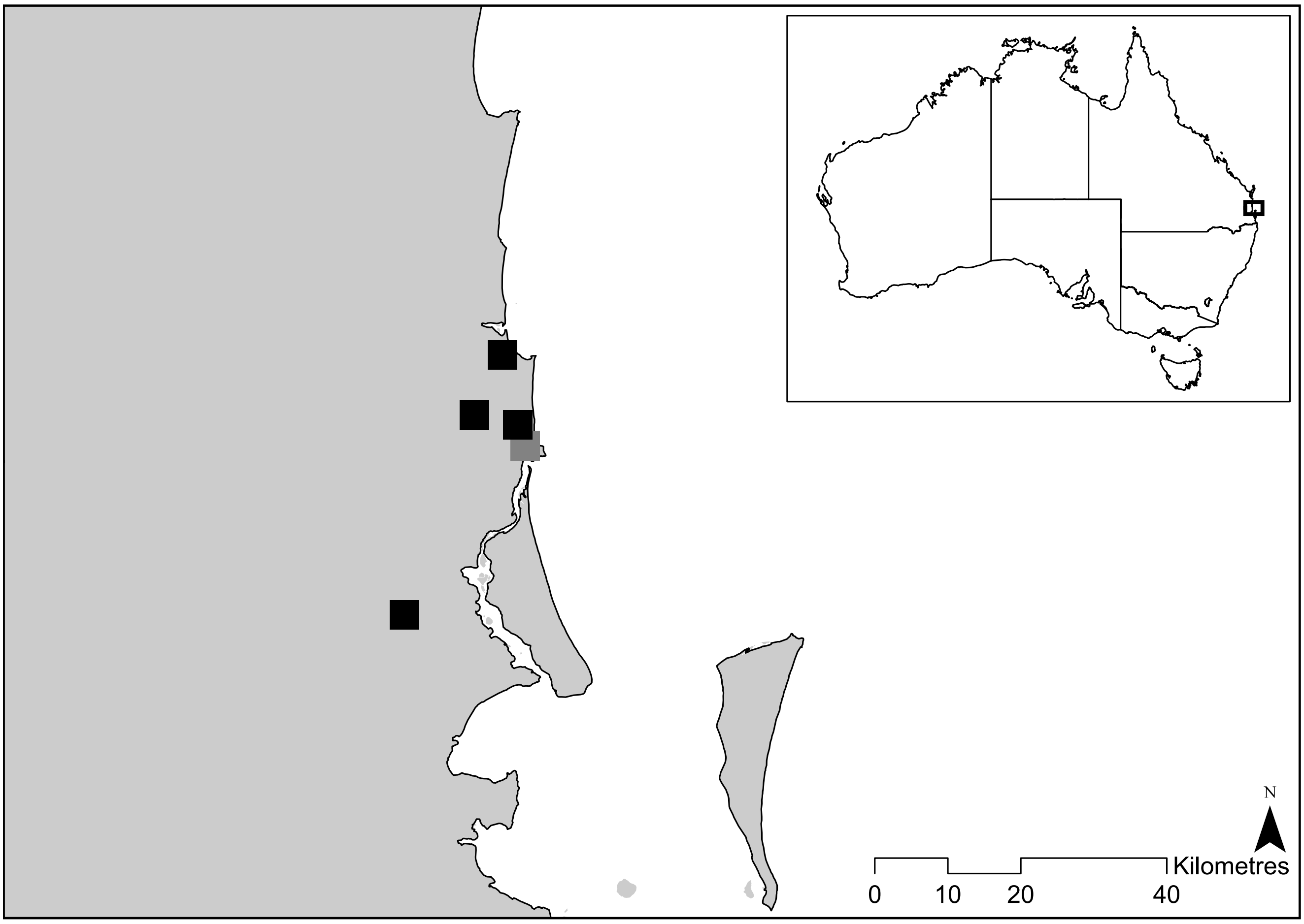
Environment Protection and Biodiversity Conservation Act 1999	Not listed
Nature Conservation Act 1992	Critically Endangered
IUCN Red list (eligible)	Not listed (Critically Endangered)

Brief description

Spindly to erect perennial shrub to 1 m tall covered with sparse to moderately dense hairs and aromatic leaves (Duretto and Forster 2007). Leaves discolorous and trifolioate; the terminal leaflet is 10-16 mm long and 2.5-5 mm wide, while the lateral leaflets are 5-12 mm long and 2-4 mm wide. Inflorescence axillary with 1-2 white flowers with four elliptic petals and triangular sepals. Seeds dark brown, oblong-ovoid, 2.8-3 mm long and 1.4-1.5 mm wide (Duretto and Forster 2007). The species is distinct and unlikely to be mis-identified. At Elimbah, the plants have fewer glands on the foliage (P Forster pers.comm. 2020).

