Australian Government
Department of Agriculture, Water and the Environment

Conservation Advice for *Banksia montana* (Stirling Range Dryandra)

In effect under the *Environment Protection and Biodiversity Conservation Act 1999* from 23 November 2021.

This document provides a foundation for conservation action and further planning.

Photo of *Banksia montana* (Stirling Range Dryandra) © Copyright, S Barrett

Conservation status

Banksia montana (Stirling Range Dryandra) is listed in the Endangered category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act).

The species is eligible for listing because prior to the EPBC Act, it was listed as Endangered under the Endangered Species Protection Act 1992 (Cwlth).

The main factors that make the species eligible for listing in the Endangered category are small population size, very restricted distribution and extreme population decline due to inappropriate fire regimes and *Phytophthora cinnamomi* dieback.

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 montana* (C.A Gardner ex A.S. George) A.R Mast & K.R Thiele (2007).

A member of the family Proteaceae, Stirling Range Dryandra was first formally described as *Dryandra montana* in 1996 (George 1996). In 2007, all dryandras were transferred to the genus *Banksia*, and thus the species became *Banksia montana* (Mast & Thiele 2007).

Description

The Stirling Range Dryandra is an erect woody shrub 1–2.5 m in height. The leaves are 60–225 mm long and 9–12 mm wide, with a petiole 5–30 mm long. They are hairy and pinnately divided, deeply divided or divided to the midrib, with 22–52 elongated, triangular, close fitting 5–8 mm lobes cut to the mid-rib and pointing towards the apex. The yellow flowers are produced from January to March, forming villous inflorescences on the old wood inside the foliage. The innermost bracts are 13–15 mm long and the perianth is 17–20 mm long. Both have soft, straight hairs. The pistil is 25–30 mm, curved and hairy (Florabase 2020). The upper stems and fruits are covered by short red hairs. Follicles are hairy at the base and ovate, ranging from 9–11 mm long and 7–8 mm broad.

Distribution

Stirling Range Dryandra is endemic to mountain summit areas between 900 m and 1080 m above sea level in the eastern Stirling Range, approximately 70 km north of Albany, on the southern coast of Western Australia (DEC 2008). It is found exclusively within the Esperance Plains bioregion of south-western Western Australia (DAWE 2012). Stirling Range Dryandra occurs only on a few eastern peaks and is found in a small number of subpopulations, occupying a total area of less than 1 km^2 (Silcock et al. 2021). It is considered extinct from one peak. Its range is entirely within the Stirling Range National Park. The species is part of a group of plants forming the Eastern Stirling Range Montane Heath and Thicket Community (Barrett 2000).

Six subpopulations have historically been identified, though only four subpopulations, totalling 41 adult plants and 16 juveniles were extant as of early 2018, and it is unlikely other subpopulations exist (Silcock et al. 2021). This was an increase from 37 mature individuals in 2011 (Cochrane et al. 2010; Barrett et al. 2011; DBCA 2020). These subpopulations are found on Bular Mial (Bluff Knoll), East Bluff, Pyungoorup and Isongerup on the eastern Stirling Range. The closest town to these subpopulations is Mount Barker. Presumed extinct subpopulations include Coyanarup, and Kyanorup Eminence, though the lower altitude and the different plant

community at the latter site suggests the original record may be inaccurate and the Stirling Range Dryandra was never present. All subpopulations rapidly declined after a bushfire in 2000, which reduced the original population of 137 adults by 63 percent and 39 juveniles by 77 percent (DAWE 2017).

