Australian Government
Department of Agriculture, Water and the Environment

Consultation on Species Listing Eligibility and Conservation Actions

Grevillea burrowa (Burrowa grevillea)

You are invited to provide your views and supporting reasons related to:

1) the eligibility of *Grevillea burrowa* (Burrowa grevillea) for inclusion on the EPBC Act threatened species list in the Critically Endangered category; and

2) the necessary conservation actions for the above species.

The purpose of this consultation document is to elicit additional information to better understand the status of the species and help inform on conservation actions and further planning. As such, the below draft assessment should be considered to be **tentative** as it may change following responses to this consultation process.

Evidence provided by experts, stakeholders and the general public are welcome. Responses can be provided by any interested person.

Anyone may nominate a native species, ecological community or threatening process for listing under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or for a transfer of an item already on the list to a new listing category. The Threatened Species Scientific Committee (the Committee) undertakes the assessment of species to determine eligibility for inclusion in the list of threatened species and provides its recommendation to the Australian Government Minister for the Environment.

Responses are to be provided in writing by email to:
species.consultation@environment.gov.au

Please include species scientific name in Subject field.

or by mail to:

The Director
Bushfire Affected Species Assessments Section
Department of Agriculture, Water and the Environment
John Gorton Building, King Edward Terrace
GPO Box 858
Canberra ACT 2601

Responses are required to be submitted by 29 July 2022.

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General background information about listing threatened species

The Australian Government helps protect species at risk of extinction by listing them as threatened under Part 13 of the EPBC Act. Once listed under the EPBC Act, the species becomes a Matter of National Environmental Significance (MNES) and must be protected from significant impacts through the assessment and approval provisions of the EPBC Act. More information about threatened species is available on the department's website at: https://www.awe.gov.au/environment/biodiversity/threatened.

Public nominations to list threatened species under the EPBC Act are received annually by the department. In order to determine if a species is eligible for listing as threatened under the EPBC Act, the Threatened Species Scientific Committee (the Committee) undertakes a rigorous scientific assessment of its status to determine if the species is eligible for listing against a set of criteria. These criteria are available on the Department's website at: http://www.awe.gov.au/system/files/pages/d72dfd1a-f0d8-4699-8d43-5d95bbb02428/files/tssc-guidelines-assessing-species-2021.pdf.

As part of the assessment process, the Committee consults with the public and stakeholders to obtain specific details about the species, as well as advice on what conservation actions might be appropriate. Information provided through the consultation process is considered by the Committee in its assessment. The Committee provides its advice on the assessment (together with comments received) to the Minister regarding the eligibility of the species for listing under a particular category and what conservation actions might be appropriate. The Minister decides to add, or not to add, the species to the list of threatened species under the EPBC Act. More detailed information about the listing process is at: https://www.awe.gov.au/environment/biodiversity/threatened/nominations.

To promote the recovery of listed threatened species and ecological communities, conservation advices and where required, recovery plans are made or adopted in accordance with Part 13 of the EPBC Act. Conservation advices provide guidance at the time of listing on known threats and priority recovery actions that can be undertaken at a local and regional level. Recovery plans describe key threats and identify specific recovery actions that can be undertaken to enable recovery activities to occur within a planned and logical national framework. Information about recovery plans is available on the department's website at: https://www.awe.gov.au/environment/biodiversity/threatened/recovery-plans.

Privacy notice

The Department will collect, use, store and disclose the personal information you provide in a manner consistent with the Department's obligations under the Privacy Act 1988 (Cth) and the Department's Privacy Policy.

Any personal information that you provide within, or in addition to, your comments in the threatened species assessment process may be used by the Department for the purposes of its functions relating to threatened species assessments, including contacting you if we have any questions about your comments in the future.

Further, the Commonwealth, State and Territory governments have agreed to share threatened species assessment documentation (including comments) to ensure that all States and Territories have access to the same documentation when making a decision on the status of a potentially threatened species. This is also known as the 'Common Assessment Method' (CAM). As a result, any personal information that you have provided in connection with your comments may be shared between Commonwealth, State or Territory government entities to assist with their assessment processes.

The Department's Privacy Policy contains details about how respondents may access and make corrections to personal information that the Department holds about the respondent, how respondents may make a complaint about a breach of an Australian Privacy Principle, and how the Department will deal with that complaint. A copy of the Department's Privacy Policy is available at: https://www.awe.gov.au/about/commitment/privacy .

Information about this consultation process

Responses to this consultation can be provided electronically or in hard copy to the contact addresses provided on Page 1. All responses received will be provided in full to the Committee and then to the Australian Government Minister for the Environment.

In providing comments, please provide references to published data where possible. Should the Committee use the information you provide in formulating its advice, the information will be attributed to you and referenced as a 'personal communication' unless you provide references or otherwise attribute this information (please specify if your organisation requires that this information is attributed to your organisation instead of yourself). The final advice by the Committee will be published on the department's website following the listing decision by the Minister.

Information provided through consultation may be subject to freedom of information legislation and court processes. It is also important to note that under the EPBC Act, the deliberations and recommendations of the Committee are confidential until the Minister has made a final decision on the nomination, unless otherwise determined by the Minister.

Consultation questions for *Grevillea burrowa* (Burrowa grevillea)

SECTION A - GENERAL

1. Is the information used to assess the nationally threatened status of the species/subspecies robust? Have all the underlying assumptions been made explicit? Please provide justification for your response.

2. Can you provide additional data or information relevant to this assessment?

3. Have you been involved in previous state, territory or national assessments of this species/subspecies? If so, in what capacity?

PART 1 – INFORMATION TO ASSIST LISTING ASSESSMENT

SECTION B DO YOU HAVE ADDITIONAL INFORMATION ON THE ECOLOGY OR BIOLOGY OF THE SPECIES/SUBSPECIES? (If no, skip to section C)

Biological information

4. Can you provide any additional or alternative references, information or estimates on longevity, average life span and generation length?

5. Do you have any additional information on the ecology or biology of the species/subspecies not in the current advice?

SECTION C ARE YOU AWARE OF THE STATUS OF THE TOTAL NATIONAL POPULATION OF THE SPECIES/SUBSPECIES? (If no, skip to section D)

Population size

6. Has the survey effort for this taxon been adequate to determine its national adult population size? If not, please provide justification for your response.

7. Do you consider the way the population size has been derived to be appropriate? Are there any assumptions and unquantified biases in the estimates? Did the estimates measure relative or absolute abundance? Do you accept the estimate of the total population size of the species/subspecies? If not, please provide justification for your response.

8. If not, can you provide a further estimate of the current population size of mature adults of the species/subspecies (national extent)? Please provide supporting justification or other information.

   If, because of uncertainty, you are unable to provide a single number, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of possible species/subspecies numbers, and also choose the level of confidence you have in this estimate:

   Number of mature individuals is estimated to be in the range of:

   ☐ 1–50 ☐ 51–250 ☐ 251–1000 ☐ >1000 ☐ >10 000

Level of your confidence in this estimate:

☐ 0–30% - low level of certainty/ a bit of a guess/ not much information to go on

☐ 31–50% - more than a guess, some level of supporting evidence

☐ 51–95% - reasonably certain, information suggests this range

☐ 95–100% - high level of certainty, information indicates quantity within this range

☐ 99–100% - very high level of certainty, data are accurate within this range

SECTION D ARE YOU AWARE OF TRENDS IN THE OVERALL POPULATION OF THE SPECIES/SUBSPECIES? (If no, skip to section E)

9. Does the current and predicted rate of decline used in the assessment seem reasonable? Do you consider that the way this estimate has been derived is appropriate? If not, please provide justification of your response.

Evidence of total population size change

10. Are you able to provide an estimate of the total population size during the early 1800s *(at or soon after the start of the most recent three generation/225-year period)*? Please provide justification for your response.

    If, because of uncertainty, you are unable to provide a single number, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of possible species/subspecies numbers, and also choose the level of confidence you have in this estimate.

    Number of mature individuals is estimated to be in the range of:

    ☐ 1–50 ☐ 51–250 ☐ 251–1000 ☐ >1000 ☐ >10 000

    Level of your confidence in this estimate:

    ☐ 0–30% - low level of certainty/ a bit of a guess/ not much information to go on

    ☐ 31–50% - more than a guess, some level of supporting evidence

    ☐ 51–95% - reasonably certain, information suggests this range

    ☐ 95–100% - high level of certainty, information indicates quantity within this range

    ☐ 99–100% - very high level of certainty, data are accurate within this range

11. Are you able to comment on the extent of decline in the species/subspecies' total population size over the last approximately 225 years (i.e., three generations/10 year period)? Please provide justification for your response.

    If, because of uncertainty, you are unable to provide an estimate of decline, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of decline, and also choose the level of confidence you have in this estimated range.

Decline estimated to be in the range of:

☐ 1–30% ☐31–50% ☐51–80% ☐81–100% ☐90–100%

Level of your confidence in this estimated decline:

☐ 0–30% - low level of certainty/ a bit of a guess/ not much information to go on

☐ 31–50% - more than a guess, some level of supporting evidence

☐ 51–95% - reasonably certain, suggests this range of decline

☐ 95–100% - high level of certainty, information indicates a decline within this range

☐ 99–100% - very high level of certainty, data are accurate within this range

12. Please provide (if known) any additional evidence which shows the population is stable, increasing or declining.

SECTION E ARE YOU AWARE OF INFORMATION ON THE TOTAL RANGE OF THE SPECIES/SUBSPECIES? (If no, skip to section F)

Current Distribution/range/extent of occurrence, area of occupancy

13. Does the assessment consider the entire geographic extent and national extent of the species/subspecies? If not, please provide justification for your response.

14. Has the survey effort for this species/subspecies been adequate to determine its national distribution? If not, please provide justification for your response.

15. Is the distribution described in the assessment accurate? If not, please provide justification for your response and provide alternate information.

16. Do you agree that the way the current extent of occurrence and/or area of occupancy have been estimated is appropriate? Please provide justification for your response.

17. Can you provide estimates (or if you disagree with the estimates provided, alternative estimates) of the extent of occurrence and/or area of occupancy.

    If, because of uncertainty, you are unable to provide an estimate of extent of occurrence, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of extent of occurrence, and also choose the level of confidence you have in this estimated range.

    Current extent of occurrence is estimated to be in the range of:

    ☐ <100 km^2 ☐ 100 – 5 000 km^2 ☐ 5 001 – 20 000 km^2 ☐ >20 000 km^2

Level of your confidence in this estimated extent of occurrence

☐ 0–30% - low level of certainty/ a bit of a guess/ not much data to go on

☐ 31–50% - more than a guess, some level of supporting evidence

☐ 51–95% - reasonably certain, data suggests this range of decline

☐ 95–100% - high level of certainty, data indicates a decline within this range

☐ 99–100% - very high level of certainty, data is accurate within this range

If, because of uncertainty, you are unable to provide an estimate of area of occupancy, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of area of occupancy, and also choose the level of confidence you have in this estimated range.

Current area of occupancy is estimated to be in the range of:

☐ <10 km^2 ☐ 11 – 500 km^2 ☐ 501 – 2000 km^2 ☐ >2000 km^2

Level of your confidence in this estimated extent of occurrence:

☐ 0–30% - low level of certainty/ a bit of a guess/ not much data to go on

☐ 31–50% - more than a guess, some level of supporting evidence

☐ 51–95% - reasonably certain, data suggests this range of decline

☐ 95–100% - high level of certainty, data indicates a decline within this range

☐ 99–100% - very high level of certainty, data is accurate within this range

SECTION F ARE YOU AWARE OF TRENDS IN THE TOTAL RANGE OF THE SPECIES/SUBSPECIES? (If no, skip to section G)

Past Distribution/range/extent of occurrence, area of occupancy

18. Do you consider that the way the historic distribution has been estimated is appropriate? Please provide justification for your response.