Distribution

Zieria exsul is known from Buderim, Palmview, Currimundi and Elimbah on the Sunshine Coast, in the South Eastern Queensland bioregion (Australasian Virtual Herbarium 2020; Department of Agriculture, Water and Environment 2012). A record from Caloundra collected in the 1990s (Queensland Herbarium 2020) is considered extinct (A Bean pers.comm. 2020).



Current (black squares) and historic (grey square) distribution of *Zieria exsul* in the South Eastern Queensland bioregion (shaded grey) in Queensland (AVH 2020; DAWE 2012; QH 2020).

Population estimate and trends

Zieria exsul is currently known from <500 mature individuals in four subpopulations: Buderim, Palmview, Currumundi and Elimbah. All sites comprise single subpopulations (although the Buderim subpopulation is now fragmented into multiple remnants), mostly with very small numbers of plants. Individual plants can be difficult to distinguish due to roots and branches sprawling under dense leaf-litter (J Silcock pers.comm. 2020). Time-series monitoring has not been undertaken, but all subpopulations are likely to be declining due to threats associated with urbanisation.

The Buderim subpopulation comprises an estimated 450 mature individuals that occur in small patches spread over ca. 2 km of narrow and disturbed remnants. The remnants encompass a road reserve, State land and freehold land between Mountain Creek State High School, and the intersection of the Sunshine Motorway and Mooloolaba Road. *Zieria exsul* was described as 'common' when first collected here in 1992, and 34 plants including 30 seedlings were recorded in one patch in 2002. Three patches of 600 (estimated to be comprised of 400 mature individuals and >150 seedlings), 11 and 3 plants (all mature individuals) were located in 2020, and it is likely that other historical records of <5 plants from 2009-2017 persist.

Four individuals have been located between 2014-2017 at separate sites along tracks and powerlines in Palmview Conservation Park, where the species seems to be extremely rare. Eleven plants were found at Currimundi on private freehold land in 2020 (J Silcock pers.obs. 2020) and about 12 on road reserve at Elimbah (C Vaughan pers.comm. 2020). The site of a 1997 collection in Caloundra is now housing estate (A Bean pers.comm. 2020), and no further plants were found in surveys of remaining habitat in the vicinity in 2020 (J Silcock pers.comm. 2020).

There have been few systematic targeted surveys for *Z. exsul*, but a high level of botanical collection in the region. The species can be difficult to detect and the recently located subpopulation south of its known range and a large patch found at Bunderim, indicates other small subpopulations may exist (C Vaughan pers.comm. 2020).

Habitat and ecology

Zieria exsul occurs sparsely in numerous heath and open-forest habitats. The majority of records are from sandy soils among wallum heathland and woodland ecotones, often between continuously wet areas and higher well-drained areas (P Forster pers.comm. 2019). At Currimundi *Z. exsul* occurs in open *Allocasuarina littoralis* riparian woodland along Currimundi Creek (QH 2020). The historical Caloundra record was from mixed eucalypt/casuarina woodland (QH 2020). Associated species include *Corymbia trachyphloia, C. intermedia, Syncarpia glomulifera, Melaleuca quinquenervia, Eucalyptus siderophloia* and *E. racemosa* (QH 2020).

Zieria exsul flowers from spring to autumn and fruit have been collected in March and May (QH 2020). The species is fast-growing and short-lived, with individuals reaching maturity after 2 years and living for <10 years (P Forster pers. comm. 2019). Generation length is estimated to be 4 years. *Zieria exsul* is thought to germinate after fire or other disturbance before being shaded-out as surrounding vegetation recovers. The species also germinates in absence of disturbance, with numerous young plants observed at Currimundi, Elimbah and Buderim in 2020 (J Silcock, C Vaughan, pers.comm. 2020) and several seedlings emerging beneath a parent plant in cultivation (G Leiper pers. comm. 2019). Plants typically occur in small clumps, suggesting dispersal is limited. The species propagates readily from cuttings (G Leiper pers.comm. 2019).

