Australian Government
Department of Agriculture, Water and the Environment

Consultation on Species Listing Eligibility and Conservation Actions

Banksia brownii (feather-leaved banksia)

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

1) the eligibility of *Banksia brownii* (feather-leaved banksia) for inclusion on the EPBC Act threatened species list in the 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 June 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 *Banksia brownii* (Brown's Banksia)

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:

☐ 1–5000 ☐ 5001–10,000 ☐ 10,000–25,000 ☐ 25,000>50,000 ☐ >50 000

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

<u>SECTION D</u> **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 1930s *(at or soon after the start of the most recent three generation/10 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:

    ☐ 1–25,000 ☐ 25,000–50,000 ☐ 50,000–100,000 ☐ >100,000 ☐ >200,000

    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 90 years (i.e. three generations)? 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 – 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 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 – 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

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

<u>SECTION G</u> 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?

Australian Government
Department of Agriculture, Water and the Environment

Conservation Advice for *Banksia brownii* (feather-leaved banksia)

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 approved conservation advice and listing assessment for the species. It provides a foundation for conservation action and further planning.

Photo of male feather-leaved banksia flower © Copyright Gilfillan & Barrett 2008

Conservation status

Banksia brownii (feather-leaved banksia) is being assessed by the Threatened Species Scientific Committee to be eligible for listing as Critically Endangered under Criterion 1. 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: Critically Endangered A3ce + A4ace
- Criterion 2: B1ab(i,ii,iii,iv,v)**+**B2ab(i,ii,iii,iv,v): Endangered
- Criterion 3: Not eligible
- Criterion 4: Not eligible
- Criterion 5: Insufficient data

The main factors that make the species eligible for listing in the Critically Endangered category are: population reduction of over 80 percent over the past three generations and projected population reduction of over 80 percent over the next three generations and a period including both the past and future.

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 Threat Database.

Species information

Taxonomy

Conventionally accepted as *Banksia brownii* AS George (1987) (Family: Proteaceae).

Description

Feather-leaved banksia, also known as Brown's banksia, is a smooth-barked shrub or small tree that grows up to 6 m high. The linear leaves, 3–12 cm long and 5–10 mm wide, are finely divided to the midrib, giving them a feathery appearance. These leaves are dark green and hairless above, but white and woolly beneath. Cylindrical reddish-brown flower-spikes form at the ends of the lower branchlets and underlie the upper branchlets. Flowers are pale brown or reddish to golden brown, opening from the top of the cylindrical spike from May to July. Seeds are retained in woody cones and mostly released to germinate when the parent plant begins to senesce or is killed by fire or similar disturbance (Brown et al. 1998, cited in Gilfillan & Barrett 2008, Lamont & Galea 1993).

Two forms of feather-leaved banksia are recognised; a northern form confined to the Stirling Range which has short, thin, hard leaves and a southern form which has long, wise, soft leaves occurring in the Albany-Cheyne Beach area (Keighery 1988).

Distribution

Feather-leaved banksia is endemic to south-western Western Australia (WA) and is currently known from 18 subpopulations occurring over 90 km, from Stirling Range National Park (NP) south to Albany and Cheyne Beach (Gilfillan & Barrett 2008; Coates et al. 2018). The currently known extant populations occur in Stirling Range NP, Waychinicup and Hassell NPs, Millbrook, Cheyne Rd, and South Sister Nature Reserves (NRs), and on Vancouver Peninsula (Appendix A).

Feather-leaved banksia has three geographically disparate clusters of subpopulations that are considered to be historically isolated (Coates et al. 2015). Genetic studies have demonstrated significant levels of differentiation among subpopulations of the species corresponding to these three geographically and historically isolated disjunct subpopulation groups; Stirling Range NP, Millbrook-Waychinicup and Vancouver Peninsula (Coates et al. 2015, 2018). These genetically distinct subpopulation groups also display ecological differences, and occupy contrasting habitats in terms of substrate, associated vegetation and climate. As such, they are considered to be separate conservation units for management and recovery (Coates et al. 2015).

Naturally occurring subpopulations

Detailed subpopulation information is available in Appendix A. As of 2008, the species was known from approximately 19,500 mature plants across 20 subpopulations, with 10 subpopulations that had gone extinct since 1996, due to the impacts of *Phytophthora cinnamomi* dieback. As of 2018, there were still 30 known subpopulations, though an additional two had gone extinct and 10 had less than 100 plants. Of these, eight had less than 10 mature plants remaining. Many of the extinct subpopulations were in Stirling Range NP (13, 15, 16B & C, 17, 21 A& B, 23, 24)) (S Barrett 2021. Pers comm 9 November). Genetic diversity studies based on material from extinct subpopulations via ex situ seed collections and extant populations, indicate that 38 percent of total genetic diversity, based on contributions of within subpopulation variation and differentiation, has been lost from the species through subpopulation extinctions (Coates et al. 2015).

As of 2021, the total number of mature individuals is estimated at >25,000. Much of the available data for smaller subpopulations were gathered in the early–mid 2000s, though there were at least around 25,000 individuals observed in 2020 and 2021 across three subpopulations: 1B (Millbrook NR), 22 (Waychinicup NP) and 26 (Cheyne Rd NR). Though the number of individuals has increased since 2008, this is likely a natural fluctuation, mostly caused by the germination of 240,000 seedlings after a fire at Millbrook NR prior to 2015 (Coates et al. 2015). Given that a juvenile period of 5–6 years is suspected, (see below), these plants that germinated prior to 2015 are mature as of 2021. Despite such fluctuations, all subpopulations will likely continue on a downward trajectory due to disease (S. Barrett 2021. Pers comm 9 November) and fire regimes that cause declines in biodiversity.

Fires in the Stirling Range NP during 2018 and 2019 burnt many Stirling Range NP subpopulations (subpopulations. 11, 12, 14, 16, 18, 20, 21, 27, 28) though poor recruitment has occurred at many of these sites aside from some areas on subpopulation 12 (Yungemere Peak). There has also been observed seedling death due to *P. cinnamomi* in 2021 as a result of wet conditions during summer and winter. Fire-affected subpopulations are undergoing assessment of germination and survival after the 2019 bushfire (S Barrett 2021. Pers comm 9 November).

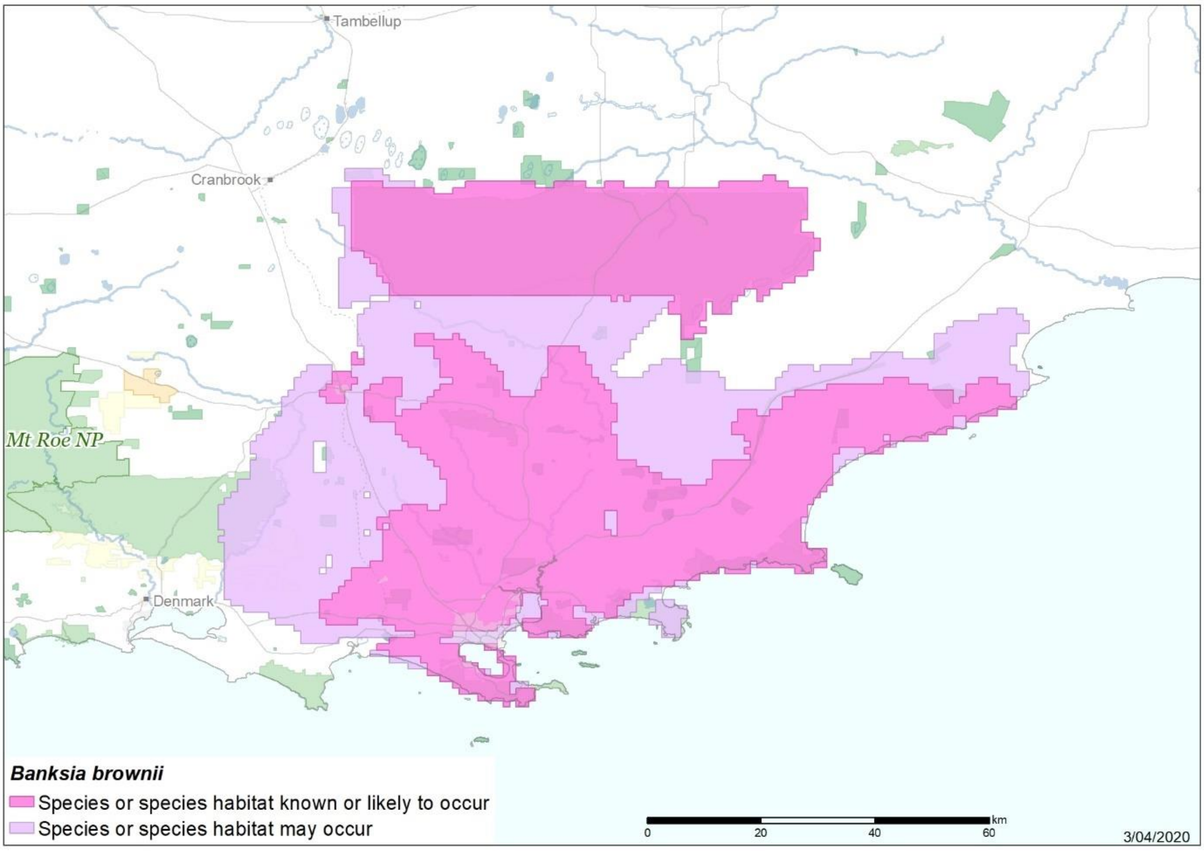
<u>Ex situ subpopulations</u>

The establishment of three translocated populations in new secure and disease-free locations was considered to be one of the most effective actions to initiate successful recovery of feather-leaved banksia (Coates et al. 2018). Given the recognition of three genetically and biogeographically distinct conservation units within the species, three separate translocations were considered optimal to maximise the conservation of genetic diversity (Coates et al. 2018). The three translocated subpopulations represent the Stirling Range subpopulations (Site 1), the Millbrook- Waychinicup subpopulations (Site 2) and the Vancouver Peninsula subpopulation (Site 3). Translocation sites were chosen based on soil and vegetation profiles, tenure, absence of threats (most notably *P. cinnamomi*), fire risk and potential control measures, and proximity to the known subpopulations (Coates et al. 2018). It was not possible to locate a translocation site in the Stirling Range, and thus site 1 was located north of the Porongurup Range in revegetated woodland on private property within 26 km of Stirling Range subpopulations. Site 2 is located in a *Eucalyptus globulus* (blue gum) plantation managed by the Australian Blue gum Plantations (ABP) and Site 3 is located on Snake Hill in Torndirrup NP. Each plant has been permanently tagged for monitoring purposes, caged to prevent grazing, and bushfire and *P. cinnamomi* control measures are present at all sites (Coates et al. 2018).