19. Can you provide estimates (or if you disagree with the estimates provided, alternative estimates) of the former extent of occurrence and/or area of occupancy.

    If, because of uncertainty, you are unable to provide an estimate of past extent of occurrence, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of past extent of occurrence, and also choose the level of confidence you have in this estimated range.

    Past extent of occurrence is estimated to be in the range of:

    ☐ <100 km^2 ☐ 100 – 1 000 km^2 ☐ 1 001 – 5 000 km^2 ☐ >5 000 km^2

Level of your confidence in this estimated extent of occurrence

☐ 0–30% - low level of certainty/ a bit of a guess/ not much data to go on

☐ 31–50% - more than a guess, some level of supporting evidence

☐ 51–95% - reasonably certain, data suggests this range of decline

☐ 95–100% - high level of certainty, data indicates a decline within this range

☐ 99–100% - very high level of certainty, data is accurate within this range

If, because of uncertainty, you are unable to provide an estimate of past area of occupancy, you may wish to provide an estimated range. If so, please choose one of the ranges suggested in the table below of ranges of past area of occupancy, and also choose the level of confidence you have in this estimated range:

Past area of occupancy is estimated to be in the range of:

☐ <10 km^2 ☐ 11 – 100 km^2 ☐ 101 – 500 km^2 ☐ >500 km^2

Level of your confidence in this estimated extent of occurrence:

☐ 0–30% - low level of certainty/ a bit of a guess/ not much data to go on

☐ 31–50% - more than a guess, some level of supporting evidence

☐ 51–95% - reasonably certain, data suggests this range of decline

☐ 95–100% -high level of certainty, data indicates a decline within this range

☐ 99–100% - very high level of certainty, data is accurate within this range

PART 2 – INFORMATION FOR CONSERVATION ADVICE ON THREATS AND CONSERVATION ACTIONS

SECTION G DO YOU HAVE INFORMATION ON THREATS TO THE SURVIVAL OF THE SPECIES/SUBSPECIES? (If no, skip to section H)

20. Do you consider that all major threats have been identified and described adequately?

21. To what degree are the identified threats likely to impact on the species/subspecies in the future?

22. Are the threats impacting on different populations equally, or do the threats vary across different populations?

23. Can you provide additional or alternative information on past, current or potential threats that may adversely affect the species/subspecies at any stage of its life cycle?

24. Can you provide supporting data/justification or other information for your responses to these questions about threats?

SECTION H DO YOU HAVE INFORMATION ON CURRENT OR FUTURE MANAGEMENT FOR THE RECOVERY OF THE SPECIES/SUBSPECIES? (If no, skip to section I)

25. What planning, management and recovery actions are currently in place supporting protection and recovery of the species/subspecies? To what extent have they been effective?

26. Can you recommend any additional or alternative specific threat abatement or conservation actions that would aid the protection and recovery of the species/subspecies?

27. Would you recommend translocation (outside of the species' historic range) as a viable option as a conservation actions for this species/subspecies?

SECTION I DO YOU HAVE INFORMATION ON STAKEHOLDERS IN THE RECOVERY OF THE SPECIES/SUBSPECIES?

28. Are you aware of other knowledge (e.g., traditional ecological knowledge) or individuals/groups with knowledge that may help better understand population trends/fluctuations, or critical areas of habitat?

29. Are you aware of any cultural or social importance or use that the species/subspecies has?

30. What individuals or organisations are currently, or potentially could be, involved in management and recovery of the species/subspecies?

31. How aware of this species/subspecies are land managers where the species/subspecies is found?

32. What level of awareness is there with individuals or organisations around the issues affecting the species/subspecies?

    a. Where there is awareness, what are these interests of these individuals/organisations?

    b. Are there populations or areas of habitat that are particularly important to the community?

PART 3 – ANY OTHER INFORMATION

33. Do you have comments on any other matters relevant to the assessment of this species/subspecies?

Conservation Advice for *Grevillea burrowa* (Burrowa grevillea)

This draft document is being released for consultation on the species listing eligibility and conservation actions

The purpose of this consultation document is to elicit additional information to better understand the status of the species and help inform conservation actions, further planning, and a potential recovery plan. The draft assessment below should therefore be considered **tentative** at this stage, as it may change as a result of responses to this consultation process.

Note: Specific consultation questions relating to the below draft assessment and preliminary determination have been included in the consultation cover paper for your consideration.

This document combines the draft conservation advice and listing assessment for the species. It provides a foundation for conservation actions and further planning.

Grevillea burrowa (Burrowa grevillea) © Copyright, A. Messina, Royal Botanic Gardens Board (2022)

Conservation status

Grevillea burrowa (Burrowa grevillea) is proposed to be listed in the Critically Endangered category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999 (Cwth)* (EPBC Act).

Grevillea burrowa was assessed by the Threatened Species Scientific Committee to be eligible for listing under criterion 2 as Critically Endangered. The Committee's assessment is at Attachment A. The Committee's assessment of the species' eligibility against each of the listing criteria is:

- Criterion 1: Insufficient data
- Criterion 2: B1ab(iii,v)+2ab(iii,v): Critically Endangered
- Criterion 3: Insufficient data
- Criterion 4: D: Not eligible; D2: Vulnerable
- Criterion 5: Insufficient data

The main factors that make the species eligible for listing in the Critically Endangered category are restricted distribution and locations, and projected continuing decline (the area, extent and quality of habitat, and the number of mature individuals), due to multiple threats: fire regimes that cause declines in biodiversity, climate change, and introduced species.

Species can also be listed as threatened under state and territory legislation. For information on the current listing status of this species under relevant state or territory legislation, see the Species Profile and Threats Database.

Species information

Taxonomy

Conventionally accepted as *Grevillea burrowa* Molyneux & Forrester (2015), Family: Proteaceae.

Grevillea burrowa (Burrowa grevillea) was previously known as *Grevillea victoriae* von Mueller (1855) (Royal grevillea), an unresolved species complex. This species complex has since received multiple revisions with several new species and subspecies described (McGillivray & Makinson 1993; Makinson 1997, 2000; Molyneux & Stajsic 2000; Stajsic & Molyneux 2006; Stajsic 2010). In 2015, this complex was further revised and this new taxon, the Burrowa grevillea, was formally described (Molyneux & Forrester 2015).

Description

The Burrowa grevillea is a branching shrub generally 1.5–4 m high and 2–4 m wide but can grow to 6 m high and 7 m wide. Leaves have slightly curved back, smooth edges and are generally 65–80 mm long and 25–35 mm wide but can vary in their width and length. The upper surface of the leaves may be sparsely covered in fine, silky hair, giving them a silver colour, with the lower surface densely covered in fine, silky hair, otherwise leaves are smooth and dull green. Flower groups can be located at the end or at the middle of the stem, are slightly curved, and have from one to three branches. The stalk of the flower group is 2–12 mm long, and densely covered in fine, silky hair. Individual flower stems are 12–20 mm long but may be as long as 32 mm. The outer side of the flower is red-pink in colour, and will generally be in groups of 12–18 but up to 30 flowers. Fruits are generally smooth but may have minute hairs. This description is drawn from Molyneux & Forrester (2015) and VicFlora (2018).

The Burrowa grevillea is morphologically closest to *G. oxyantha* subsp. *ecarinata,* which has leaves of similar shape and size. The two species are most easily distinguished by their distribution (described below for the Burrowa grevillea), as *G. oxyantha* subsp. *ecarinata* is mostly found in New South Wales (NSW) with few subpopulations in Victoria (Vic), whereas the Burrowa grevillea is only found at two ridgelines in Vic (Molyneux & Forrester 2015). Furthermore, the Burrowa grevillea has a shorter floral stem than *G. oxyantha ecarinata* and usually possesses fewer flowers, and a greater percentage of single branch flower groups (Molyneux & Forrester 2015; VicFlora 2018). Additionally, the Burrowa grevillea will have occasional hairs on the inside of the flower (on the ovary) (Molyneux & Forrester 2015; VicFlora 2018), though this characteristic is likely not consistent (VicFlora 2018).

The Burrowa grevillea is distinguished from *G. brevifolia* (cobberas grevillea) by its raised leaf veins on the upper and lower surfaces, and longer and wider leaves in general (Molyneux & Forrester 2015). The Burrowa grevillea is distinguished from *G. oxyantha* subsp. *oxyantha* by its raised leaf veins on the upper surface, and the juvenile buds bent to no more than 90–degrees (Molyneux & Forrester 2015).

Distribution

Current distribution

The Burrowa grevillea is endemic to the Burrowa Plateau in north-eastern Vic, where it is currently known from three subpopulations (Table 1), approximately 3 km apart within the Burrowa-Pine Mountain National Park (NP) on adjoining ridgetops and upper slopes (Molyneux & Forrester 2015; VicFlora 2018). One subpopulation occurs along the Mount Burrowa Walking Track, while the second and third subpopulations span a ridgeline running north-east from Black Mountain (Molyneux & Forrester 2015). The Black Mountain subpopulations are subdivided by a narrow rocky saddle (Molyneux & Forrester 2015). The Mount Burrowa Walking Track subpopulation is estimated to cover 2.1 ha, while the Black Mountain subpopulations cover 9 ha and 12 ha either side of the saddle respectively (Molyneux & Forrester 2015).

Population size

Molyneux & Forrester (2015) estimated the total population size at 2,000–4,000 mature individuals (Table 1). Molyneux & Forrester (2015) at the time of their study estimated the age class of the Burrowa grevillea to comprise 65% mature individuals of intermediate size (including 15% long-mature plants 4–6 m in height), and 35% seedlings and juveniles, with very few old, dead plants. Molyneux & Forrester (2015) suggest this age class distribution represents a healthy, regenerating population, likely following a bushfire in 1952. This age class structure has likely changed substantially since the 2019-20 bushfires impacted both Black Mountain subpopulations (Table 1) (RBG 2022. pers comm 14 February).