Zieria exsul may represent a 'neo-endemic' species that has evolved from a stabilised hybrid between *Z. laxiflora* and *Z. minutiflora* (Duretto and Forster 2007). However, it typically co-occurs with *Z. minutiflora* only, except at Elimbah were both species are present (C Vaughan pers.comm. 2020). *Zieria exsul* produces fertile seed that does not demonstrate introgression to either parent (P Forster pers.comm. 2019).

IUCN Red List assessment data

	Estimate	Reliability
Extent of occurrence Trend	130 km^2 Decreasing	Medium High
Area of occupancy (actual) Trend	24 km^2 (2 km^2) Decreasing	Medium High
No. of mature individuals Trend	<500 Decreasing	Medium High
No. of locations (key threat) Trend	4 (habitat loss/infrastructure maintenance) Decreasing	Medium High
No. of subpopulations Trend	4 Decreasing	High High
Generation length	4 years	Medium
Extreme fluctuations	Not documented	Medium
Severely fragmented	Yes	High
Continuing decline	Observed and projected	High

Current eligibility against IUCN Red List criteria

IUCN criterion	Criteria eligibility
A3b	CR: >80% population reduction projected in the future within 3 generations (12 years); based on an index of abundance appropriate to the taxon and decline in AOO and habitat quality.
B1+2ab(i-v)	EN: EOO <5000 km^2; AOO <500 km^2; severely fragmented and 4 locations; and continuing decline observed in EOO, AOO, area/extent/quality of habitat, number of locations and mature individuals.
C2a(ii)	EN: <500 mature individuals; continuing decline observed and projected; and 95% of mature individuals in one subpopulation.
D	VU: <1000 mature individuals; <5 locations; and plausible future threat that could drive taxon to CR or EX in a very short time.
E	DD: insufficient data available to reliably estimate extinction probability.

Threats

Threat and timing	Scope	Severity	Threat impact	Evidence and justification
Habitat loss *Past and ongoing*	Majority	Very rapid	High	The habitat of *Z. exsul* has been decimated for urbanisation, forestry and agriculture. Remnant subpopulations are tiny, isolated by cleared land and considered severely fragmented. Only one subpopulation is protected in conservation estate. The Elimbah subpopulation and part of the Buderim subpopulation will be impacted during impending roadworks. Although propagation and mitigation translocation for *ex situ* conservation in botanical gardens will be undertaken (C Vaughan pers.comm. 2020), the species has not been translocated before and long-term persistence cannot be guaranteed (Silcock *et al.* 2019). The largest subpopulation (Buderim) occurs in the corridor proposed for the Sunshine Coast Mass Transit Project, flagged for construction by 2024 (Sunshine Coast Regional Council 2020). Destruction of this subpopulation would result in a 95% population reduction within three generations (12 years).
Infrastructure maintenance *Ongoing*	Majority	Very rapid	High	Two of four subpopulations persist in small roadside remnants that will be impacted by impending roadwork (see above) and remain vulnerable to ongoing maintenance. The largest subpopulation, containing 95% of mature individuals, occurs under powerlines and along a future transport corridor. The species occurs at four locations, as habitat loss associated with urbanisation occurs at the land tenure/ subpopulation scale.
Invasive weeds *Ongoing*	Minority	Rapid	Medium	Parts of the Buderim subpopulation have been overrun by weeds, notably Singapore daisy and lantana, and *Z. exsul* is persisting in small patches where weed abundance is lower. Few weeds are present at the other subpopulations.
Recreation and urban impacts *Ongoing*	Majority	Slow	Low	All subpopulations occur in heavily and increasingly urbanised areas. The Currimundi subpopulation occurs 10 m from a busy concrete walking path with informal footpaths within 1 m of plants.
Inappropriate disturbance regimes *Future*	Whole	Unknown	Unknown	The majority of plants occur singly or in small groups in narrow remnants where fire is suppressed or no longer possible. The species is thought to rely on fire or other disturbance to maintain its open habitat and facilitate germination, but its disturbance ecology and requirements remain poorly-understood.
Genetic diversity *Future*	Whole	Unknown	Unknown	Subpopulations are fragmented with few extant individuals present at any one time. Genetic diversity is thought to be low overall (P Forster pers.comm. 2019).