Bushfires in May 2018 and December 2019 led to 100 percent mortality of all known mature Stirling Range Dryandra individuals across all four known extant subpopulations (DBCA 2020). Thirty-three individuals were killed in the 2018 fire, followed by the final eight individuals during 2019. Over 1000 seedlings germinated after the 2018 fire and 857 juveniles were recorded in 2020 (DBCA 2020). By autumn 2021, 725 juveniles and 22 seedlings that had germinated after the 2019 fire were present (DBCA 2021). These extant subpopulations are currently comprised entirely of juvenile plants. Small-scale reinforcement translocations from seed orchards have also been undertaken using seedling plants, which involved moving individuals from ex situ subpopulations to extant subpopulations, in order to aid population viability through increased genetic diversity and population size (Hancock et al. 2014). This practice was trialled successfully in 2019 for three subpopulations and the seedlings planted during this trial are currently juveniles (DBCA 2020). Direct seeding was also trialled in 2018 and 2020, whereby seeds were directly planted into the soil in extant subpopulations.

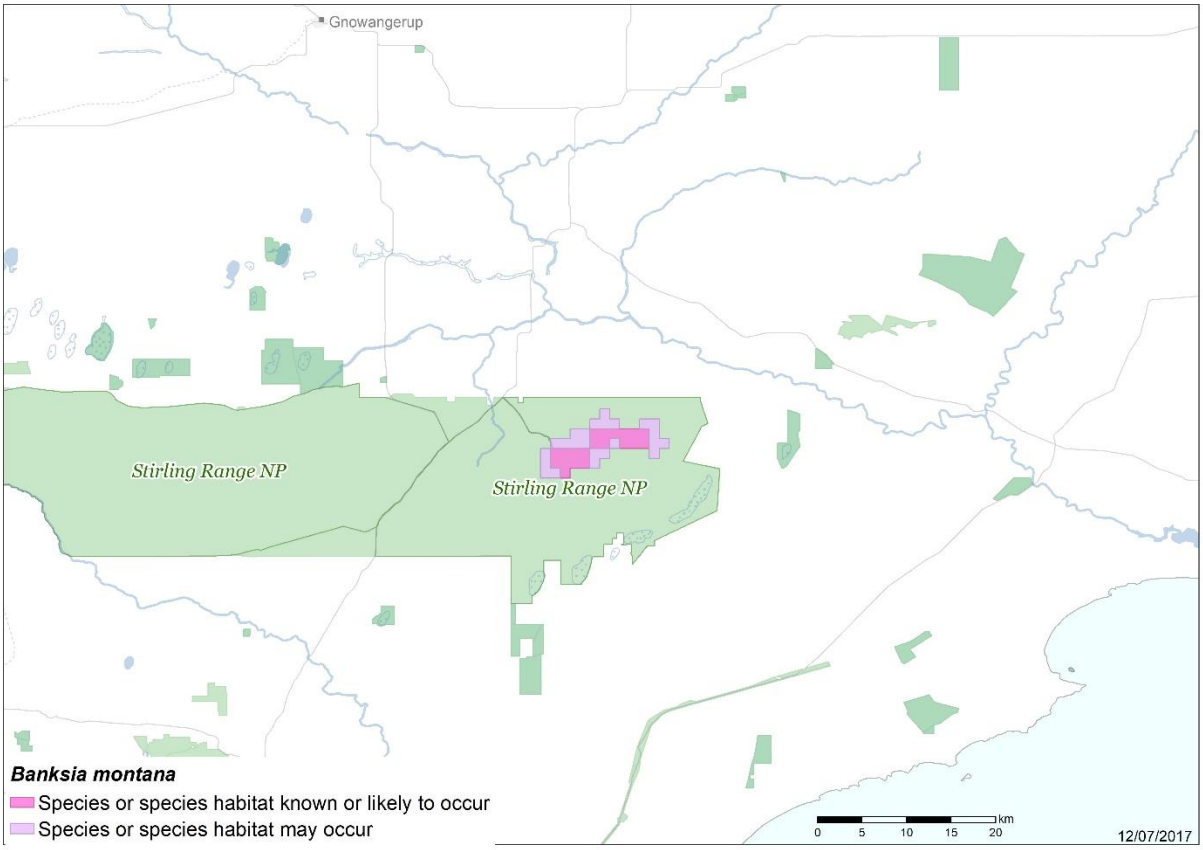
In August 2003 and June 2004, 89 juvenile plants grown from seeds were planted ex situ at Luscombe's seed orchard, approximately 50 km away from the natural range. There are now two translocated subpopulations, though the Benmore Tree farm established in 2010 only has a few individuals (DBCA 2020). As of 2019/20, 65 mature individuals and two plants were surviving in each orchard respectively, though no recruitment has occurred at either site (Silcock et al. 2021). This constitutes a highly significant proportion of the total population, increasingly so, as extant subpopulations have declined and been extirpated (Cochrane et al. 2010). As of 2020, the seed orchards are the only subpopulations with mature individuals. The larger population is being used for reinforcement translocations of seedling individuals to natural extant subpopulations (DBCA 2020).