Detailed monitoring of the translocated populations is undertaken every 12 months and compared to selected original subpopulations, with more frequent informal monitoring undertaken where possible (Coates et al. 2018). This includes counting the number of surviving plants and their height, width of the crown in two directions, reproductive state, number of inflorescences and fruits, whether second generation plants are present, and the general health of the plants (Coates et al. 2018). As of 2018, after 10 years, survival at site 1 was 20 percent, site 2 was 49 percent and site 3 was 50 percent. After three years of good health and survival at site 1, extended dry periods resulted in a decline of plant numbers and the site may have become unsuitable for the species (Coates et al. 2018).

After these trials, it is considered possible to establish new subpopulations of this species, though it may require higher moisture conditions than other Proteaceae from south-west WA (Coates et al. 2018). In 2021, two translocations of the Stirling Range genetic type from multiple subpopulations were undertaken, and these sites will be subsequently monitored (S Barrett 2021. Pers comm 9 November 2021).

Map 1 Modelled distribution of feather-leaved banksia



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 containing herein.
Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture (a) the specific habitat type or geographic feature that represents to recent observed locations of the species (known to occur) or preferred 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

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 it is shared and used.

Feather-leaved banksia occurs on the traditional lands of the Ganeang, Goreng and Minang dialectal groups of the Noongar Nation. Koikyenunuruff (Stirling Range) is a culturally significant site to Noongar Peoples and features in Dreaming stories (DPAW 2016; South West Aboriginal Land & Sea Council 2020). Bula Meela (Bluff Knoll), where an extinct subpopulation of feather-leaved banksia occurred, is the location where the spirits of Ganeang, Goreng and Minang Traditional Owners go after death (South West Aboriginal Land & Sea Council 2020). An Aboriginal Heritage Place, Kojaneerup (5145), has been registered with the Western Australian Department of Planning, Lands and Heritage in or adjacent to lands where the species occurs, and an additional 41 cultural heritage sites have also been registered in the area around the species' distribution (DPLH 2020). Additionally, the Wagyl Kaip & Southern Noongar Indigenous Land Use Agreements (2018), executed by the Western Australian Government and the Noongar Nation, includes lands in or adjacent to lands where the species occurs.

Relevant biology and ecology

Habitat

Feather-leaved banksia occurs on rocky sand clay loam soils, sandy clay soils on lateritic ridges and granite, and sandy clay loam on sandstone and metamorphic rock on slopes, gullies and mountains (Robinson & Coates 1995; Gilfillan & Barrett 2008). Prior to the discovery of the three separate groups of subpopulations, there were thought to be two distinct subpopulation clusters with separate habitats (southern and Stirling Range). These habitat types included low woodland of *Eucalyptus marginata* (jarrah) on shallow sand over laterite in southern subpopulations, and among heath on rocky slopes and tops in the Stirling Range (Taylor 1988, cited in Gilfillan & Barrett 2008). Currently, it is considered that the three subpopulation groups occupy different habitats in terms of substrate, associated vegetation and climate (Coates et al. 2018). However, it appears that the Stirling Range subpopulations are more ecologically and climactically dissimilar than the other two subpopulation groups.

<u>Stirling Range</u>

Subpopulations from the Stirling Range are found on mountain tops and slopes from 500–1100 above sea level in thicket and mallee heath (Gilfillan & Barrett 2008). Compared to the surrounding area, soil moisture is likely to be considerably higher on the mountain peaks of the Stirling Range, and the conditions on the mountains are distinctively montane, with extreme temperatures, high humidity and occasional snowfall (DBCA 2020).

In Stirling Range NP, feather-leaved banksia occurs within the Eastern Stirling Range Montane Heath and Thicket Community (Gilfillan & Barrett 2008). This community grows on shallow, siliceous soils over sandstone, metamorphosed sandstone and metamorphosed siltstone. It consists of dense heath and thicket dominated by *Banksia oreophila* (western mountains banksia) and *Kunzea montana* (mountain kunzea), and includes *Adenanthos filifolius, Andersonia axilliflora* (giant andersonia), *Aotus genistoides*, *B. coccinea* (scarlet banksia), *Beaufortia anisandra* (dark beaufortia), *Calothamnus montanus* (hawkeswood), *Darwinia collina* (yellow mountain bell), *Leucopogon gnaphalioides* and *Sphenotoma* sp. Stirling (DBCA 2020).

Feather-leaved banksia also occurs in the Montane Mallee Thicket priority ecological community, protected in Western Australia, which grows on sand clay loam on sandstone and metamorphic rock including quartzite, slate and phyllite (Muhling & Brakel 1985, cited in Gilfillan & Barrett 2008) on the mid to upper slopes of mountains and hills in the Stirling Range. Species that characterise this community include *Banksia solandri* (Stirling Range banksia), *Banksia grandis* (bull banksia), western mountain banksia, *Banksia foliolata*, scarlet banksia, jarrah, *Isopogon latifolius*, *Andersonia echinocephala*, *Adenanthos filifolius*, *Sphenotoma* sp. Stirling Range and *Gastrolobium rubrum* (Barrett 2005).

Millbrook - Waychinicup and Vancouver Peninsula

In the southern subpopulations, the species is found in mallee heath shrubland and woodland communities in sandy clay soils on lateritic ridges or granite (Gilfillan & Barrett 2008). The associated vegetation is rich in proteaceous (*Banksia, Lambertia, Isopogon, Hakea, Adenanthos*) and myrtaceous (*Eucalyptus, Agonis, Kunzea, Beaufortia*) species (Gilfillan & Barrett 2008). This habitat does not have a montane climate, unlike the Stirling Range and thus plants in these subpopulations persist with presumably lower rainfall and fewer temperature extremes.

The main difference between the Vancouver Peninsula and Millbrook - Waychinicup subpopulation groups is the substrate. The Vancouver Peninsula subpopulation occurs on granite/ fringing granite, whilst Millbrook - Waychinicup subpopulations occur on laterite (S Barrett 2021. pers comm 9 November).

Pollination biology

Much of the information on the biology and ecology of feather-leaved banksia comes from studies at Millbrook NR conducted over two seasons (1990 and 1993) and South Sister NR in one season (1993). Limited information is available on the biology and ecology of the Stirling Range form of the species (Gilfillan & Barrett 2008).

The flowering period of feather-leaved banksia has been recorded from March to August, with freshly opened inflorescences most abundant during winter (George 1981, cited in Gilfillan & Barrett 2008; Collins et al. 1994, cited in Gilfillan & Barrett 2008; Collins et al. 1996, cited in Gilfillan & Barrett 2008; Day et al. 1997). Flowering appears to peak during June, and there may be a positive correlation between the number of inflorescences produced per plant, the duration of flowering, canopy volume and mean canopy width (Collins et al. 1994, cited in Gilfillan & Barrett 2008; Collins et al. 1996, cited in Gilfillan & Barrett 2008; Day et al. 1997). Fruiting success (proportion of inflorescences that set fruit) and fruit set (proportion of flowers that develop into follicles) is low, which is characteristic of hermaphroditic plants (Day et al. 1997, cited in Gilfillan & Barrett 2008). However, it is also dependent on pollinator efficiency and pollination success. Evidence of insect damage suggests that inflorescence consumers may reduce fruit set (Gilfillan & Barrett 2008).

The major pollinators of feather-leaved banksia are birds and small mammals (Coates et al. 2018). Specifically, *Phylidronyris novaehollandiae* (New Holland honeyeaters), *Anthochaera caranculata* (red wattlebirds), the nocturnal *Rattus fuscipes* (bush rat) and *Tarsipes rostratus* (honey possum) have all been found to carry significant loads of pollen at sites in South Sister and Millbrook NRs (Kelly & Coates 1995; Collins et al. 1994, cited in Gilfillan & Barrett 2008; Collins et al. 1996, cited in Gilfillan & Barrett 2008; Day et al. 1997).