Current management

- There is no recovery plan for this species.
- This species is protected in Palmview CP, but no active management is occurring.
- Some individuals are being grown in cultivation where they readily produce fruit and fertile seed that germinates (G Leiper pers.comm. 2019).
- Plants impacted by roadworks at Elimbah and Buderim are being translocated to suitable habitat by the Department of Transport and Main Roads, where additional propagated plants will be introduced (C Vaughan pers. comm. 2020).
- A proposal has been made to plant 48 individuals propagated from the Elimbah subpopulation in suitable habitat within the Moreton Bay Regional Council local government area. The site will have a protective mechanism (e.g. a Voluntary Declaration under the *Vegetation Management Act 1999*) to limit the potential for future clearing. The same protective mechanism will be placed over any individuals propagated from the impacted Buderim subpopulation (C Vaughan pers.comm. 2020).
- Cuttings from the Elimbah subpopulation are being grown for *ex situ* conservation in Queensland botanical gardens (C Vaughan pers.comm. 2020).

Conservation objectives

- Monitor and maintain known subpopulations.
- Protect habitat of known subpopulations in appropriate conservation agreements.
- Increase the number of individuals and subpopulations by translocation into secure tenure.

Information required

Theme	Specific actions	Priority
Population surveys	Ongoing monitoring of extant populations to determine population trends and dynamics in response to threats and management actions.	High
	Further searching in remnant habitat, particularly along Currimundi Creek and in the vicinity of Sugarbag Road in Caloundra.	High
Life history and ecology	Undertake research to better understand the life history, ecology and germination requirements of the species including conservation genetics, pollination, seed production and viability, germination requirements, and habitat suitability for translocations.	High
Inappropriate fire/disturbance regimes	Undertake research to better understand the optimum fire regime and disturbance requirements for the long-term persistence of the species.	High

Management actions required

Theme	Specific actions	Priority
Habitat protection	Protect habitat of known subpopulations along with other suitable habitat in appropriate conservation agreements where possible.	High
Inappropriate fire regimes	Implement appropriate fire regimes to increase habitat quality and stimulate germination at known subpopulations.	High
	Conduct burns at historic locations in attempts to stimulate germination.	High
Ex situ conservation/translocations	Maintain and expand *ex situ* subpopulation to represent the maximum range of genetic diversity possible in preparation for future translocation.	High
	Translocate individuals to historic locations or other suitable and secure tenure.	High
Invasive weeds	Control weeds at the Buderim subpopulation.	High

Experts consulted

Colin Vaughan, Paul Forster, Glenn Leiper, Lui Weber, Tony Bean and Jen Silcock.

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5. Recovery actions, research and management priorities

5.1 Imperilled species

Most of the 50 imperilled species have strong recovery prospects with intensive site-based management, often complemented by *ex situ* conservation and translocation efforts. For many species, this will involve a continuation and expansion of existing recovery efforts. Some species, however, have become restricted to a tiny number of plants at one or two degraded sites (e.g. *Acacia leptoneura, Caladenia pumila, Commersonia erythrogyna* and *Daviesia cunderdin*, which are all known from <5 mature individuals in highly modified habitat), and long-term recovery is wholly dependent on *ex situ* options. The observed decline of narrow-range Victorian mountain endemic *Epilobium brunnescens* subsp. *beaugleholei* is largely due to natural events and recovery options are mostly limited to monitoring and establishing *ex situ* seedbanks and living collections.

Monitoring is a high priority for all imperilled species to inform population trends and response to threats and recovery actions. Given the restricted distribution and low population abundance of most imperilled species, monitoring will involve complete censuses conducted at regular intervals using repeatable monitoring techniques appropriate to each species. Most imperilled species would benefit from targeted research into their life history and ecology, particularly in terms of seed biology and germination requirements, seed bank ecology, appropriate disturbance/fire regimes, and susceptibility and responses to disease. Taxonomic work is required to formally describe three imperilled species: *Grevillea* sp. Gillingarra (R.J. Cranfield 4087), *Lenwebbia* sp. (Main Range P.R. Sharpe+4877) and *Pultenaea* sp. Genowlan Point (NSW 417813). Emerging molecular systematics and taxonomic research shows that some orchid species included in the Action Plan (including *Caladenia busselliana* and *Calochilus richiae*) are difficult to distinguish based on the genetic markers so far investigated (H Zimmer pers.comm. 2020). In cases where a taxon is also difficult to distinguish morphologically, further work is required to clarify taxonomic status (H Zimmer pers.comm. 2021). Clear definition and treatment of such taxa will underpin future conservation planning.