Table 1 Summary of Stirling Range Dryandra population information and threats, as of December 2020, gathered from Silcock et al. (2021).

Subpopulation (tenure)	Number of mature individuals (juveniles)	Trend
1 Bular Mial (Bluff Knoll) (national park)	1995: 21 (0) 2004: 7 (15) 2018: 4T 2020: 0 (630) (34T)	Decreasing
2 Coyanarup (national park)	2000: 0 (0) 2018: 0 (16T) 2020: 0 (13T)	Presumed extinct
3 Kyanorup (national park)	2000: 0 (0) 2020: 0	Presumed extinct
4 Pyungoorup (national park)	1996: 23 (0) 2004: 19 (0) 2018: 7 2020: 0 (9)	Decreasing

5 Isongerup (national park)	1997: 13 (1) 2004: 3 (0) 2018: 0 2020: 0 (204)	Decreasing
6 East Bluff (national park)	1996: 61 (8) 2004: 16 (1) 2018: 1 (23T) 2020: 0 (14) (15T)	Decreasing
7 (T) Luscombe's Seed Orchard (private property)	2003-2010: (138T*) 2019: 65T	Unknown
8 (T) Benmore Tree Farm (private property)	2010-2013: (48T*) 2016: 21T 2020: 2T	Decreasing

Map 1 Modelled distribution of Stirling Range Dryandra



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 Aboriginal Sites Register kept by the Western Australian Department of Indigenous Affairs lists one significant artifact/scatter site in the vicinity of the Stirling Range Dryandra's distribution (DPAW 2016). The Traditional Owner group for the area is the Minang. The Eastern Stirling Range Montane Heath and Thicket Community is culturally significant to Aboriginal people in the area, and input from these groups is used in the management of the Stirling Range. Aboriginal involvement in the management of land is covered by an agreement under the Conservation and Land Management Act 1984 (DPAW 2016).

Relevant biology and ecology

The Stirling Range Dryandra grows on sandstone, metamorphosed sandstone and metamorphosed siltstone in the Eastern Stirling Range Montane Heath and Thicket Community (Barrett 2000), more than 900 m above sea level on the eastern Stirling Range. It flowers annually between January and March, with rates of flowering and seed production varying considerably between plants and years (DEC 2008). Fruits persist in the canopy for up to four years, after which they begin to disintegrate. Several plants in all subpopulations assessed from 2001 to 2004 produced very little seed (Yates & Barrett, as cited in DEC 2008). The reasons for variable flower, fruit and seed production in Stirling Range Dryandra subpopulations are not clear and may be related to plant age, health, vigour and the effectiveness of pollination.

Ladd et al. (1996) investigated pollen presenter and style characteristics in the genera *Dryandra* and *Banksia* (now *Banksia*). In the Stirling Range Dryandra, the pollen presenter is 1 mm in length and 0.3 mm in diameter. The style is constricted below the pollen presenter and is bowed in shape and the stigmatic groove is oblique terminal. The approximate distance from the pollen presenter to the receptacle is 26 mm. Ladd et al. (1996) suggest that these characteristics are consistent with mammal or insect pollination. *Tarsipes rostratus* (Honey Possum) has been recorded on IR camera (Bluff Knoll) and is assumed to be actively pollinating natural subpopulations (DBCA 2021).