Seasonal abundance of New Holland honeyeaters, red wattlebirds and *Acanthorhynchus superciliosus* (western spinebills) has also been positively correlated with the density of feather-leaved banksia inflorescences (Collins et al. 1994, cited in Gilfillan & Barrett 2008). At Millbrook NR, nearly 80 percent of the pollen in pollen smears from New Holland Honeyeaters were from feather-leaved banksia during May, increasing to 97 percent in June (coinciding with peak flowering time). A similar trend was found at South Sister (Collins et al. 1994, cited in Gilfillan & Barrett 2008; Day et al. 1997, cited in Gilfillan & Barrett 2008). Furthermore, pollinator exclusion experiments at South Sister NR (Collins et al. 1994, 1996, cited in Gilfillan & Barrett

2008) found that fruiting success and fruit set was low in mammal and bird and mammal only exclusion treatments (9.3 percent and 19.8 percent fruiting success respectively). These experiments highlight the importance of vertebrates as pollinators of feather-leaved banksia, though the importance of different vertebrate pollinator groups may vary between sites. A greater level of pollen removal occurred during the day at Millbrook NR compared to South Sister NR, and the rate of night-time, but not daytime flower opening (which may be triggered by animal visitors) was higher at South Sister than at Millbrook. These site differences are likely to correspond to a greater number of nocturnal mammal pollen vectors at South Sister NR and a greater number of diurnal bird pollen vectors at Millbrook NR (Collins at el. 1994, cited in Gilfillan & Barrett 2008; Day et al. 1997).

Invertebrate pollinators are thought to play a minor role in pollination of the species. The honeybee (*Apis mellifera*) is the only invertebrate observed to come into contact with the stigma and pollen when foraging on flowers (Collins et al. 1994, cited in Gilfillan & Barrett 2008; Day et al. 1997).

Reproduction

Both the Millbrook and South Sister subpopulations have displayed a mixed mating system that involves a substantial amount of self-fertilisation with a small degree of outcrossing and biparental breeding (Sampson et al. 1994; Collins et al. 1994, cited in Gilfillan & Barrett 2008; Day et al. 1997). It has been suggested that the low level of outcrossing may be related to the species' fire strategy – as it is non-sprouting and is killed by fire, fecundity is likely to be increased with a degree of self-compatibility and this reduces the risk of sudden elimination in a fire-prone area (Carpenter & Recher 1979, cited in Gilfillan & Barret 2008). The mating system is also consistent with the fact that the species is self-compatible and is pollinated by species whose foraging behaviour is conducive to pollen transfer onto the stigma of the same flower or other flowers on the inflorescence and same plant (Day et al. 1997). Due to this mating system, around 20 percent of genetic diversity would be expected to be among subpopulations and small subpopulations may be more prone to inbreeding than larger ones. It is suggested that large subpopulations are needed to conserve the genetic diversity of the species (Gilfillan & Barret 2008).

Seed dispersal and recruitment

Feather-leaved banksia is an obligate seeder with a canopy stored seed bank (serotinous obligate seeder) (Gilfillan & Barrett 2008). This means that, if a fire occurs, seed reserves accumulated in woody cones are released en masse from the canopy when the parent is burnt (Silcock et al. 2021), though the degree of serotiny varies between populations and decreases over time. The seeds are also released when the parent senesces or the branch supporting the cone dies. An appropriate fire regime is important for the persistence of fire-sensitive serotinous species, as a subpopulation exists only as seeds after fire and no seeds are stored in the soil until the next fire. Therefore, if seedlings fail to establish, the subpopulation may become locally extinct. Seedling recruitment can occur spontaneously in the inter-fire period, but this is limited, and fire is usually necessary to trigger large seed releases (Galea & Lamont 1993).

Seeds are stored in the canopy for approximately 4 years before the follicles split and release seed, though the seed may be viable for at least 30 years (Coates et al. 2018). A study of the effects of fire at Millbrook Rd found that seed release from cones after a fire was gradual, completing at 97 days post-fire with 45.8 percent of seed released. The number of seedlings recorded 200 days post fire represented only 4.4 percent of the total number of pre-fire unopened follicles (corresponding to 6.1 seedlings per parent) (Galea & Lamont 1993). This contrasts with the post-fire recruitment of 0.04 seedlings per parent in the Mt Success subpopulation and 0.08 seedlings per parent in the SE Ellen Peak population after a nine-year fire interval (S. Barrett, unpublished data, cited in Gilfillan & Barrett 2008). Germination was documented to have occurred by September 2020 after a fire in December of 2019 (S Barrett 2021. pers comm 9 November).

The mean number of cones per plant may be variable between subpopulations, as the southern coastal subpopulations had a much greater number of cones per plant than the two studied Stirling Range subpopulations. Differences in cone production may also occur within subpopulations and may be related to differences in aspect or topography, which can affect fruiting success (Gilfillan & Barrett 2008). The nutrient status of the site also affects fruit, cone and follicle production, as these reproductive structures are nutritionally and physiologically expensive to produce, especially in nutrient poor soils.

Time to maturity and lifespan

The species is considered to live for up to 50 years (S Barrett 2021. pers comm 9 November) and field observations indicate that feather-leaved banksia plants in southern subpopulations reach reproductive maturity (first flowering) after approximately five to six years (Lamont & Baker 1988, cited Gilfillan & Barrett 2008; S. Barrett, personal observation, cited Gilfillan & Barrett 2008). However, on Mt Hassell in Stirling Range NP, only three plants out of twenty were flowering eight years after a fire (S. Barrett, personal observation, Gilfillan & Barrett 2008). Cochrane et al. (2010) considers the juvenile period of feather-leaved banksia to be 10 years in upland habitat compared with six years in coastal locations. However, this is likely just the period that is required to flower, and the species will take longer to produce an adequate seed bank (see below).

Kelly and Coates (1995) suggested fire intervals of at least 10 years are required for adequate seed banks to accumulate in the species. A minimum desirable fire interval may be estimated by a doubling of the primary juvenile period (time to first flower) (Gill and Nicholls 1989), though Gilfillan & Barrett (2008) suggest 2.5 times the juvenile period may be more appropriate for slow maturing serotinous species. This suggests a fire interval of 15 years would be required to reach maturity and accumulate an adequate seed bank in the southern subpopulation groups, which Coates et al. (2018) also consider to be fire-free period required to reach maturity and accumulate an adequate seed bank). Based on a time to first flowering of seven years in the Stirling Range a fire interval of 17–20 years was recommended for Stirling Range subpopulations by Gilfillan & Barrett (2008). However, noting that the Stirling Range time to first flowering estimate has increased to ten years (Cochrane et al. 2010), and, using the above methodology, an updated fire interval estimate is around 20–25 years.

Fire history

Known fire history of each subpopulation is available in Appendix A. Frequent fire (<15 year intervals) has not been a threat to southern (non-Stirling Range) subpopulations, however fires occurred in the Stirling Range in close succession in 1991 and 2000 , resulting in poor post-fire regeneration. Lack of seedling recruitment post-fire is thought to be primarily related to a short fire interval; however, both fire severity and/or season may also contribute to poor recruitment. (Gilfillan & Barrett 2008)

More recently, Stirling Range NP subpopulations have been impacted by fires in 2018 and 2019. In May 2018, an escaped prescribed fire burnt 17,000 hectares in the eastern extent of Stirling Range NP (OBRM 2018), and in December 2019, a bushfire burnt through much of the area. Subpopulations 14, 16 and 20 were impacted by the 2018 fire and subpopulations 11, 12, 18, 21, 27 and 28 were burnt in 2019. Relatively low levels of recruitment have occurred at many of the smaller populations burnt in either 2018 or 2019, aside from subpopulation 12 (Yungemere Peak), and there has been observed seedling death in all subpopulations due to *P. cinnamomi*. The same subpopulations were not affected by both fires, though any future fire events in the area may threaten all sites in Stirling Range NP.

Commensal species

Feather-leaved banksia is the sole host to the Critically Endangered herbivorous plant-louse *Trioza barrettae.* A coordinated approach to prevent co-extinction has recently involved the successful translocation of the plant louse from the Vancouver Peninsula feather-leaved banksia subpopulation to translocation site 3 (Taylor & Moir 2014; Moir et al. 2012, 2016; Coates et al. 2018).

Habitat critical to the survival

Habitat critical to the survival of the species includes the area of occupancy of important populations; areas of similar habitat surrounding important populations that provide potential habitat for natural range extension and allow pollinators or biota essential to the continued existence of the species to move between subpopulations; and additional occurrences of similar habitat that may contain the species or be suitable for future translocations or other recovery actions.

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 subpopulation, in keeping with the terminology used in the EPBC Act and state/territory environmental legislation.

There is sufficient evidence through the species eligibility for listing as Critically Endangered to consider all populations/the national population as important populations of this species under particular pressure of survival and which therefore require protection to support the recovery of the species.

Threats

Feather-leaved banksia is threatened by *Phytophthora cinnamomi* dieback and other diseases, fire regimes that cause declines in biodiversity and climate change.