Twenty-nine imperilled species have at least part of their population protected in a reserve managed for conservation, although for 11 of these the reserves are <10 hectares and situated in highly-fragmented landscapes. Thirty-four species are restricted to small remnants (reserves, private land, road and rail reserves) in highly cleared and modified habitats. Twenty of these occur predominantly on road and/or rail reserves, highlighting the need to enhance the protection of these linear remnants, and for their appropriate management (Tulloch *et al.* 2016). Thirty species occur wholly or partly on private land, and halting further habitat loss through strengthening legislative protection and securing perpetual conservation agreements to support site-specific management is a high priority.

The most common recovery actions required to abate population declines fall under the broad banner of habitat protection, management and restoration; encompassing protection from feral, native and/or domestic herbivores (a high priority for 28 species), invasive weed control (19 species), protection from infrastructure maintenance activities (14 species), and disease management (14 species). For species affected or potentially affected by *P. cinnamomi*, this involves site hygiene measures (e.g. reducing access, foot washing facilities), phosphite spraying and ongoing monitoring of impacts, including interactions with other threats such as fire and grazing. For the five species imperilled due to myrtle rust, recovery options are currently limited to ongoing monitoring, collection of cuttings for *ex situ* propagation and potential future translocation, and research relating to the genomics of the myrtle rust pathogen, potential identification of rust-resistant genotypes, and efficacy of possible management actions to maintain wild subpopulations (Makinson *et al.* 2020).

Fire management is a high priority for 33 species, including 28 that require planned burns or other active disturbance to stimulate recruitment and/or reduce competition from surrounding vegetation. The 2019-20 wildfires stimulated recruitment of four imperilled New South Wales species: *Gentiana bredboensis, Hibbertia circinata, Pimelea cremnophila* and *P. venosa*. Despite this, all remain known from tiny populations and require ongoing post-fire monitoring and management to ensure their persistence.

Extension and liaison with stakeholders and the broader community to manage existing subpopulations and/or detect new subpopulations is a high priority for 10 species, and medium priority for a further 22 species.

Ex situ collections (including seed banking, seed orchards and/or living collections in botanic gardens) for insurance and potential future translocation have been established for all except 10 imperilled species. Translocations have been attempted for 22 species, and are a high priority for a further 20. Some translocated plants of 16 species are surviving, although there has been no recruitment of 14 species. For four species the numbers of surviving translocated plants are so low that the chances of establishing a self-sustaining subpopulations are minimal (Silcock *et al.* 2019). Translocated *Borya mirabilis* plants in Victoria had survived and were recruiting vegetatively, but lack of site maintenance resulted in the death of all plants by 2019 (N Reiter pers.comm. 2020). *Senecio behrianus* is the only species where translocated plants have successfully recruited and are still surviving, in this case vegetatively at five sites (D Cook pers.comm. 2020), although plants have been in the ground for <5 years and were not included in IUCN assessments. These results highlight that translocation success is far from assured even with long-term commitment, early plant performance may not reflect longer-term performance, and that translocations must be implemented in conjunction with *in situ* recovery of wild subpopulations and *ex situ* conservation (Dillon *et al.* 2018; Monks *et al.* 2019; Silcock *et al.* 2019).

Conservation listings underpin funding priorities as well as providing a level of protection from land clearing and development activities. Correcting misalignments between jurisdictions (see Section 3.3) and achieving comprehensive and up-to-date extinction risk assessments for Australia's vascular plants (Alfonzetti *et al.* 2020) is an urgent priority to advance plant conservation.

5.2. Poorly-known species

Numerous potentially imperilled species were excluded from this Action Plan due to a lack of time-series monitoring data to document declines, or a lack of survey effort across the entire range of the species. For example, the long-lived trees *Atalaya collina* and *Decaspermum struckoilicum* each occur in two small remnants of dry rainforest on private land in the South Eastern Queensland and Brigalow Belt bioregions, respectively. These remnants are vulnerable to weed invasion and fire incursion and both species are suspected to be declining, but long-term monitoring data are needed to confirm this trend. The shrub *Bossiaea peninsularis* is known from two small subpopulations on roadside remnants in South Australia and is suspected to be declining due to numerous threats, but there has been no population monitoring or recent targeted surveys (D Duval pers.comm. 2020). Similarly, preliminary field surveys have found *Rhodamnia arenaria*, which is restricted to the rainforests of Cape York, is extremely susceptible to myrtle rust dieback (J Radford-Smith pers. comm. 2020). However, its habitat is largely inaccessible and the larger, southern subpopulation remains unsurveyed. The species was therefore omitted from the Action Plan as severe declines could not be confirmed across the population.