The Stirling Range Dryandra is a serotinous non-sprouting shrub. Plants are killed by fire and persistence of the species is contingent on seeds stored in the canopy being released, germinating, seedlings establishing and plants growing to reproductive maturity before the next fire. Recruitment in the absence of fire is rare but has been recorded and suggests that seed in the soil may remain viable for some years (DEC 2008). Keith (1996) identified several fire driven mechanisms of plant population decline and extinction for non-sprouting 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. These included high frequency, low frequency fires and aseasonal fires. Bradstock et al. (1998) used a spatially explicit model to simulate plant extinction in relation to fire frequency and scale and found that extinction probabilities in non-sprouting perennial shrubs increased with fire frequency and scale.

Non-sprouters like the Stirling Range Dryandra are more sensitive to frequent fire regimes than sprouters because they are entirely dependent on seeds for persistence, and therefore require a minimum fire free period to reach reproductive maturity and produce enough seeds to replace themselves. Local extinction will occur if the fire interval is shorter than the time taken for the plants to reach reproductive maturity (the primary juvenile period), which may be orders of magnitude greater than time to first flowering within a drying climate. The primary juvenile period for Stirling Range Dryandra is long. Flowering is first recorded nine years after fire in extant wild subpopulations, though has been recorded earlier in seed orchards, likely due to improved moisture and nutrition (DAWE 2016). Individuals have lived for at least 30 years (DEC 2008), but time to senescence is likely considerably longer. The generation length is therefore estimated as 10.5 years. Alternatively, in the long absence of fire, non-sprouting fire recruiting plants may senesce and die before there is an opportunity for regeneration (Whelan 1995; Bond & van Wilen 1996), though the Eastern Stirling Range Montane Heath community is sub-alpine

in nature and thus fire exclusion may not pose a significant threat to the ongoing sustainability of the community. In species that store their seed in the canopy, the seed dispersed to the soil does not persist for long following the death of the parent. Therefore, fire that is infrequent is of high importance for the successful reproduction of this species.

Age specific fecundity is of central importance for the demography of species, like the Stirling Range Dryandra, that are killed by fire. The most important factor is the quantity of seed that must be held by parent plants to enable post-fire replacement of the population. Gill and Nicholls (1989) proposed that "Until further data becomes available it is suggested that a doubling of the general juvenile period of the species observed at the monitoring site be used as the guide to when the species is likely to be able to replace itself to pre-fire abundance levels." For the Stirling Range Dryandra, the minimum time recorded for first flowering is nine years after seedling emergence. Using Gill and Nicholls' formula the minimum fire interval for the Stirling range Dryandra to persist may be 18 years. This formula, and a minimum fire interval of 18 years, is used to inform current management actions but should not be used as the time interval to impose fire as the species is very long-lived.

During the past 50 years there have been five major fires in the eastern Stirling Range. These occurred in February 1972, April 1991, October 2000, May 2018 and December 2019. Analyses of aerial photography and field surveys indicate that some Stirling Range Dryandra subpopulations were burnt by multiples of these fires. As of 2005, some Stirling Range Dryandra subpopulations had three fires in 28 years, with fire return times of 28 and 9 years (Yates & Barrett, unpublished data, as cited in DEC 2008). In the subsequent 15 years, subpopulations have further been impacted by two fires, with return times including 27, 18 years and, for some subpopulations, just one year. All subpopulations were affected by one of the 2018 and 2019 fires, resulting in 100 percent mortality in natural extant subpopulations (DBCA 2020). Most of this mortality occurred as a result of the 2018 fire, with 33 mature individuals killed. The remaining 8 mature individuals were killed in the 2019 fire (DBCA 2020). High levels of germination occurred after the 2018 fire, though some of these seedlings were killed through drought and fire in 2019.