Table 1 Distribution and population size of known subpopulations of *Grevillea burrowa*

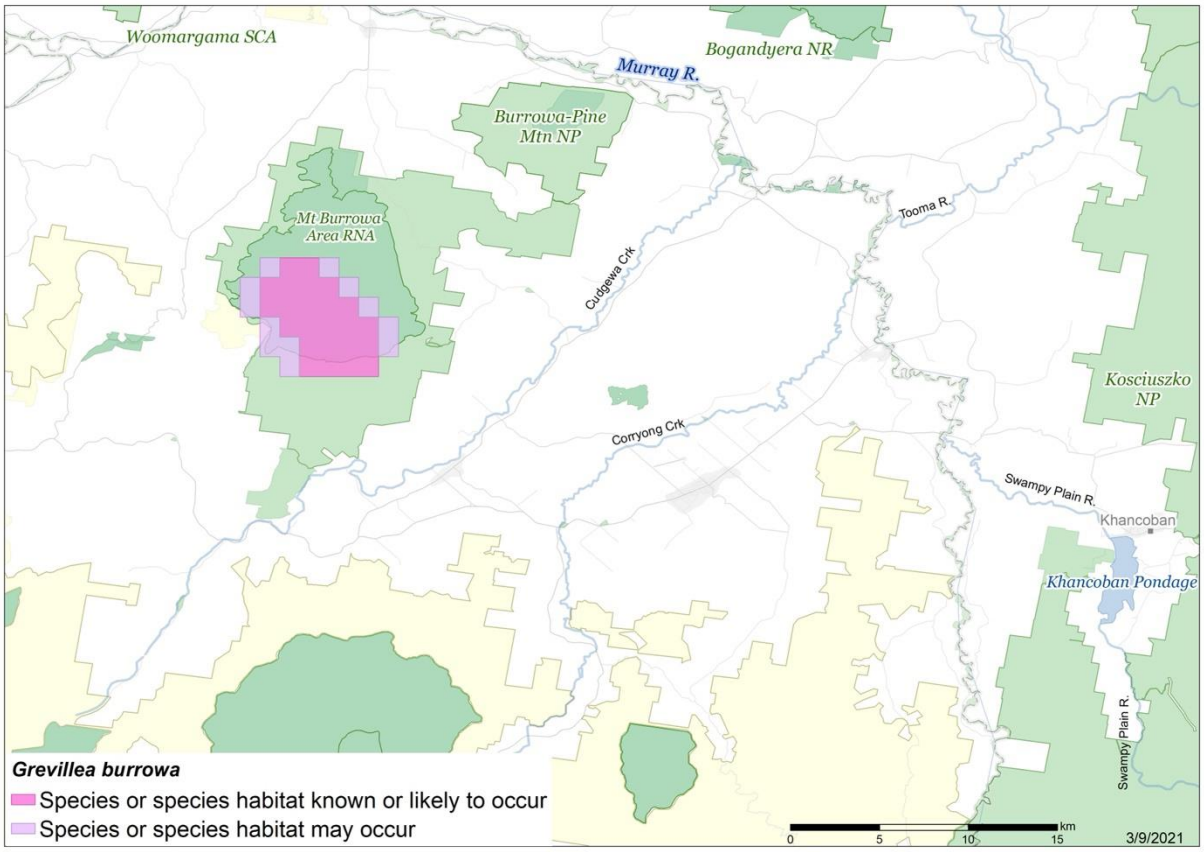
Locality	Population size	Fire history
Mount Burrowa Walking Track 1 subpopulation	2012-13: 100s of individuals (Molyneux & Forrester 2015) Not assessed since 2019-20 fires.	1952: bushfire likely affected all subpopulations. 2019-20: bushfire overlapped with 100% of the species' modelled distribution (Gallagher 2022) and impacted the entirety of Burrowa-Pine Mountain NP (DELWP 2020a). These bushfires impacted both Black Mountain subpopulations, confirmed from field observations (RBG 2022. pers comm 14 February). The Mount Burrowa subpopulation has not been assessed in the field, though it is likely the entire population was damaged, inferred from the overlap with the modelled distribution. Note: additional small/patchy fires from prescribed burns or unrecorded lightning strikes are likely to have occurred (CFA 2022. pers comm 23 February).
Black Mountain 2 subpopulations – along ridgeline, sub-divided by a narrow rocky saddle	2012-13: 1000s of individuals* (Molyneux & Forrester 2015) Nov 2021: 1000s of seedlings* (RBG 2022. pers comm 14 February) Feb 2022: 1000s of seedlings* (RBG 2022. pers comm 14 February)	
Total	2012-13: 2000-4000 mature individuals (Molyneux & Forrester 2015)	

*population estimate is for both Black Mountain subpopulations.

Historical distribution

The historical distribution of the Burrowa grevillea was likely similar to the current distribution, as there is no evidence to suggest there has been a significant decline nor population fluctuation since European colonisation (Molyneux & Forrester 2015).

Map 2 Modelled distribution of Burrowa grevillea



Source: Base map Geoscience Australia; species distribution data Species of National Environmental Significance database.
Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything contained herein.
Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture (a) the habitat or geographic feature that represents to recent observed locations of the species (known to occur) or habitat occurring in close proximity to these locations (likely to occur); and (b) the broad environmental envelope or geographic region that encompasses all areas that could provide habitat for the species (may occur). These presence categories are created using an extensive database of species observations records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.

Cultural and community significance

Cultural and community significance to Indigenous Australians

The cultural, customary, and spiritual significance of species and the ecological communities they form are diverse and varied for Indigenous Australians and their stewardship of Country. This section describes some examples of this significance but is not intended to be comprehensive or applicable to, or speak for, Indigenous Australians. Such knowledge may be held by Indigenous Australians who are the custodians of this knowledge and have the rights to decide how this knowledge is shared and used.

The Burrowa grevillea is known from occurrences on the lands of the Dhudhuroa and Pallanganmiddang Peoples (Tindale 1974; Blake & Reid 2002; Molyneux & Forrester 2015). There is little published information on how Dhudhuroa and Pallanganmiddang people related to Country in this region and what that may mean for the cultural significance of the Burrowa grevillea. The names of the 'Burrowa' grevillea and the 'Burrowa-Pine Mountain' NP are derived from a word in an Indigenous Australian language, however, there is little published information about the origin of the name (Molyneux & Forrester 2015).

Grevilleas are a culturally significant plant for Indigenous peoples across Australia (Royal Botanic Gardens Victoria 2014). Flowers from other species of Grevilleas are bush tucker and can be sucked or soaked in water to produce a sweet drink (Flood 1980; Australian National Botanic Gardens 2007). Further consultation with the Traditional Owners of these lands will benefit the conservation of the species by providing awareness of traditional knowledge and management practices on Country.

Cultural and community significance for recreational activities

Additionally, Burrowa-Pine Mountain NP has significant scenery and conservation values and is a popular attraction for visitors and hikers (Parks Victoria 2008). Pine Mountain is said to be one and half times as large as Uluru, making it one of Australia's largest monoliths (Parks Victoria 2008).

Relevant biology and ecology

Habitat ecology

The Burrowa grevillea occurs in montane dry woodland on the Burrowa Plateau in Burrowa-Pine Mountain NP (Molyneux & Forrester 2015; VicFlora 2018), at altitudes of 600–1200 m above sea level (ASL) (ALA 2021), identified as Ecological Vegetation Class 36 (DELWP 2021). The species distribution also extends onto Rocky Outcrop Shrubland/Rocky Outcrop Herbland Mosaic on north facing slopes (Ecological Vegetation Class 73) (Molyneux & Forrester 2015; DELWP 2021). This species occurs on a Palaeozoic rhyolite supporting impoverished shallow to skeletal soils (Molyneux & Forrester 2015). The species most commonly found in montane dry woodland include *Eucalyptus dives* (broad-leaved peppermint), *Eucalyptus rubida* (candlebark), and *Eucalyptus radiata* (narrow-leaved peppermint) (DSE 2007), though the Burrowa grevillea has also been reported in association with various other *Eucalyptus* spp., *Acacia* spp., *Kunzea* spp., and other shrub species (Molyneux & Forrester 2015). The Burrowa grevillea also occurs with *Grevillea jephcottii* (green grevillea) (Molyneux & Forrester 2015).

Reproductive Ecology

The reproductive ecology of the Burrowa grevillea is not well understood and requires further investigation. The species has been reported to flower in late winter through spring and summer and occasionally extending into early autumn (Molyneux & Forrester 2015). The species is likely bird pollinated. The most active nectar feeders of Burrowa grevillea are *Acanthorhynchus tenuirostris* (eastern spinebill), and *Lichenostomus penicillatus* (white-plumed honeyeater), recorded in late spring to early summer (Molyneux & Forrester 2015). Pollination of grevillea species can also occur via insects and occasionally possums (Smith & Gross 2002; White et al. 2020).

This species is an obligate-seeder (Molyneux & Forrester 2015; White et al. 2020) and will regenerate from seeds after fire. Molyneux & Forrester (2015) estimate that the Burrowa grevillea is a long-lived species, based on the presence of mature individuals at the time of their study, with no major wildfires since 1952. This suggests a longevity of at least 60 years, though Molyneux & Forrester (2015) suggest the species may live for as long as 80–100 years.

Seed dispersal occurs via ants (myrmecochory) (White et al. 2020) and is therefore limited to a few metres (Auld 2001). The seedbank will persist for long periods in the soil (White et al. 2020), though the estimated longevity of seeds is unknown. The primary and secondary juvenile periods are currently unknown. The age of maturity is unknown, though it is estimated that it will take between 5–20 years after fire before the seedload is sufficient to replace the adult population (White et al. 2020). Several *Grevillea* spp. with limited distribution have been shown to have a small seedbank size (Pickup et al. 2003), a factor that often contributes to their rarity (Lamont & van Leeuwen1988; Keddy et al. 1989; Guo et al. 1998). It is likely that the Burrowa grevillea only produces a small number of seeds, based on its restricted distribution.

Fire ecology

In many plants in the family Proteaceae (including *Grevillea* spp.), germination of seeds is triggered by fire-related cues, including heat, smoke, and scarification (Edwards & Whelan 1995; Bradstock et al. 1996; Morris 2000). The Burrowa grevillea is an obligate-seeder and regenerates from seeds after fire (Molyneux & Forrester 2015; White et al. 2020). The mature Burrowa grevillea plants are usually killed by fire (Molyneux & Forrester 2015) and a sufficient fire-free interval is required for seedlings to reach maturity and replenish the seedbank (Edwards & Whelan 1995; Auld et al. 2007). Typically, populations of woody plant species can be sustained under average fire-free intervals of approximately 15 years (Keith 1996). In *Grevillea* spp., generally 5–10 years must pass following fire until significant reproductive output is achieved (DELWP 2022. pers comm 14 February). In November 2021 and February 2022 (i.e., two years after the 2019–20 bushfires), thousands of seedlings of approximately 30 cm in height were observed at the Black Mountain subpopulations (RBG 2022. pers comm 14 February), demonstrating that at least two years are required for regeneration following fire. Additionally, little reproductive output is expected until approximately five years after fire. At least 12 years are likely to be required after fire before seed production exceeds seed predation in the Burrowa grevillea, and seed quality approaches that of a mature vigorous population (CFA 2022. pers comm 23 February). Accordingly, the minimum fire-free interval for the species is estimated to be 5–12 years.

Observations of the age class distribution for Burrowa Grevillea (Molyneux & Forrester 2015) suggest that there have been separate recruitment events between the 1952 and 2019–20 bushfires. Additional recruitment was possibly triggered from prescribed burns or unrecorded fires from lightning strikes (CFA 2022. pers comm 23 February).

Habitat critical to the survival

The Burrowa grevillea occurs in montane dry woodland, rocky outcrop shrubland, and rocky outcrop herbland mosaic on north facing slopes, on Palaeozoic rhyolite supporting impoverished shallow to skeletal soils (Molyneux & Forrester 2015; VicFlora 2018) (see 'Relevant ecology and biology' section above). Any similar habitat in Burrowa-Pine Mountain NP or the surrounding areas is likely to be necessary to ensure the long-term maintenance and evolutionary development of the species.

The habitat critical to the survival of the Burrowa grevillea comprises the area of occupancy of the known subpopulations, areas of similar habitat surrounding the known subpopulations (these areas provide potential habitat for natural range extension or for allowing pollinators or biota essential to the continued existence of the species to move between subpopulations), and additional occurrences of similar habitat that may contain important subpopulations of the species or be suitable for future translocations or other recovery actions intended to create important subpopulations.

No Critical Habitat as defined under section 207A of the EPBC Act has been identified or included in the Register of Critical Habitat.

Important populations

In this section, the word 'population' is used to refer to a subpopulation (as defined by the IUCN 2001), in keeping with the terminology used in the EPBC Act and state/territory environmental legislation.