The impacts of the 2019-20 wildfires on threatened plants are still being documented and are likely to be variable depending on the disturbance ecology of the species. Some apparently rare flora are likely to germinate *en masse* following fire, which is an integral component of their life cycle. Other species that inhabit fire-refugia may have undergone significant declines due to unprecedented burn incursion. Surveys to date indicate some threatened flora that occur in sclerophyllous habitats are regenerating and have even benefited from the disturbance (G Phillips pers. comm. 2020). However targeted surveys are yet to be undertaken for many highly restricted species that had 100% of their habitat burnt in high-intensity fires, such as *Acacia saxicola* (Qld) and *Westringia cremnophila* (Vic) (M Laidlaw, J Morgan pers.comm. 2020). Most of the fire-sensitive rainforest habitat of *Auranticarpa edentata* at Forty Mile Scrub National Park in north Queensland was incinerated in 2020 and the survival of the species requires urgent evaluation.

Large numbers of highly-restricted ground orchids in the genera *Caladenia, Diuris* and *Prasophyllum*, as well as lesser-known genera such as *Danhatchia*, are known from very small numbers of plants in one or two locations (Swarts and Dixon 2009). However, members of these genera are cryptic and fluctuate seasonally in emergence and flowering, making trends difficult to detect without long-term data. Short-lived forbs can also be cryptic and experience extreme fluctuations in relation to seasonal conditions and disturbance, making inference of long-term trends difficult. *Cardamine gunnii* and *C. tryssa* are known from tiny populations in modified wetland habitats in southern Australia, and are facing threats from weeds, altered hydrology and climate change. Both are considered vulnerable to extinction but can be abundant in some seasons and require further surveys and monitoring to confidently assess population trends (N Walsh pers.comm. 2018).

There are numerous species that have not been seen in recent decades, e.g. *Habernaria harroldii* in south-eastern Queensland, *Gentiana baeuerlenii* in south-eastern NSW, *Haloragis scoparia* in south-western Australia, and the aptly-named *Homoranthus elusus* in the New England Tablelands of NSW. All of these species occur in modified habitats and face ongoing threats. Such species are obviously of the highest priority for targeted surveys, research and monitoring.

5.3. Taxonomic uncertainty

Some potentially imperilled species remain taxonomically uncertain, notably numerous ground orchids. Orchids are disproportionately represented on the list of imperilled plants, however their taxonomy is complex and subject to ongoing debate and research (H Zimmer pers.comm. 2021). Six taxa identified as being 'category 5' by Silcock & Fensham (2018) have subsequently had their taxonomy questioned: *Caladenia macroclavia* (SA), *C. lindleyana* (Tas), *Diuris byronensis* (NSW), *Eriochilus paludosus* (SA), *Pterostylis psammophila* (SA) and *Spiranthes elytra* (SA). The taxonomic status of these taxa, and a suite of other ground orchids, needs to be validated before any conservation actions can be determined. Other examples of rare taxa that fall into this category include *Banksia vincentia* (NSW) and *Pimelea* sp. Tunbridge (TAS).

5.4. Future directions

This Action Plan highlights five key areas that will underpin and advance conservation of the most imperilled elements of Australia's unique flora:

1. Continue and expand site-based conservation of all imperilled species to prevent diminishment of our rich floristic heritage. Numerous recent examples show that targeted and adequately-funded recovery actions have mitigated population declines, and in some cases facilitated quite rapid increases in population abundance for some highly threatened species.
2. Ensure that monitoring is consistent, repeatable and uses species-appropriate methods, to allow confident interpretation of population trends in response to management actions.
3. Pursue targeted surveys and research on poorly-known species where threats and/or declines are inferred or suspected.
4. Support taxonomic research to clarify the status of potentially imperilled species.
5. Review this Plan in 10 years to inform the trajectory of our most imperilled plant species, encompassing the plants included here and others that may subsequently be assessed as imperilled.

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Further information:

http://www.nespthreatenedspecies.edu.au

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