The Eastern Stirling Range Montane Heath and Thicket Community has also been significantly affected by *Phytophthora cinnamomi* dieback. *P. cinnamomi* is an introduced soil-borne plant pathogen that causes death in susceptible species by affecting root systems, a phenomenon known as *Phytophthora* dieback (Barrett et al. 2008; DPAW 2016). Plants eventually die because they cannot uptake the required water and nutrients (DBCA 2020b). The impact of the disease on plant communities is variable between sites, as it is dependent on temperature, soil type, nutrient and water status, and species susceptibility. The greatest impact usually occurs where soils are infertile, and drainage is poor (Weste &Marks 1987; Shearer & Tippett 1989; Wilson et al. 1994). Rainfall patterns in the area, combined with topography, shallow nutrient-deficient peaty soils and the susceptible plant community, provides ideal conditions for survival and spread of the pathogen throughout the eastern Stirling Range (Grant & Barrett 2003).

Native fauna, introduced fauna and humans act as vectors of dieback, aiding the wide and rapid spread of the disease throughout the Stirling Range and enabling it to establish new centres of infection (CALM 2000). Dieback has infested the Bluff Knoll, East Bluff and Pyungoorup subpopulations of Stirling Range Dryandra. The Isongerup population remains uninfested. Recovery of the pathogen from dead Stirling Range Dryandra plants, field observations and

shade house inoculation indicate that the Stirling Range Dryandra is susceptible to *P. cinnamomi* Dieback (Barrett et al. 2008; Shearer et al. 2013). However, disease susceptibility or disease avoidance may vary between plants as before recent fires, some individuals continued to survive in a healthy state within infested vegetation. Changes in vegetation structure and floristics caused by *P. cinnammomi* will also have an effect on the abundance of vertebrate pollinators in communities (Wills 1993), but possible effects on pollinators such as honey possum include loss of food, loss of habitat and increased predation risk (Wilson, et al. 1994; Nichols 1998).

In 2013, a new species of mealybug, *Pseudococcus markharveyi (Banksia montana* Mealybug), was documented on the Stirling Range Dryandra. The species had not previously been documented and is similar morphologically to other species in the genus *Pseudococcus* (Westwood 1840; Gullan et al. 2013). It was originally discovered in 2007 through sampling of threatened plant species (Moir et al. 2012a, b). The species is dependent on Stirling Range Dryandra and feeds exclusively on the sap of this species. Thus, loss of plant material and mortality of individuals due to *P. cinnamomi di*eback poses a large threat to the survival of the *Banksia montana* Mealybug. Given the conservation status of the remaining extant subpopulations of the Stirling Range Dryandra, the *Banksia montana* Mealybug is considered critically endangered, with high risk of co-extinction (Moir et al. 2012a; Gullan et al. 2013; Moir et al. 2016; DAWE 2017).

Habitat critical to the survival

Due to the species eligibility for listing (highly restricted range and/or severe fragmentation and /or /small population size), all habitat is considered critical to the survival of the species.

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, to declare all populations/the national population of this species under particular pressure of survival and which therefore require protection to support the recovery of the species**.**

Threats

The Stirling Range Dryandra is threatened by the altered fire regimes associated with climate change, disease, grazing and browsing by native and introduced species and habitat disturbance by human recreation. The species is threatened by several fire-related threats, including high frequency fire, fire-disease interactions, fire-drought interactions, and fire-herbivore interactions. The small population size and limited distribution of the species leaves it vulnerable to extinction through stochastic events such as bushfire, though this threat has been mitigated to some extent through development of seed orchards (DBCA 2020).