All populations of the Burrowa grevillea are important for the long-term recovery and survival of the species.

Threats

The Burrowa grevillea is predominantly threatened by fire regimes that cause declines in biodiversity plus climate change and introduced species (Table 2). The restricted range of the species may increase its risk of extinction via stochastic processes.

Historical land clearing may have reduced the distribution and population size of the species, as the surrounding area has largely been cleared for grazing (Australian Government 2021), although no data on this threat is available for this species. The Burrowa grevillea may also be threatened by various pest species that can skeletonise leaves, though there is little published information on this threat. These threats have not been included Table 1 as the consequences are unknown.

Table 2 Threats

Threats in Table 2 are noted in approximate order of highest to lowest impact, based on available evidence.

Threat	Status [a]	Evidence
Habitat loss, disturbance, and modification impacts		
Fire regimes that cause declines in biodiversity[b]	Timing: current Confidence: observed Likelihood: almost certain Consequence: major Trend: increasing Extent: across the entire range	The Burrowa grevillea is fire sensitive, as fire kills standing plants, but facilitates regeneration from the soil-stored seedbank (Molyneux & Forrester 2015; White et al. 2020). The 2019-20 bushfires impacted the entirety of Burrowa-Pine Mountain NP (DELWP 2020a). Approximately 100% of the Burrowa grevillea's modelled distribution was burnt in the 2019-20 bushfires (Gallagher 2022). Post-fire recovery was observed during surveys of the two Burrowa grevillea subpopulations at Black Mountain in November 2021 and February 2022, with thousands of seedlings present (RBG 2022. pers comm 14 February). Recovery was aided by favourable climatic conditions including significant rainfall since the fires. Recruitment has also benefited from post-fire aerial and ground deer control programs (DELWP 2022. pers comm 23 February). There are several mechanisms by which the fire regime can impact a species with obligate-seeder traits such as the Burrowa grevillea (Keith 1996; DAWE 2022). These include the frequency of fire (high vs low), the season of fire, and the interactions between fire and climate change and other threats (weeds, introduced species, etc.). The Burrowa grevillea is likely to be sensitive to high fire frequency, and the interactions between fire and climate change, and fire and introduced species. *High frequency fires* Obligate-seeders require a minimum time between successive fires to allow time for the species to accumulate sufficient soil-stored seeds to ensure population persistence (Keith 1996, 2012). This is termed the minimum fire interval. The minimum fire interval for the Burrowa grevillea is unconfirmed but is inferred from other species and personal observations (see 'Reproductive Ecology' section above). If the fire free interval is less than the 5–12-year minimum fire interval, the species is unlikely to have replenished its population to pre-fire levels and population declines are projected. Fire frequency is predicted to continue to increase due to climate change (Dowdy et al. 2019; Bureau of Meteorology & CSIRO 2020; van Oldenborgh et al. 2021). Accordingly, ensuring that no fires occur in this critical recovery period for species becomes challenging with drying climates and higher incidences of recurrent fires. *Out of season fires* Fires occurring out of season may also impact obligate-seeder species that are adapted to a particular fire season. The Burrowa grevillea flowers in early winter, spring, and summer (see 'Reproductive Ecology' section above). An earlier fire season may increase post-fire seedling mortality, as spring fires will expose seedlings to low soil moisture during summer drought (Miller at al. 2019). The seasonal flowering, dormancy, and germination cues required for the Burrowa grevillea is not well understood, though out of season fires, in combination with a detrimental fire frequency will likely severely impact this species. *Interactions between fire and other threats*

Threat	Status [a]	Evidence
		There are also a range of mechanisms by which fire interacts with other threats (including climate change, introduced species, weeds, and decreased pollination) and impacts the recovery potential of the species following fires (see relevant sections below).
Damage associated with road maintenance and recreational activities	Timing: current Confidence: suspected Likelihood: possible Consequence: minor Trend: static Extent: across part of its range	The Burrowa grevillea's entire recorded population exists within the Burrowa-Pine Mountain NP (Molyneux & Forrester 2015). As a NP, a range of recreational activities are permitted, including the use of roads and tracks by the public, trail bike riding, along with routine road maintenance (National Parks Service 1996). One subpopulation of the Burrowa grevillea occurs on the Mount Burrowa Walking Track, so plants may be damaged during path maintenance and by recreational walkers (Sindel et al. 2009). Additionally, such activities may promote weed invasion (Sindel et al. 2009).
Disease		
Dieback caused by *Phytophthora cinnamomi*	Timing: future Confidence: suspected Likelihood: possible Consequence: major Trend: unknown Extent: across the entire range	*Phytophthora cinnamomi* is an introduced soil-borne pathogen, which infects a large range of plant species and may contribute to plant death, especially when other stressors are present such as drought, and fire (DOEE 2018). *Phytophthora cinnamomi* can disperse in water flowing from infected sites and roots to healthy plants, as well as through mud clinging to vehicles, animals, and people (DOEE 2018). *Phytophthora cinnamomi* can also spread locally through wet soils via hyphae or zoospores, and to a lesser extent uphill via root-to-root contact (DSE 2009). Dieback caused by *P. cinnamomi* is listed as a key threatening process under the EPBC Act. There are currently no records of *P. cinnamomi* within Burrowa-Pine Mountain NP and surrounding area (Parks Victoria 2022. pers comm 14 February). Though *P. cinnamomi* has been recorded at the nearby Mount Lawson State Park (Parks Victoria 2022. pers comm 14 February), approximately 15 km away from Burrowa-Pine Mountain NP. It is possible that the range of *P. cinnamomi* will increase, as it prefers warm wet soils, which could become more prevalent with wetter summers and warmer winters caused by climate change (DSE 2009; Thompson et al. 2014; Homet et al. 2019). This may lead to infestation in cooler, more mountainous areas (DES 2009), such as at the higher elevations (600–1200 m) where Burrowa grevillea is found. Additionally, there is risk of *P. cinnamomi* being tracked into the park from bushwalkers (DOEE 2019), which puts the subpopulation near the Mount Burrowa Walking Track at higher risk. Proteaceae are one of the most susceptible plant families to *P. cinnamomi* (DSE 2009), with numerous *Grevillea* spp. known to be vulnerable (DOEE 2018). It is therefore likely that the Burrowa grevillea will be severely impacted if *P. cinnamomi* spreads to Burrowa-Pine Mountain NP.

Threat	Status [a]	Evidence
Climate change		
Increased frequency of extreme temperatures, droughts and fire danger weather, and changes in precipitation	Timing: current Confidence: observed/projected Likelihood: almost certain Consequence: major Trend: increasing Extent: across the entire range	Temperatures are expected to increase, and rainfall is expected to decrease with climate change in NE Victoria (Dowdy et al. 2019; Bureau of Meteorology & CSIRO 2020; van Oldenborgh et al. 2021). The changes in temperature and precipitation patterns may seriously affect the Burrowa grevillea through several mechanisms, including increased time in drought, increased average temperatures, and the increased frequency of fires caused by drier and hotter average conditions. *Increased time in drought* Predicted increased frequency of drought may cause widespread plant mortality in forest ecosystems, as many plants are vulnerable to drought stress and hydraulic failure of their vascular system (Allen et al. 2010; Choat et al. 2012; De Kauwe et al. 2020). Many plants from the family Proteaceae, including *Grevillea* spp., are expected to decline in range and population size, primarily due to the effect of declining rainfall on seed production and seedling survival (Midgley et al. 2006; Fitzpatrick et al. 2008; Shimizu-Kimura et al. 2017). Obligate-seeder species such as the Burrowa grevillea may be particularly vulnerable to increased frequency or duration of drought as they rely on post-fire germination for population persistence. Post-fire drought can reduce flowering, seedling emergence, and seedling survival (Choat et al. 2018) *Increased temperatures* Increased temperatures (and reduced soil moisture) may slow growth rates for the Burrowa grevillea, reducing its propensity to develop sufficient reproductive capacity before fire recurrence (Choat et al. 2018). Additionally, an increased frequency and severity of heat waves may deplete soil stored seed banks by exceeding their temperature thresholds, reducing the number of seeds available for post-fire regeneration and recovery of the population (Ooi et al. 2009, 2012, 2014). *Interaction with the fire regime* The interaction between climate change and the fire regime could significantly impact the Burrowa grevillea population. Climate change can increase fire frequency through changes in landscape dryness (Gallagher et al. 2021), and the resulting reduction in seed production and survival from reduced soil moisture will increase the minimum fire-free interval that is required for the species to replenish the seedbank (Midgley et al. 2006; Fitzpatrick et al. 2008; Shimizu-Kimura et al. 2017) (see above). For example, Victorian temperatures have been increasing, and rainfall decreasing over the last 25 years, which has increased the risk of severe bushfires and drought (CSIRO & Bureau of Meteorology 2015; Parks Victoria 2021a) across the species' range. This indicates an increased risk from high-fire frequency and a potential decline in the fire-free interval (Enright et al. 2015; Dowdy et al. 2019; Gallagher 2020; Gallagher et al. 2021). The interaction of increasing drought and fire frequency across the species' range may result in 'interval squeeze', whereby climate drives increased pressure via higher fire frequency, while also reducing resilience via slower rates of maturation and lower fecundity (Enright et al. 2015; Henzler et al. 2018).

Threat	Status [a]	Evidence
Introduced species		
Damage caused by introduced deer	Timing: current Confidence: suspected Likelihood: likely Consequence: moderate Trend: stable (dependent on management) Extent: Across part of its range	Four species of introduced deer have established populations in Victoria (Hampton & Davis 2020). Sambar deer (*Rusa unicolor*) is the most widespread species, occupying approximately 29% of Vic (Forsyth et al. 2015; DELWP 2020b), and is listed as a key threatening process to native vegetation under Vic's *Flora and Fauna Guarantee Act 1988* (FFG Act). The distribution and abundance of deer has increased across Vic (Forsyth et al. 2018; DELWP 2020b). Introduced deer can disturb shrub/ground layer vegetation and contribute to decreased plant abundance and diversity, by browsing/grazing plants, antler rubbing, trampling causing soil compaction and erosion, and wallowing (Keith & Pellow 2005; DELWP 2020b; Hampton & Davis 2020). Introduced deer are known to browse on *Grevillea* spp. (Claridge 2016). The growth form of Burrowa grevillea (shrub from 1.5–4 m tall) puts it within the browsing height for deer, as well as making the species more susceptible to thrashing (Claridge 2016). Following the 2019-20 bushfires, introduced deer may be putting additional pressure on species recovery. Deer may have increased access to palatable seedlings after fires, particularly low-intensity and patchy fires (such as prescribed burns) and may seriously threaten the regeneration of seedlings by browsing on new plants (Downes 1983; Keith & Pellow 2005; Keith 2012; Hampton & Davis 2020; DELWP 2020b). Low levels of post-fire herbivory on the Burrowa grevillea have been reported following the 2019-20 bushfires (Gallagher et al. 2022). It is possible that the higher elevation where the green grevillea occurs is restricting access for deer for browsing, which are more likely to occupy lower elevation habitats (Parks Victoria 2022, pers comm 14 February). However, deer may graze on co-occurring species, which could alter habitat structure, leading to changes in the fire regime, increase the incursion of weeds, or reduce floral resources (D'Antonio & Vitousek 1992; Grigulis et al. 2005; Hampton & Davis 2020). Introduced deer are being actively managed in Burrowa-Pine Mountain NP following the 2019-20 bushfires (Parks Victoria 2021a), where ground shooting operations were reported to have significant success in controlling deer numbers within the park (Parks Victoria 2022. pers comm 14 February). However, changes to fire frequency (see above) may result in interactive impacts between fire and introduced herbivores such as deer in the future (Crowther et al. 2016; Hampton & Davis 2020; Gallagher et al. 2022).