Table 2: Threats impacting feather-leaved banksia

Threat	Status and severity [a]	Evidence

Disease		
Dieback caused by *P. cinnamomi*	• Timing: current • Confidence: observed • Consequence: catastrophic • Trend: increasing • Extent: across the entire range	Dieback caused by *P. cinnamomi* is listed as a Key Threatening Process under the EPBC Act (DoEE 2018). *Phytophthora cinnamomi* a soil-borne pathogen which infects a large range of plant species and contributes to plant dieback and death, especially when other stressors such as waterlogging, drought and fire are present (DoEE 2018). It was introduced to south-western WA and is now widespread. The impact of the disease on plant communities is variable and is dependent on the susceptibility of species in the community, as well as temperature, soil type, nutrient status and hydrology (Gilfillan & Barrett 2008). The most damage usually occurs in areas with infertile soil and poor drainage. The disease is especially virulent in the Proteaceae plant family, of which feather-leaved banksia is a member. Feather-leaved banksia is highly susceptible to infestation by *P. cinnamomi.* Almost 80% mortality has been observed at the Millbrook subpopulation 1 in 2021 (DBCA 2022. pers comm 29 March), and similarly, over 80% of plants were killed at a site 96 days after inoculation by the pathogen (McCredie et al. 1985; Wills 1993), the second highest susceptibility out of 49 *Banksia* species studied. Other susceptibility investigations also rate the species as highly susceptible, corresponding to the death of over 80% (Bryan Shearer, unpublished data, cited in Gilfillan & Barrett 2008) or over 95 percent (Shearer et al. 2012) of plants. Barrett et al. (2008) assessed the extinction risk of 33 Stirling Range NP plants to extinction through *P. cinnamomi* dieback, and rated feather-leaved banksia as the fourth most likely species to go extinct. The species was given a risk of extinction rating of 33.1 (out of a maximum of 36), which classified for the very high category. *Phytophthora cinnamomi* can disperse in water flowing from roots of infected plants to roots of healthy plants, and soil clinging to vehicles, animals and walkers (DoEE 2018). Human activity is thought to have spread the pathogen to many subpopulations in the Stirling Range, though native animal vectors may also have aided in spreading the pathogen (Gilfillan & Barrett 2008). *Phytophthora cinnamomi* may also interact with fire to increase the impact of the disease and accelerate collapse of obligate seeding plants such as feather-leaved banksia (Moore et al. 2015). In areas where the pathogen is present, the densities of these plant species are highest in sites not affected by recent fires (Barrett & Yates 2015). Observations indicate that the impact of *P. cinnamomi* may be exacerbated post-fire, due to altered hydrology and increased surface run-off, as well as increased root tissue vulnerability (B. Shearer, personal communication, cited in Gilfillan et al. 2008). Aside from direct mortality of feather-leaved banksia, the death of susceptible species through *P. cinnamomi* dieback may cause dramatic changes in vegetation floristics, structure and community composition that will affect the species (Weste & Marks 1987 cited in Gilfillan & Barrett 2008;

		Shearer and Tippett 1989, cited in Gilfillan & Barrett 2008; Wills 1993; Wilson et al. 1994; Laidlaw et al. 2006 .; DoEE 2018). Changes in vegetation structure and floristics caused by *P. cinnamomi* also affect the abundance of vertebrate pollinators in these communities (Wills 1993; Laidlaw 2006 et al.; DoEE), potentially by direct or indirect effects on food sources, loss of thick ground cover used as shelter and increased predation risk (Wilson et al. 1994; DoEE 2018). A study in the Waychinicup area found significantly higher bush rat abundance in healthy sites compared with *P. cinnamomi* infested sites (Whelan 2003, cited in Gilfillan & Barrett 2008), suggesting that *P. cinnamomi* may indirectly affect feather-leaved banksia through loss of pollinators. While it is not known how long the pathogen *P. cinnamomi* has been in the region, records of subpopulation extinction in began in the mid-1990s, starting with very large subpopulations in the Eastern Stirling Range montane heath and thicket community (Barrett & Yates 2015). In 1965, there were healthy stands of the species on Bluff Knoll, and from 1985–1989 it was considered a common and dominant shrub in the thicket on the Bluff Knoll plateau (Pignatti et al. 1993). However, monitoring since 1994 has not detected the species on Bluff Knoll and this subpopulation is presumed to be locally extinct (Barrett & Yates 2015). *Phytophthora cinnamomi* has also interacted with fire to quickly destroy subpopulations of the species. After a fire in 2000, the mean number of plants in eight quadrats on Mt Success declined from around 25 to 0–1 (Barrett & Yates 2015). This is likely because fire destroyed the mature plants and *P. cinnamomi* dieback killed seedlings, resulting in subpopulation extinction. Twelve subpopulations have become locally extinct primarily due to *P. cinnamomi* dieback (Coates et al. 2018). Of the currently known subpopulations of feather-leaved banksia, only one is considered to occur in uninfested vegetation, though *P. cinnamomi* occurs nearby (S Barrett 2021. pers comm 9 November). Currently, all subpopulations are considered to be in decline due to disease (S Barrett 2021. pers comm 9 November). The impacts of *P. cinnamomi* are likely to continue to increase due to climate change (Thompson et al. 2014; Homet et al. 2019).
Aerial canker (*Zythiostroma* sp.)	• Timing: current • Confidence: observed • Consequence: major • Trend: increasing • Extent: across parts of the range	Aerial canker has been observed to cause mortality of plants in the Vancouver Peninsula and Waychinicup subpopulations, as well as limb death in the Millbrook NR subpopulations (Gilfillan & Barrett 2008). It has also been recorded at the Yungemere Peak subpopulation, where sampling in 2003 verified the presence of the fungus (B. Shearer, personal communication, cited in Gilfillan & Barrett 2008). Aerial canker causes dieback from the tips of leaves, with larger branches impacted over time, eventually leading to plant mortality in some cases (Shearer et al. 1995) It has caused high mortality rate in scarlet banksia (*B. coccinea*) on the south coast of WA (Shearer et al. 1995). As of 2021, aerial canker continues to have a significant impact on subpopulations, particularly on Yungemere Peak

		(pre-fire) and Waychinicup NP (S Barrett 2021. pers comm 15 November).
Armillaria root rot fungus (honey fungi)	• Timing: current • Confidence: observed • Consequence: moderate • Trend: static • Extent: across parts of the range	The root rot fungus *Armillaria* sp. has caused the death of plants in the Vancouver Peninsula subpopulation. *Armillaria* fungus can cause white root rot, leading to stunted leaves, dieback and potentially death. It spreads using root contact and spores (Robinson 2008). *Armillaria luteobubalina* (Australian honey fungus) is a widespread pathogen in the southwest of Western Australia and is known to be associated with the deaths of *Banksia* spp. in coastal woodlands (Robinson 2008). The species infects the roots and eventually kills the plant when the root is girdled. Seedlings and saplings are most vulnerable to infection, and drought or fire may aid infection in otherwise healthy plants (Robinson 2008). The pathogen kills the host plant and then feeds off the root system, allowing it to persist for decades in the same area (Robinson 2008).
Habitat disturbance and modification		
Fire regimes that cause declines in biodiversity	• Timing: current • Confidence: observed • Consequence: catastrophic • Trend: increasing • Extent: across the entire range	Feather-leaved banksia is a serotinous obligate seeder, and recruits from canopy-stored seed primarily after fires kill mature plants. The total population can undergo natural fluctuations in the number of mature individuals if multiple subpopulations are exposed to the same fire event. Keith (1996) identified several fire driven mechanisms of plant population decline and extinction for obligate seeder shrubs. These mechanisms included death of standing plants and seeds, failure of seed release and/or germination, failure of seedling establishment, interruption of maturation or developmental growth, and failure of seed production. Keith (1996) also identified fire regimes associated with multiple mechanisms of plant population decline and extinction, including both high frequency and low frequency fires. Fires also interact with disease and herbivores, which elevate risks of recruitment failure in the post-fire environment (Moore et al. 2015;). *High frequency fire* Feather-leaved banksia subpopulations are threatened by a high frequency fire regime that does not allow plants to sexually mature and produce a sufficient seed bank, ultimately leading to a lack of recruitment of juveniles. As an obligate seeder, feather-leaved banksia requires an appropriate interval between fires to reach reproductive maturity and produce sufficient seed for the next generation whilst not senescing (tolerable fire interval). Fire intervals less than 15-25 years (depending on the subpopulation, seed bank accumulation rates and recruitment success) may result in subpopulation declines, and potentially local extinction. If the fire frequency is less than the minimum fire interval, the species is unlikely to have replenished its population to pre-fire numbers and population declines are projected. A high frequency fire regime can also reduce vegetation cover, leading to increases in soil temperature from solar insolation and increases in surface or sub-surface flow on mountain slopes,

		which may exacerbate the impact and spread of *P. cinnamomi* (Barrett 2000; Moore et al. 2015). Within the Stirling Range NP, eight of the 13 subpopulations were burnt in 1991 and 2000, an interval of nine years. Of these, five were considered either almost extinct or presumed extinct as of 2008 (Gilfillan & Barrett 2008). By 2015, approximately 74% of the Eastern Stirling Range Montane Heath and Thicket Threatened Ecological Community had experienced short, nine-year fire intervals over the previous 50 years (Barrett & Yates 2015). Drivers of high frequency fires (due to a reduction in the fire-free interval) are climate induced wildfire and drought (see below) and prescribed burning. Fire management strategies use prescribed burns to reduce fuel and minimise the impact of wildfire; however, prescribed burns can also increase the frequency of wildfires. For example, a widespread fire in 2018 was the result of an escaped prescribed burn and was followed a year later by a wildfire in 2019 (OBRM 2018). *Low fire frequency* Serotinous obligate seeding banksia like feather-leaved banksia are also threatened by fire intervals which are too infrequent. The long-term absence of fire leads to senescence of mature adults without subsequent recruitment from the canopy-stored seedbank (Keith 1996). For example, subpopulation 5 at South Sister Nature reserve has undergone long-term decline due to the absence of fire. These declines are particularly pronounced through their interactions with diseases such as *P. cinnamomi* and aerial canker. In such cases, the subpopulation undergoes attrition at a faster rate, and due to the very low levels of inter-fire recruitment, subpopulation collapse occurs. *Fire season* Fire season affects the long-term survival of plants through mortality of adults, the availability of propagules, and the post-fire establishment of seedlings (Miller et al. 2019), as well as dispersal of plant propagules (Keith et al. 2020). When a fire occurs out of season there are a number of mechanisms that lead to recruitment failure and reduce the recovery potential of species following fire (DAWE 2021). These include directly via disruption of phenological processes, or indirectly by affecting other species that influence habitat, food or trophic interactions. Examples include: 1) seedling mortality due to desiccation as a consequence of the interaction between out of season fires and fire-hydrological interactions, particularly by temperate region obligate seeders (Miller et al. 2019), 2) low rate of seed production due to sub-optimal flowering cues (Morgan 1995) and/or dormancy cues (Ooi et al. 2007), particularly by species that rely on seasonal pollinators or specific flowering conditions, and 3) disruption to processes that facilitate post-fire recovery and limit dispersal (Jasinge et al. 2018; Keith et al. 2020), particularly by species with seasonal growing conditions.