Table 2: Threats impacting Stirling Range Dryandra

Threat	Status and severity [a]	Evidence
Climate change		
Increased frequency and severity of fires	• Timing: current • Confidence: known • Consequence: catastrophic • Trend: increasing • Extent: across the entire range	Increased frequency and severity of fires brought about by climate change are a major threat to Stirling Range Dryandra. Projections of higher temperatures, more frequent droughts and reduced mean rainfall for south-west Western Australia suggest that the frequency, intensity and scale of bushfires in the region will increase (CSIRO & Bureau of Meteorology 2015). Therefore, the potential for fire intervals less than the 18-year seed development threshold for this species is likely to rise (Barrett and Yates 2015). Major bushfires have impacted subpopulations in 1972, 1991, 2000 and 2019, with some subpopulations affected by several of these fires. The 1991 bushfire affected a small part of East Bluff and a significant part of Bluff Knoll, though the full impact of these fires and those in 1972 is unknown. In contrast, the impact of the 2000 fire on Stirling Range Dryandra was closely monitored and resulted in 70 percent mortality in three subpopulations and eight percent of the Pyungoorup population (Yates and Barrett, unpublished data, as cited in DEC 2008). Seedling recruitment following the 2000 fire was very low and considerably less than the number of plants killed by the fire. After the fire, the previous population of 137 adults and 38 juveniles was reduced to 51 adults and nine juveniles (DEC 2008). This was exacerbated by high levels of vertebrate post-fire browsing and grazing. A bushfire in December of 2019 exacerbated the impacts of a previous fire in 2018 (see 'Prescribed burning' below). The eight remaining mature individuals of Stirling Range Dryandra were killed (DBCA 2020), with the combination of the 2018 and 2019 bushfires burning 100 percent of known subpopulations and 100 percent of known mature individuals. Some seedlings that germinated after the 2018 fire were also killed, though most mortality since 2018 is thought to have been due to drought conditions (DBCA 2020). In 2020, 857 juveniles were identified, suggesting that 60 percent of the juveniles alive in 2019 survived until 2020. By autumn 2021, 725 juveniles and 22 seedlings that germinated after the 2019 fire were present. The loss of all

		extant mature individuals in 2018-2019 increases the risk of extinction for the *Banksia montana* Mealybug.
Increased temperatures and change to precipitation patterns	• Timing: current • Confidence: known • Consequence: catastrophic • Trend: increasing • Extent: across the entire range	The CSIRO & Bureau of Meteorology (2015) predict Western Australia will experience decreased rainfall and increased average temperatures, as well as greater frequency of droughts. This may cause substantial changes to the unique climate in which the Stirling Range Banksia occurs (Monks et al. 2019). Rainfall 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 plain (Keighery & Marchant 1993). 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 associated with climate change could accelerate this process, significantly reducing the area of habitat suitable for the Stirling Range Dryandra (Monks et al. 2019). However, the species can grow in lowland conditions when provided sufficient water and nutrients, as evidenced by the success of growth and propagation in ex situ seed orchards. Further research is required to appropriately determine the impact of drier, hotter conditions on the species. Furthermore, fire-drought interactions are particularly an issue for obligate seeders, as they rely on fire for recruitment, yet seedlings have rudimentary root systems vulnerable to desiccation if post- fire drought occurs (Burgman and Lamont 1992).
Habitat disturbance and modification		
Prescribed burning	• Timing: current • Confidence: known • Consequence: catastrophic • Trend: increasing • Extent: across the entire range	The catastrophic May 2018 fire is thought to be the result of escaped prescribed burns in the area. Strong winds resulted in planned burns on private property and crown land growing out of control and becoming bushfires (BOM 2018). Post fire surveying suggested substantial population reduction in fire-affected Stirling Range Dryandra subpopulations. Thirty-three of the 41 remaining extant plants were killed. However, seedling recruitment was relatively high. More than 1000 seedlings germinated compared to less than 30 after the 2000 fire (DBCA 2020). The impacts of the 2018 were exacerbated by