Threat	Status [a]	Evidence
Weed invasion	Timing: future Confidence: suspected Likelihood: possible Consequence: minor Trend: unknown Extent: across the entire range	Weeds can invade, establish in, and outcompete native vegetation, particularly following disturbance events such as fires (Hobbs 1991: Hobbs 2002; Brown et al. 2016). In particular, grassy weeds can increase fuel loads and alter fire regimes (Milberg & Lamont 1995). These altered fire regimes can create conditions that are detrimental to the maintenance of native species and favourable to the establishment and spread of weeds (D'Antonio & Vitousek 1992; Grigulis et al. 2005). Temperate eucalypt woodlands, such as the montane habitat that Burrowa grevillea occurs in, may be susceptible to weed invasion following disturbance (Yates & Hobbs 1997). Particularly exotic grasses and herbs, which may be more effective competitors for limited soil and nutrients (Humphries et al. 1994). The invasion of these habitats by weeds can then prevent the regeneration of native woody species (Hobbs & Atkins 1991). The Burrowa grevillea may also be threatened when is extends onto rocky habitats, which can be vulnerable to weed invasion after disturbance (fire) (Pigott & Sage 1997). There have been historical reports of European blackberry (*Rubus fruticosus*), Paterson's curse (*Echium plantagineum*), St. John's wort (*Hypericum perforatum*) and radiata pine (*Pinus radiata*) occurring in low abundance along the fringes of Burrow-Pine Mountain NP (NPS 1996). However, no weeds have been reported as a major threat in Burrowa-Pine Mountain NP. Accordingly, weed invasion is considered to be a minor threat to the Burrowa grevillea.
Herbivory and disturbance caused by the European rabbit (*Oryctolagus cuniculus)*	Timing: current Confidence: inferred Likelihood: possible Consequence: minor Trend: unknown Extent: across the entire range	Montane dry woodlands (the habitat where the Burrowa grevillea most frequently occurs) is at low risk from European rabbits, due to sclerophyllous and therefore low-quality foliage for browsing, with shallow soils unsuitable for burrows (Long et al. 2003). However, rocky outcrop shrubland and herbland mosaic (where Burrowa grevillea is less frequently found), can have high densities of European rabbits due to the suitability of exposed rocks for burrows, despite low quality browsing material (Long et al. 2003). Additionally, the shallow, dry soils in this habitat support a very fragile herb layer, which may result in rabbits concentrating on taller herbs and shrubs when the herb layer dries in late spring (Long et al. 2003). This may put the Burrowa grevillea at risk in these habitats, particularly after disturbance when more palatable Burrowa grevillea seedlings are present (Long et al. 2003). Changes in vegetation structure caused by the European rabbit, and the occasional browsing on Burrowa grevillea seedlings, may put this species at risk, particularly when it occurs in rocky outcrop shrubland/herbland mosaic. However, the European rabbit is suspected to occur in low densities in the NP (Parks Victoria 2022. pers comm 23 February), suggesting its impact on the Burrowa grevillea is minor.

Threat	Status [a]	Evidence
Pollinator ecology		
Reduced pollination success	Timing: current Confidence: inferred Likelihood: possible Consequence: moderate Trend: unknown Extent: unknown	Field observations show the Burrowa grevillea is largely pollinated by honeyeaters (Molyneux & Forrester 2015) (see 'Reproductive Ecology' section above). The Burrowa grevillea will require sufficient pollination after regeneration to ensure new recruitment and population persistence. Therefore, a reduction in pollination efficiency for the Burrowa grevillea may seriously impact the population. Pollination efficiency may be reduced by introduced European honeybee (*Apis mellifera*), or from the fragmentation and reduction of co-occurring floral resources caused by increased fire frequency or out of season fires (see above). *Introduced European honeybee* The European honeybee has become a widely distributed feral animal in Australian ecosystems (DAWE 2020). The European honeybee can compete for pollen resources with native pollinators, and this has been observed in several Grevillea *spp.* in NSW (UNE 2021). Species such as grevilleas, which are adapted for pollination by birds, may have reduced pollination efficiency if bees are in a high abundance (Oldroyd et al. 1997). A reduction in pollination may occur when bees reduce the amount of nectar in the plant without successful pollination, reducing the attractiveness of the plant to more effective pollinators (Taylor & Whelan 1988; Whelan et al. 2009). The European honeybee has not been comprehensively surveyed in the region; however, it is suspected to co-occur with the Burrowa grevillea. Accordingly, European honeybees could impact pollination and therefore recruitment in the Burrowa grevillea, particularly following fires. *Decreased floral resources* The impacts of increased frequency of fires, and out of season fires may have flow-on effects for pollinators. Higher fire frequency can negatively impact pollinator species either from reduced flowering or direct impacts to pollinator species (Carbone et al. 2019). For obligate-seeder species, such as the Burrowa grevillea that flowers largely in winter, honeyeater abundance after fire will generally increase slowly to coincide with the winter flowering (Franklin et al. 2016). If flowering is reduced or disrupted, this may reduce the abundance of pollinators and the species may consequently have reduced pollination and recruitment. If the fire regime for the area reduces the overall floral diversity by impacting a wide range of co-occurring fire-affected flowering plants, this may also reduce pollinator abundance due to decreased floral resources (Phillips et al. 2010).

[a]Timing—identifies the temporal nature of the threat
Confidence—identifies the nature of the evidence about the impact of the threat on the species
Likelihood—identifies the likelihood of the threat impacting on the whole population or extent of the species
Consequence—identifies the severity of the threat
Trend—identifies the extent to which it will continue to operate on the species
Extent—identifies its spatial context in terms of the range of the species

[b]Fire regimes that cause a decline in biodiversity include the full range of fire-related ecological processes that directly or indirectly cause persistent declines in the distribution, abundance, genetic diversity, or function of a species or ecological community. 'Fire regime' refers to the frequency, intensity or severity, season, and types (aerial/subterranean) of successive fire events at a point in the landscape.

Categories for likelihood are defined as follows:
Almost certain - expected to occur every year
Likely - expected to occur at least once every five years
Possible - might occur at some time
Unlikely - known to have occurred only a few times
Unknown - currently unknown how often the threat will occur
Categories for consequences are defined as follows:
Not significant - no long-term effect on individuals or populations
Minor - individuals are adversely affected but no effect at population level
Moderate - population recovery stable or declining
Major - population decline is ongoing
Catastrophic - population trajectory close to extinction

Each threat has been described in Table 2 in terms of the extent that it is operating on the species. The risk matrix (Table 3) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; the spatial extent, and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with experts and using available literature.

Table 3 Risk Matrix

Likelihood	Consequences				
	Not significant	Minor	Moderate	Major	Catastrophic
Almost certain				Fire regimes that cause declines in biodiversity Increased temperatures and changes to precipitation patterns	
Likely			Damage caused by introduced deer		
Possible		Damage associated with road maintenance and recreational activities Weed invasion Herbivory and disturbance caused by the European rabbit	Reduced pollination success	Dieback caused by *Phytophthora cinnamomi*	
Unlikely					
Unknown					

Risk Matrix legend/Risk rating:

Low Risk	Moderate Risk	High Risk	Very High Risk

Priority actions have then been developed to manage the threats, particularly where the risk was deemed to be 'very high' (red shading) or 'high' (orange shading). For those threats with an unknown or low risk (blue and green shading respectively) research and monitoring actions have been developed to understand and evaluate the impact of the threats, where appropriate.

Conservation and recovery actions

Primary conservation objective

By 2032, the abundance of the Burrowa grevillea will have increased or remained stable and subpopulations will be sustained in habitats, in which high risk threats are managed effectively.

Conservation and management priorities

Fire impacts

- Ensure that planned burns do not occur within the Burrowa grevillea habitat before an accumulation of a seedbank large enough to replace the number of fire-killed standing plants. Noting that replacement should incorporate expected post-fire rates of seedling survival which will need to be determined with further research and monitoring.
- Develop and implement an evidence-based fire management strategy that optimises the survival of the species during planned burns and bushfires. Avoid planned burns and control the impacts of herbivory in recently burnt habitat, particularly from browsing by deer and European rabbit on seedlings and saplings.
- Provide maps of known occurrences to local fire services and the Victorian Country Fire Authority (CFA) and seek inclusion of mitigation measures in fire risk management plan/s, risk register and/or operation maps, including measures to avoid damage to plants and their habitat during fire suppression and mop-up operations.

Climate change impacts

- Investigate options for maintaining in situ persistence as the climate changes, for example, by minimising other population pressures, enhancing resilience, and promoting recruitment or supplementing existing populations.

Disease impacts

- Implement a *P. cinnamomi* management plan to ensure it is not introduced into known locations of the Burrowa grevillea and the spread in areas outside of, but adjacent to the Burrowa grevillea population is mitigated, including Mount Lawson State Park where *P. cinnamomi* is known to occur. Where feasible, close and revegetate roads and tracks to reduce ingress of disease.
- Ensure appropriate hygiene protocols are adhered to when entering or exiting the known locations of the Burrowa grevillea, particularly within the Burrowa-Pine Mountain NP, such as those outlined in Podger et al. (2001).

Introduced species impacts (including from grazing, trampling, predation)

- Continue to implement strategies to remove and control introduced deer, as detailed in the relevant management (Parks Victoria 2016). If required, investigate the use of deer exclusion fences and/or repellent, ensuring that these activities have minimal impacts on the Burrowa grevillea and its' habitat.

- Implement weed management actions in consultation with land managers, community, and indigenous groups, using appropriate techniques to minimise the effect of herbicide on native vegetation, according to the Australian Weeds Strategy 2017-2027 (IPAC 2016).

Ex situ recovery actions

- To manage the risk of losing genetic diversity, undertake appropriate seed collection and storage, and monitor the viability of stored seed. If the species is found to produce few seed, have low seed quality, or if seeds are difficult to store long-term, undertake alternative ex-situ storage such as tissue culture and cryopreservation, vegetative propagation, or cultivation of living collections. Seed/tissue collection and storage should be conducted in accordance with the best practice guidelines and procedures (Commander et al. 2021; Martyn Yenson et al. 2021).
- If appropriate, investigate the feasibility of establishing translocated subpopulations that will improve the conservation outlook of the species. Translocations should be conducted in accordance with best practice guidelines and procedures (refer to Commander et al. 2018), including monitoring translocated subpopulations through to recruitment to ensure they are viable.

Stakeholder engagement/community engagement

- Work with Traditional Owners to divulge any traditional knowledge associated with the species ensuring the practices to record, store and share this knowledge are mutually supported.
- Work with Traditional Owners to implement conservation actions, including Indigenous fire management practices and other survey, monitoring and management actions.
- Liaise with government agencies, land managers and stakeholder groups, particularly Parks Victoria and the management and conservation staff for Burrowa-Pine Mountain NP, to ensure that up-to-date population data and scientific knowledge to inform the implementation of conservation actions for this species.
- Promote community awareness of the Burrowa grevillea and identify opportunities for involvement in conservation actions.
- Develop and contribute to impact assessment and planning processes on measures to protect the Burrowa grevillea and its habitat, including park management plans and environmental impact assessments.