		Feather-leaved banksia is adapted to seasonal fire regimes consisting of fire during the dry dormant summer periods followed by moist conditions during the growing and reproductive period in winter. If fires occur during the growing season, standing plants may be killed before seed is produced, inhibiting the population from being replenished. Fire that occurs in spring could result in high seedling mortality due to desiccation during the summer dry period. Indeed, in WA endangered *Banksia* woodland, seedlings that were germinated through autumn fires were likely to survive through the following summer, but no seedlings germinated by spring fires survived, threatening the structure, diversity and function of the ecological community (Roche et al. 1998). This issue is also dependent on when the seed is released, as the seeds usually require a wet-dry cycle to permit seed release. Wet-dry cycles are associated with the passage of cold front, which are more prevalent in autumn and winter than in spring. Seeds released in autumn and winter have the opportunity to get their roots down and hopefully established before the onset of summer dry conditions. *Fire-drought interactions* The CSIRO & Bureau of Meteorology (2015) predict south-west WA will experience decreased precipitation and increased average temperatures, as well as greater frequency of droughts (see *Climate change* below). More frequent (and severe) droughts will increase the frequency, intensity and scale of bushfires in the region (CSIRO & Bureau of Meteorology 2015). Therefore, the incidence of fire intervals shorter than the development threshold for this species is likely to rise, leading to fire events recurring without an appropriate canopy stored seed bank (Barrett and Yates 2015). This is referred to as "interval squeeze", which is a narrowing the favourable interval between fires, accelerating population decline (Enright et al. 2015). The interaction between fire and drought are particularly problematic for obligate seeders, as they rely on fire for recruitment, yet seedlings have poorly established root systems and are vulnerable to post-fire drought (Burgman & Lamont 1992). After a recruitment event occurs, the seeds often require rainfall to stimulate germination. If a fire is followed by drought conditions, germination may not occur, or seedling mortality will be very high. Similarly, pre-fire dry conditions could also limit population persistence by reducing the health of standing plants. *Fire disease interactions* As noted above (see *Disease*), fire interacts with *Phytophthora cinnamomi* to increase the impact of the pathogen and accelerate collapse of obligate seeding plants, such as feather-leaved banksia (Moore et al. 2015). Observations indicate that the impact of *P. cinnamomi* may be exacerbated post-fire, due to altered hydrology and increased surface run-off, as well as increased root tissue vulnerability (B. Shearer, personal communication, cited in Gilfillan et al. 2008). A high frequency fire regime can reduce vegetation cover, leading to increases in soil temperature from solar insolation and increases

		in surface or sub-surface flow on mountain slopes, which may exacerbate the impact and spread of *P. cinnamomi* (Barrett 2000; Moore et al. 2015). In areas where the pathogen is present, the densities of these plant species are highest in sites not affected by recent fires (Barrett & Yates 2015). *Phytophthora cinnamomi* also interacts with fire by killing seedlings and juveniles that were recruited by the fire, resulting in loss of mature plants with low levels of replacement by juveniles. There is potential for an extensive, intense fire to affect whole subpopulations, with the presence of *P. cinnamomi* dieback limiting post-fire recruitment (Gilfillan & Barrett 2008). *Fire-herbivore interactions* Montane ecosystems are particularly vulnerable to herbivory by both feral and native animals (Leigh et al. 1987; Kirkpatrick & Bridle 1999; Bridle et al. 2001) and browsing by *Setonix brachyurus* (quokka) and rabbits (*Oryctolagus cuniculus*) is a known threat to threatened species in the Stirling Range. Quokka populations can increase following fire, due to increased fresh growth (their preferred food source) (Hayward 2005; Rathbone & Barrett 2017). Quokka have not yet been recorded to feed on feather-leaved banksia, though if they are a food source this may increase browsing pressure and delay post-fire recovery (Rathbone & Barrett 2017).
Climate Change		
Increased temperature and decreased rainfall	• Timing: current • Confidence: observed • Consequence: major • Trend: increasing • Extent: across the entire range	The CSIRO & Bureau of Meteorology (2015) predict south-west WA will experience decreased precipitation and increased average temperatures, as well as greater frequency of droughts. This may cause substantial changes to the climate in which the species occurs, especially to the unique climate of the Stirling Range (Monks et al. 2019). Precipitation on the mountains of the eastern Stirling Range may be up to double that on the surrounding plains, and the peaks can have temperatures approximately five degrees less than the surrounding plains (Gilfillan & Barrett 2008). The onset of drier conditions in the Holocene may already have caused the contraction of some species to upland slopes and gullies. The drier, hotter conditions projected under climate change could accelerate this process, significantly reducing the area of habitat suitable for feather-leaved banksia (Monks et al. 2019). However, given the species can and does grow naturally in lowland coastal and sub-coastal conditions with coastal influences on precipitation, and further research is required to appropriately determine the impact of drier, hotter conditions on the species. This is especially true given that it has previously grown well ex situ in Perth. In a review of the impacts of climate change on *Banksia* species, the range of the species was projected to decline by 30–50 percent by 2080 according to the warming scenario (Fitzpatrick et al. 2008). Projections of higher temperatures, more frequent droughts and reduced mean precipitation for south-

		west WA due to climate change suggest that the frequency, intensity and scale of bushfires in the region will increase (CSIRO & Bureau of Meteorology 2015). These droughts will lead to more frequent fires and potentially lower post-fire recruitment due to a lack of rainfall (see *Fire regimes causing decline in biodiversity* above). While average rainfall is predicted to decline, heavy rainfall events are predicted to become more intense (Bureau of Meteorology & CSIRO 2020). An increase in atypical weather events (for example, an increase in summer rainfall) may also result in warm, moist conditions to the detriment of the species by favouring *P. cinnamomi* (Gilfillan & Barrett 2008).
Low genetic diversity		
Loss of genetic diversity	• Timing: current • Confidence: suspected • Consequence: major • Trend: increasing • Extent: across the entire range	Genetic diversity studies based on material from extinct (ex situ seed collections) and extant populations indicate that 38% of total genetic diversity and 37% of allelic richness has been lost from the species due to rapid range-wide subpopulation extinctions related to *P. cinnamomi* dieback (Coates et al. 2015). The loss of genetic diversity was reflected in the loss of 16 out of 55 and 6 out of 33 private alleles respectively from two of the subpopulation groups. Significantly higher levels of genetic diversity were found in the Stirling Range populations, though up to half of the lost genetic diversity in Stirling Range subpopulations was accounted for in three extinct eastern Stirling Range subpopulations (Coates et al. 2015). In contrast, loss of genetic diversity was much lower in Millbrook–Waychinicup with 21% or less genetic diversity lost due to extinction of two subpopulations (Coates et al. 2015). An associated impact of these extinctions will be the potential disruption to gene flow among subpopulations. Significant levels of historical gene flow are evident among the Millbrook–Waychinicup subpopulations, and, although the direct loss of genetic diversity due to subpopulation extinction is less severe than in the Stirling Range, the impact on connectivity may be greater if gene flow has been disrupted (Coates et al. 2015). Though substantial isolation by distance and lower gene flow among the Stirling Range NP subpopulations suggest that connectivity may be less important at these sites, the loss of all eastern montane subpopulations would be expected to significantly diminish genetic variation (Coates et al. 2015). Loss of genetic diversity and gene flow leaves the isolated subpopulations vulnerable to threats such as inbreeding depression and increased environmental and demographic stochasticity (Hobbs & Yates 2003; Aguilar et al. 2008). It also erodes the adaptive capacity of the species to future environmental change. The establishment of three translocated populations representing each subpopulation may mitigate this threat somewhat. These translocations were designed to maximise the conservation of genetic diversity (Coates et al. 2018), and translocated subpopulations may

		conserve genetic diversity in the event of natural subpopulations going extinct.

*Fire regimes that cause declines 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

Each threat has been described in Table 1 in terms of the extent that it is operating on the species. The risk matrix (Table 2) 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; 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 2 Feather-leaved banksia risk matrix

Likelihood	**Consequences**				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Low risk	Moderate risk	Very high risk	Very high risk **Aerial canker** **Increased temperatures and decreased rainfall**	Very high risk **Dieback caused by *P. cinnamomi*** **Fire regimes causing declines in biodiversity**
Likely	Low risk	Moderate risk	High risk ***Armillaria* root rot fungus (honey fungi)**	Very high risk	Very high risk
Possible	Low risk	Moderate risk	High risk	Very high risk **Loss of genetic diversity**	Very high risk
Unlikely	Low risk	Low risk	Moderate risk	High risk	Very high risk
Unknown	Low risk	Low risk	Moderate risk	High risk	Very high risk

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 – such events are known to have occurred on a worldwide bases but only a few ties
Unknown – currently unknown how often the incident 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 stalls or reduces
Major – population decreases

Catastrophic – population extirpation/extinction

Priority actions have then been developed to manage the threat particularly where the risk was deemed to be 'very high' or 'high'.

Conservation and recovery actions

Primary conservation outcome

Within the next three generations, the population of the feather-leaved banksia will have increased in abundance and EOO/AOO will have increased through ex situ conservation measures or remained stable.