		a fire in December 2019, which killed all remaining mature individuals.
Disturbance by human recreation	• Timing: current • Confidence: suspected • Consequence: moderate • Trend: unknown • Extent: across parts of the range	The higher peaks of the eastern Stirling Range attract visitors interested in bushwalking, nature observation and rock-climbing. Negative impacts of this recreation activity include braiding of paths, erosion, bare ground occurrence, changes to soil nutrients and, most importantly, introduction and spread of *P. cinnamomi* (Barrett et al. 2000; DPAW 2016). Human activity is thought to have spread the pathogen through the transport of infected soil, mostly by foot access, as a result of recreational and other activities (Gillen & Watson 1993; Wills 1993). Bluff Knoll is the most visited site, so has the highest levels of human disturbance.
Disease		
Dieback caused by *Phytophthora cinnamomi*	• Timing: current • Confidence: known • Consequence: catastrophic • Trend: static • Extent: across the entire range	The Eastern Stirling Range Montane Heath and Thicket Community has been significantly affected by *P. cinnamomi* dieback since it was identified in the region in 1974. *Phytophthora cinnamomi* is an introduced soil-borne plant pathogen that results in plant death through the destruction of root systems (DPAW 2014). 'Dieback caused by the root-rot fungus *Phytophthora cinnamomi*' is listed as a Key Threatening Process under the EPBC Act (DAWE 2018). The Stirling Range Dryandra is susceptible to *P. cinnamomi* dieback (Barrett et al. 2008; Shearer et al. 2013), though disease susceptibility may vary between plants, with some individuals continuing to survive in a healthy state after infection. This contrasts to some other highly susceptible species that are uniformly susceptible (McCredie et al. 1985), though it is unclear whether the disease was isolated from healthy plants. *Phytophthora cinnamomi* has infested the Bluff Knoll, East Bluff and Pyungoorup subpopulations of Stirling Range Dryandra. The Isongerup population remains unaffected (Barrett & Yates 2015). The disease has killed plants in the three affected subpopulations, though some healthy individuals persist in infested vegetation (Barrett & Yates 2015). At least one population has become locally extinct, presumably from *P. cinnamomi* dieback infestation, possibly in conjunction with fire (DEC 2008). Comparative photography shows that healthy stands in the 1960s and 1980s on the summit of Bluff Knoll are now extremely rare. This is thought to be as a result of *P. cinnamomi* (DPAW 2016). Dieback may also

		interact with fire to increase the impact of the disease and accelerate collapse of obligate seeding plants such as the Stirling Range Dryandra (Moore et al. 2015). Serotinous non-sprouting species are highly susceptible to both fire and *P. cinnamomi d*ieback, with density of these species where the pathogen is present, highest in areas not affected by any recent fires (Barrett & Yates 2015). Observations indicate that the impact of dieback may be exacerbated post-fire, due to altered hydrology and increased surface run-off (Barrett 1996), as well as increased root tissue vulnerability (B. Shearer, personal communication, as cited in DEC 2008). More research should be completed on the interaction between these threats. Since 1997, aerial phosphite application has been used to control *P. cinnamomi* in all extant Stirling Range Dryandra subpopulations. Phosphite has been shown as effective in controlling *P. cinnamomi* in several native plant species (Shearer & Fairman 1991; Komorek et al. 1997; Ali & Guest 1998; DPAW 2016; Barrett & Rathbone 2018). Phosphite does not eradicate the disease but does help mitigate its impact by reducing its spread as well as enhancing plant defence responses and plant survival. The mechanisms behind this are not fully understood, though protection may last approximately two years depending on application method and rate (DPAW 2014).
Invasive and native species		
Grazing/browsing	• Timing: current • Confidence: known • Consequence: major • Trend: decreasing • Extent: across the entire range	Montane ecosystems are vulnerable to the removal of vegetation by native and feral fauna (Leigh et al. 1987; Bridle & Kirkpatrick 1999; Bridle et al. 2001; DPAW 2016). Surveys since 1994 have confirmed the presence of feral Rabbits (*Oryctolagus cuniculus*) and native *Setonix brachyurus* (Quokka) within the range of Stirling Range Dryandra (Barrett 1996). Since the 2000 bushfire, the impacts of browsing by vertebrate fauna have become increasingly apparent, especially on seedling and juvenile plants (DPAW 2016). Subsequent management solutions include Rabbit control using 1080 oats, as well as fencing and caging of all Stirling Range Dryandra plants to protect against herbivory (DPAW 2016). More recently, Calicivirus RHDV1-K5 has been released at three subpopulations (DBCA 2021). Between 2011 and 2015, motion sensing cameras were installed to identify the vertebrates most responsible for native