Survey and monitoring priorities

- Undertake targeted surveys to locate any additional subpopulations and identify suitable translocation sites.
- Implement a long-term monitoring program to assess population size/trends, habitat condition/degradation (including impacts from the threats identified above), recruitment and longevity across the species' range.
- Monitor the size, structure, and reproductive status of the population at different stages in the fire cycle, taking opportunities to monitor after planned and unplanned fires (where they occur) and improve understanding of the fire response of the species.

Information and research priorities

- Map habitat critical to the survival of the species and identify any critical habitat on Commonwealth land.
- Investigate the ecological requirements of the Burrowa grevillea, that are relevant to persistence, particularly in the context of climate change and high fire frequency:
  - primary and secondary juvenile periods and longevity,
  - population genetic structure, levels of genetic diversity and minimum viable population size,
  - soil seedbank dynamics and the role of seed predators and various disturbances (including fire), competition, rainfall and grazing in germination and recruitment,
  - reproductive strategies, phenology, and seasonal growth, with particular focus on the required fire interval time for regeneration and replenishment of the seed bank, post-fire survival rate of seedlings, and its' generation length, and
  - pollinator biology requirements.
- Avoid any use of managed fire research and other activities that impact the persistence of the species unless there is evidence to show there would be a positive and enduring effect on the Burrowa grevillea's persistence.
- Undertake vulnerability assessments of the species' sensitivity and adaptive capacity to changing climatic conditions which draw on genetic, physiological, or ecological evidence.
- If vulnerability assessments indicate the species has a high likelihood of extinction due to climate change, undertake research to identify climate refuges that may be suitable for translocations, including both modelling and experimental approaches (e.g., trial translocations). Consideration should be given to the benefits to the species in mitigating climate change related threats, as well as the risks to the recipient site (e.g., introduction of diseases, pests and/or pathogens, and invasiveness of the species).
- Determine the susceptibility of the Burrowa grevillea to *P. cinnamomi.*
- Monitor the abundance and distribution of European honeybees across the Burrowa grevillea's range and investigate if European honeybees are competing with pollinators for pollen resources in the Burrowa grevillea.

Links to relevant implementation documents

This Conservation Advice is developed to be able to subsequently inform other planning instruments, such as a Bioregional Plan or a multi-entity Conservation Plan.

Burrowa-Pine Mountain National Park Management Plan (1996)

Nature Conservation Strategy for parks and reserves managed by Parks Victoria (2021)

Threat abatement plan for competition and land degradation by rabbits (2016)

Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (2014)

Victoria's bushfire emergency: biodiversity response and recovery. Version 2 (2020).

Victorian Deer Control Strategy (2020)

Conservation Advice and Listing Assessment references

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The Threatened Species Scientific Committee finalised this assessment on DD Month Year.

Attachment A: Listing Assessment for *Grevillea burrowa*

Reason for assessment

This assessment follows evaluation by experts of the conservation status of the species following the 2019/20 bushfires.

Assessment of eligibility for listing

This assessment uses the criteria set out in the EPBC Regulations. The thresholds used correspond with those in the IUCN Red List criteria except where noted in criterion 4, sub-criterion D2. The IUCN criteria are used by Australian jurisdictions to achieve consistent listing assessments through the Common Assessment Method (CAM).

Key assessment parameters

Table 4 includes the key assessment parameters used in the assessment of eligibility for listing against the criteria. The definition of each of the parameters follows the Guidelines for Using the IUCN Red List Categories and Criteria.

Table 4 Key assessment parameters

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of mature individuals	2000	2000	4000	Molyneux & Forrester (2015) estimated at the time of their study that there were between 2000–4000 mature individuals in the population. The majority of mature individuals were killed in the 2019-20 bushfires, though this represents a natural part of the species life cycle, so is not considered a reduction in the number of mature individuals (IUCN 2022). Thousands of seedlings were present after the 2019-20 bushfires (RBG 2022. pers comm 14 February). These surveys did not quantify the number of seedlings in each subpopulation and did not determine a specific estimate of the number of seedlings aside from a generalised observation. With no other population estimates, or information on seedling survival rates, it is not possible to project the number of mature individuals following the 2019-20 bushfires. However, a net loss of mature individuals (relative to 2015 estimate) is projected, due to the ongoing impacts of increased fire frequency, out of season fires, climate change, and introduced herbivores (see Criterion 2). Therefore, the number of mature individuals is considered to be equivalent to the minimum pre-fire estimate, i.e., 2000 mature individuals.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Trend	Unknown in the past; Declining in the future			Molyneux & Forrester (2015) estimated a 30% population decrease over the next century in their study. Though despite a loss of mature individuals after the fires, this is considered as part of a natural fluctuation in the population size, as fire is required for germination (Molyneux & Forrester 2015). However, changes to fire weather conditions, rainfall patterns and temperature, and more time in drought, are likely to result in decline of suitable habitat, a net loss of mature individuals and an ongoing and irreversible decline in population size of the species in the coming decades (see Criterion 1/2).
Generation time (years)	75 years	50 years	100 years	The generation time is inferred from the mean frequency of bushfires that resulted in mass episodic seed recruitment (see Criterion 1 below). There is a lack of information on the length of the reproductive period, and the age of maturity (see 'Reproductive Ecology' section above). As all mature plants are fire-killed with germination triggered by fire, this represents the replacement of the old cohort by new regenerating individuals. Inferred from the fire history, the fire interval for the area is presumably 50–100 years (Molyneux & Forrester 2015). The mid-point of 75 years is used as an estimate for generation time.
Extent of occurrence	8 km^2	4.5 km^2	16 km^2	The estimate used in this assessment has been calculated using recorded data from 2000 to 2017 for known records and applying the shortest continuous imaginary boundary which can be drawn to encompass these records, as outlined in the Guidelines for Using the IUCN Red List Categories and Criteria (IUCN 2022). Note: Gallagher (2022) estimated EOO as 4 km^2, though this was amended to equal 16 km^2 as per the IUCN Guidelines (2022) which is taken as the maximum plausible value. Molyneux & Forrester (2015) estimated EOO as 4.5 km^2. All values are within the range of the Critically Endangered category of Criterion 2.
Trend	Unknown			All known subpopulations occur within Burrowa-Pine Mountain NP. There are no current past or present estimates on the population size, therefore the trend for EOO is unknown.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Area of Occupancy	8 km^2	Unknown	16 km^2	The estimate used in this assessment has been calculated using record data from 2000–2017 and applying 2 x 2 km grid cells, as outlined in the Guidelines for Using the IUCN Red List Categories and Criteria (IUCN 2022). Note: Gallagher (2022) estimated AOO as 16 km^2. Molyneux & Forrester (2015) estimated AOO of 0.23 km^2, though this was not calculated using 2 x 2 km grid cells (as required in the IUCN guidelines). We use 16 km^2 (Gallagher 2022) as the maximum plausible value. The minimum plausible value is unknown. The estimate used in this assessment falls within the range of the Critically Endangered category, while the maximum plausible value falls within the range of the Endangered category of Criterion 2.
AOO is a standardised spatial measure of the risk of extinction, that represents the area of suitable habitat known, inferred or projected to be currently occupied by the taxon. It is estimated using a 2 x 2 km grid to enable comparison with the criteria thresholds. The resolution (grid size) that maximizes the correlation between AOO and extinction risk is determined more by the spatial scale of threats than by the spatial scale at which AOO is estimated or shape of the taxon's distribution. It is not a fine-scale estimate of the actual area occupied. In some cases, AOO is the smallest area essential at any stage to the survival of existing populations of a taxon (e.g. breeding sites for migratory species).				
Trend	Unknown			Using the same reasoning as EOO (above), AOO is considered unknown.
Number of subpopulations	3	2	Unknown	There are 3 known subpopulations. For more information see 'basis of assessment of subpopulation number'.
Trend	Unknown			Thousands of seedlings were estimated to be present in the Black Mountain subpopulations in November 2021 and February 2022, i.e., following the 2019-20 bushfires (RBG 2022. pers comm 14 February). However, as the species has not been surveyed over time, the trend for the number of subpopulations is unknown.
Basis of assessment of subpopulation number	The entire recorded population is within Burrowa-Pine Mountain NP, where 3 subpopulations are reported (see 'Distribution' section above). It is possible that the Black Mountain individuals comprise a single subpopulation, so this has been included as the estimate for the minimum number of subpopulations. More detailed survey and/or genetic work is required to determine with certainty the exact number of subpopulations.			
No. locations	1	1	Unknown	There appears to be 1 location. For more information see 'basis of assessment of location number'.
Trend	Unknown			There is insufficient evidence to suggest whether the number of locations in the past was different to the current estimate, therefore the trend is unknown.
Basis of assessment of location number	The 2019–20 bushfires overlapped with approximately 100% of the Burrowa grevillea's modelled distribution (Gallagher 2022), with all plants in both Black Mountain subpopulations killed by the fire (RBG 2022. pers comm 14 February), with no post-fire surveys completed at the Mount Burrowa Walking Track subpopulation. Burrowa grevillea regenerates after fire from seeds (Molyneux & Forrester), and at the time of this assessment, most individuals were juveniles that recruited following the fires. Only a single threatening event (e.g., fire) would be required within the next 5–12 years for all individuals to be rapidly affected. As such, there is a single location.			

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Fragmentation	This species is not considered severely fragmented. This species occurs within a restricted distribution in north-eastern Vic, within Burrowa-Pine Mountain NP (see EOO/AOO and Map 1), in which there are an estimated 3 subpopulations (see 'basis of assessment of subpopulation number' above). The species has short-range dispersal (see 'Reproductive Ecology' section above), and it is highly likely that the subpopulations are sufficiently isolated in relation to the dispersal distance. However, following the 2019-20 bushfires, thousands of seedlings were recorded in the Black Mountain subpopulations in surveys in November 2021 and February 2022 (RBG 2022. pers comm 14 February), suggesting that natural recruitment is occurring in these subpopulations. Although the subpopulation at Mount Burrowa Walking Track has not been surveyed following the fires, at least two of three subpopulations have natural recruitment, suggesting that >50 % of the subpopulations are viable. Therefore, the species is not considered severely fragmented.			
Fluctuations	The number of mature individuals is drastically reduced following fire. However, as an obligate-seeder (Molyneux & Forrester 2015; White et al. 2020), recruitment is triggered after mature standing plants are killed by fire (see 'Reproductive ecology' section above). This is interpreted as a flux of individuals between life stages as opposed to changes in the total population according to the IUCN Guidelines (IUCN 2022). There are no known fluctuations in EOO, AOO, number of subpopulations, or locations.			

Criterion 1 Population size reduction

Reduction in total numbers (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered **Very severe reduction**	**Endangered** **Severe reduction**	**Vulnerable** **Substantial reduction**
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3, A4	≥ 80%	≥ 50%	≥ 30%

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

A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the 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, extent of occurrence and/or quality of habitat
(d) actual or potential levels of exploitation
(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites

Criterion 1 evidence

Insufficient data to determine eligibility

Generation time

The length of the reproductive period and age at maturity for Burrowa grevillea is currently unknown. The Burrowa grevillea is expected to be long-lived, with the age of the cohort before the 2019-20 bushfires estimated at approximately 60 years, based on the size of mature individuals and the time since the last major wildfire in 1952 (Molyneux & Forrester 2015). However, unrecorded recruitment events stemming from planned burns or unrecorded lightning strikes are likely to have occurred (CFA 2022. pers comm 23 February), given the presence of seedlings in the population in 2015 (Molyneux & Forrester 2015), which adds uncertainty over this estimate of longevity.