Conservation and management priorities

Disease

- Maintain a hygiene management plan and risk assessment to protect known subpopulations, including established translocated ex situ populations from the spread of *P. cinnamomi* and other diseases.
- Implement mitigation measures in areas that are known to be infected by *P. cinnamomi* (e.g. appropriate application of phosphite) until alternative disease treatments are developed. . In order to minimise potential off-target impacts that may result from the build-up of phosphorus in low-nutrient soils (Lambers et al. 2013; Hopper et al. 2021), ensure that applications of phosphite continue to be highly localised where possible.
- Determine which lineages of *P. cinnamomi* are present across the feather-leaved banksia population.

Fire management

- Avoid risks of escape of prescribed fires. Review the need for prescribed burning within or near the species' range, identify essential needs, if any, and consider eliminating the practice in montane areas. However, if prescribed fires are shown to be essential to maintain other conservation values, then critically review the evidence that a proposed burn is controllable, cannot escape, and is unable to reach known subpopulations of the species in that have been recently burnt. Only proceed when these outcomes can be achieved.
- Ensure that planned burns do not occur in areas occupied by feather-leaved banksia before an accumulation of a seedbank large enough to replace the number of fire-killed standing plants.
- Provide maps of known occurrences to DBCA fire services and seek inclusion of mitigation measures in fire risk management plans, risk registers and/or operation maps.
- Prevent fire intervals of less than 15-20 years, depending on monitored seed bank size.
- Avoid all human ignition fires in spring and prior to forecast droughts.
- Develop and implement plans for postfire control of plant diseases.
- .

Ex situ recovery actions

- Continue to maintain and protect the surviving translocated subpopulations. Where availability of propagules permits, expand the ex-situ subpopulations to represent the maximum amount of genetic diversity possible.
- Continue to collect and store seed for long-term conservation and for future translocations. Continue to establish and augment existing seed orchards to avoid disturbing natural subpopulations when collecting seed for ex situ recovery.
- Continue to conduct translocations that maximise genetic diversity and decrease the species' vulnerability to known threats. Maintain and publish records of survival and maturation.
- Identify additional sites suitable for the establishment of new subpopulations through translocations, ensuring that translocation sites are free from *P. cinnamomi*.
- Investigate opportunities to secure ex situ subpopulations within the National Reserve System via land purchase or conservation covenants.

Climate change

- Map all habitat that would be suitable for this species currently and under climate change scenarios and investigate the establishment of translocated subpopulations in suitable climate refugia.
- Manage fire regimes to minimise climate change impacts and rates of population decline in subpopulations with projected declining habitat suitability.

Habitat loss, disturbance and modification

- Avoid or minimise further loss and fragmentation of habitat.

Stakeholder engagement/community engagement

- Engage and involve Traditional Owners in conservation actions, including the discussion of Indigenous fire management practices and other survey, monitoring and management actions.
- Liaise with the local community and government agencies to ensure that up-to-date population data and scientific knowledge inform the implementation of conservation actions for this species.
- Promote public awareness of biodiversity conservation and protection through dissemination of information through print and digital media.

Survey and monitoring priorities

- Undertake annual monitoring of habitat condition/degradation (including impacts from diseases such as *P. cinnamomi*), population stability (expansion or decline), pollination activity, seed production, recruitment and longevity.
- Continue to monitor and evaluate the effectiveness of disease and fire management actions.

- Monitor the size, structure and reproductive status (i.e. size of viable seed bank) of subpopulations at different stages in the fire cycle, taking opportunities to monitor after planned and unplanned fires (where they occur).
- Survey suitable habitat for new subpopulations and to locate suitable sites for translocations.

Information and research priorities

- Investigate options for linking, enhancing or establishing additional subpopulations.
- Investigate new methods for the effective control of *P. cinnamomi* and treatment of the disease it causes, in order to reduce potential off-target impacts caused by the application of phosphite.
- Investigate the ecological requirements of feather-leaved banksia that are relevant to persistence, including:
  - seed bank dynamics and the role of various disturbances (including fire), competition, rainfall and grazing on germination and recruitment,
  - reproductive strategies, phenology and seasonal growth, and
  - pollinator biology and requirements.
- Avoid methods of fire research and other activities that impact upon the persistence of the species, unless there is evidence to show there would be a positive and enduring effect on the species' persistence.
- Map habitat critical to the survival of the species.
- Investigate the impact of drought on recruitment and seedling growth.
- Ascertain the cultural significance of feather-leaved banksia.

Recovery plan decision

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.

Links to relevant implementation documents

Approved conservation advice for *Banksia Brownii* (Brown's Banksia) (2008)

Feather-Leaved Banksia (*Banksia brownii)* Recovery Plan (2008)

Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (2018)

Reason for assessment

This assessment follows prioritisation of a nomination from the TSSC.

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

Attachment A: Listing Assessment for feather-leaved banksia

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.

Table 4 Key assessment parameters

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of mature individuals	>25,000	25,000	35,000	Feather-leaved banksia undergoes natural fluctuations in the number of mature individuals, as mature individuals are killed following fire and germination of dormant seeds is stimulated. Utilising recent surveys from 2020, 2021 and prior to 2015 (Coates et al. 2015; S Barrett 2021. pers comm 9 November) there are at least 25,000 mature individuals, though notably these mainly occur across only three subpopulations (Millbrook, Cheynes NR, Waychinnicup). Most of these plants are due to the germination of 240,000 seedlings after a fire at Millbrook NR prior to 2015 (Coates et al. 2015). Given that a juvenile period of 5–6 years is suspected, (see below), these plants that germinated prior to 2015 are mature as of 2021. There are certainly more mature and juvenile plants in the population, though the number is unclear. It is likely that many subpopulations do not currently have many mature plants (<10), based on the subpopulation counts available. However, subpopulation 13A had 5000+ mature individuals during a survey in 2004.Subpopulation 12 had 9000 seedlings present prior to 2015, many of which may have reached maturity but were lost during the 2019 bushfire (see Appendix A). The maximum number of mature individuals is unknown, though

				likely is not above approximately 35,000.
Trend	Decreasing			Though the number of mature individuals has increased since 2008 due to post-fire recruitment, all subpopulations are considered to be declining as a result of *P. cinnamomi* dieback and other threats (S Barrett 2021. pers comm 9 November).
Generation time (years)	28–30 years	28 years	30 years	The generation length of feather-leaved banksia is estimated at 28–30 years (see Criterion 1).
Extent of occurrence	3666 km^2	2679 km^2	3666 km^2	The extent of occurrence (EOO) is estimated at 3666 km^2. This figure is based on the mapping of point records obtained from state governments, museums, and CSIRO. The EOO was calculated using a minimum convex hull, based on the IUCN Red List Guidelines (IUCN 2019). The minimum plausible value was gathered from the 2019 IUCN assessment (Barret et al. 2019).
Trend				
Area of Occupancy	152 km^2	72 km^2	>152 km^2	The AOO is estimated at 152 km^2. This figure is based on the mapping of point records from 2021 obtained from state governments, museums, and CSIRO. The AOO is calculated using a 2x2 km grid cell method, based on the IUCN Red List Guidelines (IUCN 2019). The minimum plausible AOO was calculated by assuming all 18 extant subpopulations are found within one distinct 2x2km^2 grid cells per subpopulation.
Trend	contracting			There has been ongoing extinction of known subpopulations.
Number of subpopulations	18	18	>18	18 out of 30 subpopulations were extant as of 2018 (Coates et al. 2018).
Trend	Declining			There has been ongoing extinction of known subpopulations.
Basis of assessment of population number	18 out of 30 subpopulations were extant as of 2018 (Coates et al. 2018).			
No. locations	1	1	1	The number of locations is estimated at one, based on the plausible impact of *P. cinnamomi* dieback. *Phytophthora cinnamomi* is found in or in close proximity to all known subpopulations, and the species is highly susceptible to infestation (S. Barrett 2021. Pers comm 9 November; Gilfillan & Barrett 2008).

Trend	declining	The number of locations is static, as all but one subpopulation are already impacted by *P. cinnamomi*.
Basis of assessment of location number	The number of locations is estimated at one, based on the plausible impact of *P. cinnamomi* dieback. *Phytophthora cinnamomi* is found in or in close proximity to all known subpopulations, and the species is highly susceptible to infestation (S. Barrett 2021. Pers comm 9 November; Gilfillan & Barrett 2008).	
Fragmentation	Feather-leaved banksia has a restricted distribution and is known from three distinct groups of subpopulations that are genetically and biogeographically separated. However, though the groups are separate, genetic exchange has occurred between subpopulations within each group, especially Millbrook – Waychinicup (Coates et al. 2015). Hence, it appears that habitat patches are not separated by a large enough distance to considered severely fragmented.	
Fluctuations	Extreme fluctuations are likely, as nearly all of the canopy stored seed can be exhausted in a single fire in serotinous obligate seeders (IUCN 2019; Silcock et al. 2021) and the Millbrook 1B subpopulation has been observed to fluctuate from 2000+ plants in 2002 to 240,000 after a fire and back down to 18,000 (Gilfillan & Barrett 2008; Coates et al. 2015; S Barrett 2021. pers comm 9 November). This represents a fluctuation that is larger than one order of magnitude.	