However, for obligate-seeder species, generation time can be inferred as the average frequency of bushfires which resulted in mass episodic seed recruitment (Molyneux & Forrester 2015). As all mature plants are fire-killed, such an event represents the replacement of the old cohort by new regenerating individuals. Inferred from the fire history, the fire interval for the area is presumably 50–100 years (Molyneux & Forrester 2015). We can use the mid-point of 75 years as an estimate for generation time.

Past population reduction

The only monitoring data available prior to the 2019-20 bushfires estimated 2000–4000 mature individuals (Molyneux & Forrester 2015). As there are no other comprehensive estimates from other points in time, there is insufficient data to quantitively evaluate population change over time. However, Molyneux & Forrester (2015) report no evidence to suggest significant decline in population size since European colonisation.

The 2019-20 bushfires overlapped with approximately 100% of the Burrowa grevillea's modelled distribution (Gallagher 2022). Following these fires, thousands of seedlings were recorded in the Black Mountain subpopulations in surveys in November 2021 and February 2022 (RBG 2022. pers comm 14 February). No post-fire surveys were completed at the Mount Burrowa Walking Track subpopulation. Fire kills mature plants and triggers recruitment from seed in this species (Molyneux & Forrester 2015) (see 'Relevant biology and ecology' section above), so the absence of mature individuals is likely to reflect this life-history strategy rather than genuine population reduction (IUCN 2022). Additionally, substantial seedling recruitment, aided by post-fire deer control programs, suggests that the species is recovering following these fires (RBG 2022. pers comm 14 February; DELWP 2022. pers comm 23 February) and there is no immediate population reduction in response to the 2019-20 bushfires.

Accordingly, there are insufficient data to determine if the species has undergone population reduction in the past and therefore insufficient data for listing under A1, A2 or A4.

Population reduction projected under climate change scenarios (fire)

Preceding the 2019-20 bushfires, Burrowa-Pine Mountain NP had not experienced a major bushfire since 1952, suggesting the natural fire interval for the range of the Burrowa grevillea is 50–100 years (Molyneux & Forrester 2015). Changes to this natural fire regime can threaten the survival of Burrowa grevillea in the future (see Table 2 above).

Anthropogenic climate change has already started to influence fire weather conditions across the world, including Australia (Abatzoglou & Williams 2016; Dowdy 2018). Since 1950, the frequency and magnitude of extreme fire weather conditions has increased in southern Australia (Dowdy 2018). The annual frequency of dangerous fire weather days has increased between 1950–1985 and 1985–2020, including across Vic which has seen increases in temperature and decreases in rainfall over the last 25 years (Bureau of Meteorology & CSIRO 2020; Parks Victoria 2021a). Further, the average frequency of bushfire events has increased by 40% between 2007–2013 (Dutta et al. 2016). As fire frequency and severity are predicted to continue to increase due to climate change (Dowdy et al 2019; Bureau of Meteorology & CSIRO 2020; van Oldenborgh et al. 2021), the Burrowa grevillea may decline in the future, as fire-free intervals continue to shorten (i.e., through interval squeeze) (Enright et al. 2015). At least 5–12 years are required between fires to enable regeneration and recovery of the Burrowa grevillea population (CFA 2022. pers comm 23 February). Any disturbance, e.g., fire, within this period, would likely result in a net loss of mature individuals, as the seedbank is unlikely to have returned to pre-fire abundance or quality.

Since 1950, the fire season has been starting earlier and extreme fire weather conditions have been increasing during spring and summer in Australia (Dowdy 2018). Across Australia, extreme fire weather conditions are projected to continue to increase in spring (Clarke et al. 2016). As the Burrowa grevillea flowers from late winter into spring and summer (Molyneux & Forrester 2015), an earlier, more severe fire season could impact the species' flowering and recruitment (Whelan 1995). Additionally, interactions between fire and seed predators may also elevate risks of decline, especially under small or patchy fires (Regan et al. 2003), such as planned burns or unrecorded lightning strikes.

Post-fire seedling survival is likely to be driven by the interaction of numerous factors, including germination cues, seasonality of moisture availability, competition for light and nutrients (CFA 2022. pers comm 23 February), disturbance events, and the impact from identified threats such as post-fire herbivory. The most significant interactive effect is when the fire regime promotes the activity of introduced deer species in the NP. The post-fire recovery of Burrowa grevillea may be seriously threatened by deer, as an increased fire frequency will provide additional food resources for deer that may browse on palatable regenerating seedlings (Downes 1983; Keith & Pellow 2005; Keith 2012; Hampton & Davis 2020; DELWP 2020b). The increased access for deer into fire-affected areas may further alter the fire regime, as deer browse on Burrowa grevillea or other co-occurring species, altering habitat structure (Hampton & Davis 2020). This impact can lead to further interactive effects, such as increased weed incursion (Hampton & Davis 2020), and possibly a reduction in co-occurring floral resources, reducing the abundance of pollinators and therefore the pollination efficiency for the Burrowa grevillea (Phillips et al. 2010). Although it is possible that extreme fire events may reduce deer numbers in the park (Forsyth et al. 2012; Crowther et al. 2016), deer may survive fires (Crowther et al. 2016), and can increase their numbers rapidly following fire, with high quality feed from regenerating vegetation increasing their reproductive rate (Crowther et al. 2016). Therefore, even if deer numbers are reduced from fire events, it is likely that burnt habitat will be re-occupied by deer within 1–2 years following fire (Forsyth et al. 2012).

Introduced deer are being actively managed in Burrowa-Pine Mountain NP following the 2019-20 bushfires (Parks Victoria 2021a), where ground shooting operations were reported to have significant success in controlling deer numbers within the park (Parks Victoria 2022. pers comm 14 February). However, management of deer may become increasingly difficult with projected increase in fire frequency, as deer abundance may increase due to improved access into fire-affected areas and increased opportunities for browsing on palatable regenerating seedlings. If continued management is unable to successfully control deer numbers in the NP, the recovery of Burrowa grevillea may be seriously threatened following fires.

Additionally, the response of plants and ecological communities to fire can depend on interactions with microorganisms within the soil microbiome (Wang et al. 2012; Cordovez et al., 2019). The composition of the soil microbiome can shift in responses to fire, with the subsequent direction and magnitude of the effect on plant post-fire recovery different between species (Revillini et al. 2022), highlighting the variable and complex interactions that mediate seedling survival and recovery post-fire.

The changes in fire weather conditions discussed above, are likely to result in a net loss of mature individuals and an ongoing and irreversible decline in population size of the species in the coming decades. A decline of at least 30% over the next 100 years is suspected by Molyneux & Forrester (2015) inferred from the projected increase in drought and high temperatures resulting in reduced recruitment from drought stress, and increased mortality from increased fire frequency, and increased herbivory from deer. However, given the lack of sufficient evidence (e.g., specific post-fire population estimates, modelling, seedling survival rates) at the time of this assessment to estimate a projected decline, the Committee considers there are insufficient data for listing under A3.

Population reduction projected under climate change scenarios (increased temperatures, decreased rainfall, increased time in drought)

Increased time in drought and decreases in rainfall due to climate change are likely to reduce seed production and seedling survival for the Burrowa grevillea (Midgley et al. 2006; Fitzpatrick et al. 2008; Shimizu-Kimura et al. 2017). The predicted increased frequency of drought may cause widespread plant mortality in forest ecosystems, as many plants are vulnerable to drought stress and hydraulic failure of their vascular system (Allen et al. 2010; Choat et al. 2012; De Kauwe et al. 2020).

In Australia, average temperatures have increased by approximately 1.5 °C since 1910, leading to increased frequency of extreme heat events (Bureau of Meteorology & CSIRO 2020). In southern and eastern Australia, cool season rainfall is predicted to continue to decrease, while temperatures are predicted to continue to increase, leading to more time in drought (as well as more intense, short duration rainfall events) due to climate change (CSIRO & Bureau of Meteorology 2015; Bureau of Meteorology & CSIRO 2020).

In Vic, mean annual temperature is projected to increase by 0.5–1.3 °C from 2020–2039 under all plausible scenarios of greenhouse emissions, resulting in up to 5.5 °C increase in the daily maximum temperature in the Burrowa grevillea's range (Clarke et al. 2019). Additionally, rainfall has declined by 20% across the majority of Vic from 1910–2020 (Parks Victoria 2021a), and projections suggest further decreases in rainfall across Vic, particularly in winter and spring (Clarke et al. 2019). This indicates an increased risk from high-fire frequency and a potential decline in the fire-free interval (Enright et al. 2015; Dowdy et al. 2019; Gallagher 2020; Gallagher et al. 2021). The interaction of increasing drought and fire frequency across the species' range may result in 'interval squeeze', whereby climate drives increased pressure via higher fire frequency, while also reducing resilience via slower rates of maturation and lower fecundity (Enright et al. 2015; Henzler et al. 2018).

The interactive effects of reduced soil moisture and fire (discussed above) may result in a net loss of mature individuals and an on-going and irreversible decline of the population size in the coming decades. However, there is insufficient evidence at the time of this assessment to estimate projected reduction due to these factors. Accordingly, there are insufficient data to quantify projected reduction and therefore insufficient data for listing under A3.

Conclusion

There are currently insufficient data to demonstrate if the species is eligible under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 2 Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy

		Critically Endangered Very restricted	Endangered Restricted	Vulnerable Limited
B1.	Extent of occurrence (EOO)	**< 100 km²**	**< 5000 km²**	**< 20,000 km²**
B2.	Area of occupancy (AOO)	**< 10 km²**	**< 500 km²**	**< 2000 km²**
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			

Criterion 2 evidence

Eligible under Criterion 2 B1ab(iii,v)+2ab(iii,v) for listing as Critically Endangered

Extent of occurrence and area of occupancy

The extent of occurrence (EOO) and the area of occupancy (AOO) are both estimated at 8 km^2. The EOO and AOO are based on the mapping of point records from 2000 to 2017, obtained from state governments, museums, and CSIRO. The EOO was calculated using a minimum convex hull, and the AOO was calculated using the 2 x 2 km grid cell method, as outlined in the Guidelines for Using the IUCN Red List Categories and Criteria (IUCN 2022).

The species' EOO and AOO appear to meet the requirements for listing as Critically Endangered under B1 and B2 (<100 km^2 and <10 km^2 respectively).

Number of locations

The 2019-20 bushfires overlapped with approximately 100% of the Burrowa grevillea's modelled distribution (Gallagher 2022), with all of individuals of the Black Mountain subpopulations confirmed to have been killed by the fires (RBG 2022. pers comm 14 February), and the Mount Burrowa Walking Track subpopulation also likely significantly affected due to the large impact of the fires across the NP. Burrowa grevillea regenerates after fire from seeds (Molyneux & Forrester 2015) and at the time of this assessment, most individuals were juveniles that recruited following the fires. If another threatening event (e.g., fire) were to occur within the next 5–12 years (i.e., the minimal fire-free interval estimated for the species) (CFA 2022. pers comm 23 February), most individuals would be at risk of poor recovery and there may not be a sufficient seed bank to replenish the population. Accordingly, only a single threatening event (e.g., fire) would be required within the next 5–12 years for all individuals to be rapidly affected.

The number of locations used in this assessment is one. The species' number of locations appears to meet the requirements for listing as Critically Endangered under this criterion.

Continuing decline

The only monitoring data available prior to the 2019-20 bushfires estimated 2000–4000 mature individuals (Molyneux & Forrester 2015). As there are no other comprehensive estimates from other points in time, there is insufficient data to quantitively evaluate population change over time. Further survey information is required to determine whether there has been any decline since the 2019-20 bushfires.