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 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

Eligible under Criteria A3ce+A4ace as Critically Endangered

The juvenile period of feather-leaved banksia is thought to be approximately 5–10 years (based on 50 percent flowering), depending on whether the plant is found on the Stirling Range or in a southern subpopulation. The longevity of the species is estimated at around 50 years (S Barrett 2021. pers comm 9 November). Accordingly, generation time is likely to be:

$$\text{Generation time} = \text{age of first reproduction} + [0.5 * (\text{length of reproductive period})]$$
$$\text{Generation time} = 5 + [0.5 * (50 - 5)] = 28 \text{ years}$$

OR

$$\text{Generation time} = 10 + [0.5 * (50 - 10)] = 30 \text{ years}$$

An IUCN assessment for the species lists the generation time as 30 years (Barrett et al. 2019)

This gives an estimated three-generation period of approximately 84–90 years.

Past and current decline

The population of feather-leaved banksia has rapidly declined since *P. cinnamomi* entered the region. The species is highly susceptible to infestation, and over 80 percent of plants were killed at a site 96 days after inoculation by the pathogen (McCredie et al. 1985; Wills 1993). Other susceptibility investigations also rate the species as highly susceptible, corresponding to the death of over 80 percent of plants (Bryan Shearer, unpublished data, cited in Gilfillan & Barrett 2008) and over 95 percent of plants (Shearer et al. 2012).

Records of subpopulation extinction due to *P. cinnamomi* began in the mid-1990s, starting with very large subpopulations in the eastern Stirling Range montane heath and thicket communities (Barrett & Yates 2015). For example, between 1985 and 1994, the large, healthy stands on Bluff Knoll were entirely destroyed. It is unclear how many plants were extant in these large Stirling Range subpopulations. However, given that the largest currently extant subpopulation contains 18,000 individuals, despite the impacts of *P. cinnamomi* dieback, the loss of these subpopulations likely led to the death of tens or hundreds of thousands of mature individuals. Such a population reduction would likely represent a decline of over 80 percent.

Since 1996, 12 of the 30 known subpopulations have gone extinct, and eight of the eighteen known subpopulations had less than 10 plants remaining as of 2018 (Coates et al. 2018). Many of the extinct subpopulations were in Stirling Range NP (subpopulations 11, 12, 14, 16, 18, 20, 21, 27 and 28), most notably on the eastern side of the NP in the Eastern Stirling Range montane heath and thicket community (Barrett & Yates 2015; Coates et al. 2015).

Population reduction has also been observed due to inappropriate fire regimes. Eight of the 13 Stirling Range NP subpopulations were burnt in 1991 and 2000, an interval of nine years. Of these, five were considered either almost extinct or presumed extinct as of 2008, and by 2015 approximately 74 percent of the Eastern Stirling Range Montane Heath and Thicket Threatened Ecological Community had experienced short, nine-year fire intervals over the previous 50 years (Barrett & Yates 2015). This suggests that a high frequency fire regime is of particular concern in the eastern Stirling Range. Indeed, Stirling Range NP was impacted by fire both in 2018 and 2019, an interval of just one year. Though the same subpopulations were not burnt in both fires, this demonstrates that very short fire intervals are possible for the Stirling Range subpopulations, as similar species (e.g. *Banksia montana*; Stirling Range Dryandra) were impacted by both fire events. However, it is highly improbable that the same subpopulations would burn in subsequent years naturally, and notably the 2018 fire was caused by an escaped prescribed burn (OBRM 2018). Poor recruitment has occurred at many of the sites burnt in 2018 and 2019, aside from subpopulation 12 (Mt Yungemere), and there has been observed seedling death during to *P. cinnamomi* (S Barrett 2021. pers comm 9 November)

Though the number of mature individuals has increased since 2008, it is likely that this increase is simply a fluctuation in the number of mature individuals due to post-fire recruitment (Table 3). It is likely that the subpopulations that underwent recruitment will continue on a downward trajectory, and indeed all subpopulations are considered to be in decline due to disease (S Barrett 2021. pers comm 9 November).

The extinction of 12 subpopulations since 1996, including large subpopulations in the eastern Stirling Range has led to severe population decline. Eight of the extant subpopulations have also been reduced to under 10 individuals. Given the loss of many large subpopulations, and the currently small size of many extant subpopulations, it is likely that decline of >80 percent has occurred over the past three generations. However, the size of the currently extinct and very small subpopulations prior to the introduction of *P. cinnamomi* is unclear, and there is insufficient evidence to state that the extent of decline has eclipsed 80 percent with certainty. An IUCN assessment written by species experts suggests that the species is eligible for critically endangered under this criterion, based on a loss of 80 percent of the population over the past three generations (Barrett et al. 2020), though does not provide detail on changes to the population. Therefore, whilst the species has no doubt undergone decline over a three generation period, further information and data on pre- and post-decline subpopulation counts is required to confirm this.

Future decline

Feather-leaved banksia is likely to continue undergoing population reduction due to the combination of *P. cinnamomi* dieback, inappropriate fire regimes and climate change. There is currently no known long-term solution for *P. cinnamomi* dieback, and it is present in nearly all subpopulations. Mitigation measures, such as the spraying of phosphite, are in place to protect from further infection, though they do not remove *P. cinnamomi* from the area. If mitigation measures begin to fail or are ceased, it is plausible that more subpopulation extinctions will occur, and the population will be further reduced by >80 percent. This is especially likely given that susceptibility investigations have observed the diseases leads to death in over 80 percent of inoculated plants (see above), and therefore mortality will be very high if infestation increases. Given that eight subpopulations contain below 10 mature individuals and are close to extinction, it is likely they will become extinct within a three-generation period. Such losses would lead to 18/30 subpopulations being extinct. Climate change may also lead to an increase in atypical weather events (for example, an increase in summer rainfall) that result in warm, moist conditions to the detriment of the species by favouring *P. cinnamomi* (Gilfillan & Barrett 2008).

Inappropriate fire regimes fuelled by climate change also pose a large threat to the species over the next three generations. Changes to fire conditions under climate change may expose the species to "interval squeeze", which is a narrowing the favourable interval between fires, accelerating population decline (Enright et al. 2015). Fires have already consistently impacted Stirling Range NP subpopulations at intervals below the species' minimum fire-free threshold, and this is likely to continue due to projections of higher temperatures, more frequent droughts and reduced mean precipitation for south-west WA (CSIRO & Bureau of Meteorology 2015; Barrett & Yates 2015). Therefore, the incidence of fire intervals shorter than the development threshold for this species is likely to rise (Barrett & Yates 2015), leading to loss of seedlings or juveniles that have not had enough time to produce seeds for the next generation. Fires also pose a threat through their interaction with *P. cinnamomi*. Previously, fires have killed mature plants and produced seedlings that quickly succumbed to *P. cinnamomi* dieback, resulting in a net loss of plants (Gilfillan & Barrett 2008; S Barrett 2021. pers comm 9 November). The interaction between fire and drought may also be problematic, as seedlings have poorly established root systems and are vulnerable to post-fire drought after recruitment (Burgman & Lamont 1992). Though inappropriate fire regimes have not yet threatened southern subpopulations, there is the potential for a single fire that will impact many subpopulations with the presence of *P. cinnamomi* and drought limiting recruitment (Gilfillan & Barrett 2008).

The drier, hotter conditions projected under climate change may also significantly reduce the area of habitat suitable for feather-leaved banksia (Monks et al. 2019). In a review of the impacts of climate change on *Banksia* species, the range of the species was projected to decline by 30–50 percent by 2080 dependent to the warming scenario (Fitzpatrick et al. 2008). This is within 84–90 years, suggesting that the distribution will decline rapidly within three generations.

The species will likely continue undergoing very severe reduction in the number of mature individuals due to *P. cinnamomi* over the next three generations. *Phytophthora cinnamomi* may also interact with fire to stimulate population decline, and both of these threats are likely to be exacerbated by climate change. Climate change may also lead to a substantial range contraction for the species. It is suspected and projected that these threats in tandem will lead to population reduction of 80 percent in the next three generations, based on the historical impact of *P. cinnamomi* dieback on large subpopulations, the known susceptibility of the species to the pathogen, and projections concerning fire and climate change. Given that past decline may be approaching 80 percent outside of any future decline, there will also be over 80 percent population reduction over a three-generation period (84–90 years) that include both the past and future (1989–2073/2079).

Conclusion
The data presented above appear to demonstrate the subspecies 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 subspecies' 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**	**< 5,000 km²**	**< 20,000 km²**
B2.	Area of occupancy (AOO)	**< 10 km²**	**< 500 km²**	**< 2,000 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 populations; (v) number of mature individuals			
(c)	Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or populations; (iv) number of mature individuals			

Criterion 2 evidence

Eligible under Criteria B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v) as Endangered

Extent of occurrence and area of occupancy

The extent of occurrence (EOO) is estimated at 3666 km² and the area of occupancy (AOO) is estimated at 152 km². These figures are based on the mapping of point records from 1996 to 2019, obtained from state governments, museums, and CSIRO. The EOO was calculated using a minimum convex hull, and the AOO 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 2019).

The subspecies' EOO (<5,000 km^2) and AOO (<500 km^2) meet the requirements for listing as Endangered under B1 and B2.

Severe fragmentation and number of locations

"A taxon can be considered to be severely fragmented if most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance" (IUCN 2019).

Feather-leaved banksia has a restricted distribution and is known from three distinct groups of subpopulations that are genetically and biogeographically separated (Coates et al. 2018). However, though these groups are separate, genetic exchange is occurring between subpopulations within each group (Coates et al. 2015). Hence, it appears that habitat patches are not separated by a large enough distance to be considered severely fragmented.

"The term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat" (IUCN 2019).

The number of locations is estimated at one, based on the plausible impact of *P. cinnamomi* dieback. *Phytophthora cinnamomi* dieback is found in or in close proximity to all known subpopulations, and the species is highly susceptible to infestation. It has been observed that over 80 percent of plants were killed at a site 96 days after inoculation by the pathogen. If an event within 20 years (e.g. a very wet winter or high summer rainfall) leads to conditions that are suitable for the pathogen to rapidly, all plants in all subpopulations may plausibly be impacted. Given that heavy rainfall events are becoming more intense due to climate change (CSIRO & Bureau of Meteorology 2020), such an event is plausible. Rapid infestation of *P. cinnamomi* could rapidly affect all individuals in a time period that is less than one generation, especially if current management is not maintained or is unable to be completed. Therefore, as all mature individuals could plausibly be rapidly impacted by the pathogen, there is considered to be one location.

Continuing decline

Feather-leaved banksia is undergoing continuing decline due to multiple interacting threats, most notably *P. cinnamomi* dieback, inappropriate fire regimes and climate change (see Table 1 & Criterion 1). These threats are leading to extinction of subpopulations, mortality of mature individuals, and mortality of associated species. The processes that generated this decline have not ceased, and future population reduction of current juveniles is likely. There is continuing decline in (i) extent of occurrence, (ii) area of occupancy (iii) area, extent and/or quality of habitat (iv) number of locations or subpopulations and (v) number of mature individuals.

Extreme fluctuations

Extreme fluctuations represent changes in the total population (rather than a flux of individuals between different life stages), which exceed one order of magnitude (IUCN 2022). Extreme fluctuations can be diagnosed by interpreting population trajectories which show a recurring pattern of increases and decreases; or by using life history characteristics (IUCN 2022). For species with soil-stored seed banks, fires may stimulate mass recruitment from large persistent seed bank when there are few mature individuals. These seedlings may grow to maturity, die out during the interval between fires, and leave a store of seeds until they are stimulated to germinate by the next fire. Such cases do not fall within the definition of extreme fluctuations unless the dormant life stages are exhaustible by a single event or cannot persist without mature individuals. Plant taxa that were killed by fire and had an exhaustible canopy-stored seed bank (serotinous obligate seeders), for example, would therefore be prone to extreme fluctuations because the decline in the number of mature individuals represents a decline in the total number of mature individuals (IUCN 2022).

Extreme fluctuations in the number of mature individuals of feather-leaved banksia are probably, as most of the canopy stored seed can likely be exhausted after a single fire (serotinous obligate seeder), and the Millbrook 1B subpopulation has been observed to go from 2000+ plants in 2002 to 240,000 after a fire and back down to 18,000 (Gilfillan & Barrett 2008; Coates et al. 2015; S Barrett 2021. pers comm 9 November). This is a fluctuation in excess of one order of magnitude. The subspecies appears to meet the extreme fluctuations requirement for listing under this criterion.

Conclusion

The subspecies appears to have met the relevant elements of Criterion 2 to make it eligible for listing as Endangered. However, the purpose of this consultation document is to elicit additional information to better understand the subspecies 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	< 2,500	< 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 population	≤ 50	≤ 250	≤ 1,000
	(ii) % of mature individuals in 1 population =	90 – 100%	95 – 100%	100%
(b) Extreme fluctuations in the number of mature individuals				

Criterion 3 evidence

Not eligible for listing under this criterion

The number of individuals of feather-leaved banksia is estimated at above 25,000 based on recent subpopulation estimates (Table 3).

The data presented above appear to demonstrate that 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 4 Number of mature individuals

	Critically Endangered **Extremely low**	**Endangered** **Very Low**	**Vulnerable** **Low**
D. Number of mature individuals	< 50	< 250	< 1,000
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 km² 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 for listing under this criterion

As stated in Criterion 3, the number of mature individuals is not low.

Conclusion

The data presented above appear to demonstrate that the species 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 for feather-leaved banksia.

There are insufficient data to demonstrate if the species is 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.

Adequacy of survey

The survey effort is 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.

Appendix

Appendix A: Feather-leaved banksia subpopulation information (adapted from Gilfillan & Barrett 2008; Coates et al. 2018 & S Barrett 2021. pers comm 9 November)

Pop. No. & Location		**No. plants (seedlings)**	**Year of survey***	**Habitat condition (as of 2008) and fire history**
1A	Millbrook Nature Reserve	Same subpopulation as 1B		Poor
1B	Millbrook Nature Reserve	2000+ [low certainty] Unknown (240,000) 18,000 [reduced from 115,000]	2002 <2015 2021	Poor, Burnt in 2004
1C	Millbrook Nature Reserve	1	2004	Poor, Burnt in 2004
1D	Millbrook Nature Reserve	0	1996	Presumed locally extinct
1E	Millbrook Nature Reserve	0	1996	Presumed locally extinct
2	Hassell NP	30+/- (0), 9 dead 3 (0)	2001 2003	Almost locally extinct,
3A	Millbrook Rd	1 (1), 3 dead 1, 3 dead	2002 2004	Poor
3B	Millbrook Rd	6 (0), 7 dead 7 (1), 1 dead	2002 2004	Poor
3C	Millbrook Rd	1 (0), 4 dead 0 (0), 5 dead	2002 2004	Presumed locally extinct
3D	Millbrook Rd	3 (0, 1 dead 4 (0), 2 dead	2002 2004	Poor
3E	Millbrook Rd	0 (0)	1996	Presumed locally extinct
3F	Millbrook Rd	0 (0)	1996	Presumed locally extinct
4A	Shire Rec Res. No. 35381	2 (0), 3 dead 0 (0)	1996 2004	Presumed locally extinct, Burnt in 2002-3

4B	Shire Rec.Res.No.35381,	3 (1), many dead 0 (0)	1993 2004	Presumed locally extinct, Burnt in 2002-3
5	South Sister NR	91 (14) 59 dead	2002	Poor Burnt in 2019
6	Hazard Rd	3(2), 12 dead 0 (0), 3 dead	1996 2004	Presumed locally extinct
7	Phillips Rd	(3) 0 (0)	1994 1996	Presumed locally extinct
8	Vancouver Pen.Rec.Res	150+ (0), 10+/- dead 120+ (3), 50+ dead	2003 2004	Poor
9	Waychinicup National Park	16 (0) 11 seen, some missed? (0)	2003 2004	Almost locally extinct
10	Cheyne Beach Rd	15 (0) 0 (0)	1996 1998	Presumed locally extinct
11A	Mt Hassell -Stirling Range National Park	10, (200+/-) 5 dead 304	2003 <2015	Moderate Burnt in 2019, limited recruitment
11B	Mt Hassell -Stirling Range National Park	(3) 0	2003 2021	Poor Burnt in 2019, limited recruitment
12	Yungemere- Stirling Range National Park	2000+ (100+/-) 50+/- dead (9000)	2003 <2015	Moderate Burnt in 2019, good recruitment
13A	Stirling Range National Park	5000+	2004	
13B	Stirling Range National Park	0	1989	Presumed locally extinct
13C	Stirling Range National Park	0	1994	Presumed locally extinct
13D	Stirling Range National Park	0	2004	Presumed locally extinct
14	Mt Success - Stirling Range National Park	0 10 0	1999 <2015 2021	Presumed locally extinct Burnt in 2018

15	Stirling Range National Park	100+/- (1000+/-) 20+ dead 100+/- (2000+/-) 20+ dead	2002 2003	Moderate, burnt in 2000
16A	Ellen Peak - Stirling Range National Park	Not confirmed	2008	Presumed locally extinct Burnt in 2018
16B	Ellen Peak - Stirling Range National Park	0 0	2004 2021	Presumed locally extinct Burnt in 2000 and 2018
16C	Stirling Range National Park	0 (2) 0	2004 2021	Presumed locally extinct Burnt in in 1991, 2000 and 2018
17	Stirling Range National Park	0	2004	Almost locally extinct Burnt in in 1991, 2000 and 2018
18	Stirling Range National Park	100+/-, 5+ dead 0 (0) 0	2000 2004 2021	Presumed locally extinct Burnt in 1991, 2000 and 2019. limited recruitment after 2019
19	Stirling Range National Park	6 0 (0)	1996 2004	Presumed locally extinct, burnt in 1996
20	East Bluff- Stirling Range National Park	2 (0) 0	2004 2021	Moderate Presumed locally extinct (2021) Burnt in 2018
21A	Moongoongoonderup-Stirling Range National Park	50+ 0 (0 seen 0	2000 2003 2021	Presumed locally extinct Burnt in 2000 and 2019, limited recruitment after 2019
21B	Moongoongoonderup-Stirling Range National Park	10+ (75+) 0 (0 seen)	2000 2003	Presumed locally extinct Burnt in 2000 and 2019, limited recruitment after 2019
21C	Moongoongoonderup-Stirling Range National Park	20+ (100+) 0 (0 seen)	1999 2002	Presumed locally extinct Burnt in 1991, 2000 and 2019, limited recruitment after 2019
22A	Waychinicup National Park	100+, 6+ dead 100+ scattered deaths	2003 2004	Moderate
22B	Waychinicup National Park	2000+ 2000 + (0) 840	2003 2004 2020	Moderate
23	Wedge Hill - Stirling Range National Park	1 37	2003 <2015	Healthy (no *P. cinnamomi*)
24	Stirling Range National Park	0 (0), 11 stags seen	2004	Presumed locally extinct
25	Yellanup Rd	3 2, 2 dead	1996 2004	Poor

26	Cheyne Rd Nature Reserve	200+/- (0), 20+/- dead 6000	2003 2020	Poor
27	Stirling Range National Park	1	2003	Healthy Burnt in 2019, limited recruitment
28	Stirling Range National Park	0	2020	Unknown Burnt in 2019, limited recruitment
29	-	-	-	-
30	-	-	-	-

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