There is no evidence of disease (e.g., *P. cinnamomi*), herbivory, or weeds, directly impacting the Burrowa grevillea, however, introduced deer are suspected to be currently impacting the species (Table 2). The most prevalent threat to Burrowa grevillea is fire regimes that cause declines in biodiversity, and the interactive effect of this with introduced deer species (Table 2).

As discussed in Criterion 1 (see above), changes to fire weather conditions, rainfall patterns and temperature, and more time in drought are likely to result in decline of suitable habitat, a net loss of mature individuals and an ongoing and irreversible decline in population size of the species in the coming decades. Surveys of the Burrowa grevillea population following the 2019-20 bushfires found that strong regeneration was occurring in burnt areas (RBG 2022. pers comm 14 February). Though as discussed in Criterion 1 (see above), the minimum fire-interval for species is at least 5–12 years, and with the projected increased time in drought, the required fire-interval may increase for this species. If another severe disturbance event (e.g., fire) were to occur before regeneration has replenished the seedbank, we will likely see a decline in the number of mature individuals.

Additionally, increased fire frequency is likely to increase the impacts from deer (see Criterion 1 above). Fire triggers germination in obligate-seeders, such as the Burrowa grevillea, which results in an increased abundance of palatable regenerating seedlings on which deer may browse (Downes 1983; Keith & Pellow 2005; Keith 2012; Hampton & Davis 2020; DELWP 2020b). As fire frequency increases, so will access to burnt areas for deer and an increase in food resources immediately following fire events. This will severely impact the regeneration of Burrowa grevillea following fire, though may also lead to an overall decline in habitat quality due to interactive impacts.

Deer can act as vectors for weeds, potentially increasing their abundance in fire affected areas (Hampton & Davis 2020), which may further alter the fire regime and lead to a decline in habitat quality. Introduced deer can also reduce habitat quality and diversity through browsing/grazing plants, antler rubbing, trampling which causes soil compaction and erosion, and wallowing (Keith & Pellow 2005; DELWP 2020b; Hampton & Davis 2020). Additionally, deer may browse on co-occurring species, reducing the abundance of floral resources, leading to reduced pollination efficiency for the Burrowa grevillea and other co-occurring species (Phillips et al. 2010), resulting in an overall decline in biodiversity and habitat quality.

Burrowa-Pine Mountain NP is subject to the 2020–2021 deer and feral animal control program (Parks Victoria 2021b), which has had success in controlling deer numbers in the park (Parks Victoria 2022. pers comm 14 February), likely aiding the recovery of Burrowa grevillea following the 2019–20 bushfires. However, deer control must be ongoing to remain effective and management of deer may become increasingly difficult with the projected increase in fire frequency. The interactive effects of fire frequency and deer on the Burrowa grevillea are likely to continue to impact the species and lead to continuing decline, particularly if deer control ceases or is unable to account for the potential increase in deer abundance.

Indeed, Molyneux & Forrester (2015) suspect a projected decline of at least 30% over the next 100 years. Accordingly, the trend of EOO, AOO, area, extent and quality of habitat, number of locations, subpopulations and mature individuals is unknown in the past. However, the area, extent and quality of habitat, and the number of mature individuals is projected to undergo continuing decline over the coming decades, with a high degree of certainty (see Criterion 1). The species appears to meet the continuing projected decline requirement for listing under this criterion.

Severe fragmentation

This species occurs within a restricted distribution in north-eastern Vic, within Burrowa-Pine Mountain NP (see EOO/AOO and Map 1), in which there are an estimated 3 subpopulations (see 'basis of assessment of subpopulation number' above). The species has short-range dispersal (see 'Reproductive Ecology' section above), and it is highly likely that the subpopulations are sufficiently isolated in relation to the dispersal distance. However, following the 2019-20 bushfires, thousands of seedlings were recorded in the Black Mountain subpopulations in surveys in November 2021 and February 2022 (RBG 2022. pers comm 14 February), suggesting that natural recruitment is occurring in these subpopulations. Although the subpopulation at Mount Burrowa Walking Track has not been surveyed following the fires, at least two of three subpopulations have natural recruitment, suggesting that >50 % of the subpopulations are viable. Therefore, the species is not considered severely fragmented.

Extreme fluctuations

The number of mature individuals is drastically reduced following fire. However, as an obligate-seeder (Molyneux & Forrester 2015; White et al. 2020), recruitment is triggered after mature standing plants are killed by fire (see 'Reproductive ecology' section above). This is interpreted as a flux of individuals between life stages as opposed to changes in the total population according to the IUCN Guidelines (IUCN 2022). There are no known fluctuations in EOO, AOO, number of subpopulations, or locations. The species does not appear to meet the extreme fluctuations requirement for listing under this criterion.

Conclusion

The Burrowa grevillea's EOO, AOO, and number of locations appear to be very restricted; and area, extent and quality of habitat and the number of mature individuals are projected to undergo continuing decline.

The data presented above appear to demonstrate that the species is eligible for listing as **Critically Endangered** under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 3 Population size and decline

	Critically Endangered Very low	Endangered Low	Vulnerable Limited
Estimated number of mature individuals	**< 250**	**< 2500**	**< 10,000**
AND either (C1) or (C2) is true			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)	**Very high rate** **25% in 3 years or 1 generation** **(whichever is longer)**	**High rate** **20% in 5 years or 2 generation** **(whichever is longer)**	**Substantial rate** **10% in 10 years or 3 generations** **(whichever is longer)**
C2. An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:			
(a) (i) Number of mature individuals in each subpopulation	**≤ 50**	**≤ 250**	**≤ 1000**
(a) (ii) % of mature individuals in one subpopulation =	**90 – 100%**	**95 – 100%**	**100%**
(b) Extreme fluctuations in the number of mature individuals			

Criterion 3 evidence

Insufficient data to determine eligibility

Number of mature individuals

The Burrowa grevillea undergoes natural fluctuations in the number of mature individuals, characterised by the death of mature individuals and recruitment of seedlings (Molyneux & Forrester 2015; White et al. 2020). For taxa that naturally lose all or a subset of mature individuals at some point in their life cycle, the number of mature individuals should be estimated at the appropriate time, when mature individuals are available for reproduction (i.e., before fires occur when mature individuals are present; or enough time after fires when mature individuals to have recruited back from seed) (IUCN 2022).

Prior to the 2019-20 bushfires, Molyneux & Forrester (2015) estimated there were approximately 2000–4000 mature individuals. Following the 2019-20 bushfires, thousands of seedlings were recorded in the Black Mountain subpopulations in November 2021 and February 2022 (RBG 2022. pers comm 14 February). There have been no post-fire surveys of the Mount Burrowa Walking Track subpopulation. These surveys did not quantify the number of seedlings in each subpopulation or determine a specific estimate of the number of seedlings aside from a generalised observation. However, given the species life-history, the number of mature individuals is expected to have declined following the fires and increase over the next 5–20 years, as seedlings become mature.

A net loss of mature individuals (relative to 2015 estimate) is also projected, due to the ongoing impacts of increased fire frequency, out of season fires, climate change, and introduced herbivores (see Criterion 2). Therefore, the number of mature individuals is considered to be equivalent to the minimum pre-fire estimate, i.e., 2000 mature individuals.

The number of mature individuals appears to meet the requirements for listing as Endangered (<2500).

Continuing decline

As discussed in Criterion 2 (see above), the species appears to be undergoing continuing decline in the number of mature individuals. However, the rate of decline is unknown. Accordingly, the species appears to only meet the C2 continuing decline requirement for listing under this criterion and not the C1 continuing decline requirement.

Number of mature individuals in each subpopulation

Prior to the 2019-20 bushfires, thousands of individuals were recorded across all subpopulations, of which approximately 65% were mature individuals (Table 1) (Molyneux & Forrester 2015). However, the exact distribution of mature individuals across subpopulations both before and after the 2019-20 bushfires is unknown, and further surveys are required. Accordingly, the number of mature individuals in each subpopulation is considered data deficient, so there are insufficient data for the species to meet this requirement for listing under this criterion.

Percentage of mature individuals in one subpopulation

Given that mature individuals occurred in all three subpopulations (Molyneux & Forrester 2015), it is not possible for 95–100% of mature individuals to occur in one subpopulation. The percentage of mature individuals in one subpopulation is less than 100%, so the species does not appear to meet this requirement for listing under this criterion.

Extreme fluctuations in the number of mature individuals

As discussed in Criterion 2 (see above), there does not appear to be extreme fluctuations of mature individuals. The species does not appear to meet the extreme fluctuations requirement for listing under this criterion.

Conclusion

The species' population size appears to be <2500 mature individuals, and the number of mature individuals appears to be undergoing continuing decline. However, there are currently insufficient data to meet the other sub-criteria for listing under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 4 Number of mature individuals

	Critically Endangered Extremely low	Endangered Very Low	Vulnerable Low
D. Number of mature individuals	< 50	< 250	< 1000
D2.[1] *Only applies to the Vulnerable category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the species to critically endangered or Extinct in a very short time			D2. Typically: area of occupancy < 20 km^2 or number of locations ≤ 5

[1] The IUCN Red List Criterion D allows for species to be listed as Vulnerable under Criterion D2. The corresponding Criterion 4 in the EPBC Regulations does not currently include the provision for listing a species under D2. As such, a species cannot currently be listed under the EPBC Act under Criterion D2 only. However, assessments may include information relevant to D2. This information will not be considered by the Committee in making its recommendation of the species' eligibility for listing under the EPBC Act, but may assist other jurisdictions to adopt the assessment outcome under the *common assessment method*.

Criterion 4 evidence

Not eligible

Number of mature individuals

As discussed in Criterion 3, the number of mature individuals exceeds 1000. Therefore, this species is not eligible for listing under D.

Criterion D2 (listing under D2 is not currently possible under the EPBC Act)

Although the EPBC Regulations currently do not include provision for listing a species under D2, the species occurs in one location and the threats (Table 1) could drive the species to Endangered or Critically Endangered in a short period of time.

Conclusion

The data presented above appear to demonstrate the species is not eligible for listing under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Criterion 5 Quantitative analysis

	Critically Endangered Immediate future	Endangered Near future	Vulnerable Medium–term future
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

Criterion 5 evidence

Insufficient data to determine eligibility

Population viability analysis has not been undertaken.

Conclusion

There are currently insufficient data to demonstrate if the species is eligible under this criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

Public consultation

Notice of the proposed amendment and a consultation document is made available for public comment for a minimum of 30 business days. Any comments received relevant to the survival of the species/subspecies are considered by the Committee as part of the assessment process.

Adequacy of survey

The survey effort has been considered adequate and there is sufficient scientific evidence to support the assessment.

Listing and Recovery Plan Recommendations

A decision about whether there should be a Recovery Plan for this species has not yet been determined. The purpose of this consultation document is to elicit additional information to help inform this decision.

Cataloguing data

This publication (and any material sourced from it) should be attributed as: Department of Agriculture, Water and the Environment 2022, *Conservation Advice for Grevillea burrowa* (Burrowa grevillea), Canberra. 

This publication is available at the SPRAT profile for *Grevillea burrowa* (Burrowa grevillea).

Department of Agriculture, Water and the Environment
GPO Box 858, Canberra ACT 2601
Telephone 1800 900 090
Web awe.gov.au

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Version history table

Document type	Title	Date [dd mm yyyy]
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