		vegetation browsing. Quokkas were responsible for 75 percent of recorded herbivory events (Rathbone & Barrett 2017). This evidence, combined with dietary analysis, implicates Quokkas as the species most responsible for vegetation destruction through browsing. Stirling Range Dryandra is particularly vulnerable to grazing after fires, especially given its slow recovery after fires. 40 percent of seedlings that emerged following the 2000 fire were heavily grazed by either Rabbits or Quokkas, though all seedlings were subsequently protected from further grazing with cages (DEC 2008). Juvenile plants that successfully regenerated after the fires were also partially to completely defoliated. After the 2018 and 2019 fires, 99 percent of seedlings and juveniles have been fenced to protect against grazing (DBCA 2021). Invertebrate grazing has been observed on the foliage of in situ plants, but more so on plants in the seed orchard. where fruit predation has also been high (S. Barrett, personal observation, as cited in DEC 2008). Considering the low number of individuals of Stirling Range Dryandra, this predation pressure may impact on subpopulations if it reduces the vigour of plants.

Each threat has been described in Table 2 in terms of the extent that it is operating on the species. The risk matrix (Table 3) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; 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 in-house expertise using available literature.

Table 3 Stirling Range Dryandra risk matrix

Likelihood	**Consequences**				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Low risk	Moderate risk	Very high risk	Very high risk **Grazing by native and invasive species**	Very high risk **Natural fire** **Prescribed burns** **Dieback caused by**

Likelihood	Consequences				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
					Phytophthora cinnamomi **Increased temperatures and change to precipitation patterns**
Likely	Low risk	Moderate risk	High risk **Disturbance by human recreation**	Very high risk	Very high risk
Possible	Low risk	Moderate risk	High risk	Very high risk	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

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 objective

By 2030, known populations are still viable and extant, and juveniles have been protected from disease.

Conservation and management priorities

Breeding, seed collection, propagation and other ex situ recovery action

- Continue to maintain the two existing seed orchards to ensure their ongoing survival and ability to provide individuals suitable for translocation to in situ subpopulations.
- Maintain reinforcement translocations and continue direct seeding using seed from seed orchards to augment extant subpopulations.
- Establish new seed production area outside of Stirling Range National Park and upgrade current seed orchards with better reticulation to improve plant health.
- Maintain stored seed and germplasm to preserve genetic material. Seed collections have been made for the species, currently stored in the WA Seed Centre.
- Continue to develop cutting propagation and tissue culture techniques. Material for tissue culture has been collected by the Botanic Gardens and Parks Authority (BGPA) and is important to restock future subpopulations. Cuttings from in situ subpopulations have also been collected by BGPA.

- If research determines that the species is unlikely to persist in natural habitat due to climate changed induced due to altered temperatures and rainfall patterns, investigate the possibility of establishing a translocated subpopulation in suitable climate refugia.

Fire and climate change

- Continue to survey subpopulations to monitor ongoing impacts from the 2018 and 2019 bushfires.
- Implement a fire management strategy to protect translocated and reintroduced subpopulations from further fire that includes rapid detection and control of ignitions as a regional priority. If possible, exclude fire from all subpopulations for the indefinite future.
- If prescribed burning is applied, ensure that the fire is controllable, and unable to reach the peaks where Stirling Range Dyrandra is found.
- Prescribed burning practices must ensure that there is no increase in fire frequency that will adversely impact the species and ecological community.

Disease

- Ensure sites for reintroduction of translocated individuals are appropriately protected against *P. cinnamomi* and are not infected prior to translocation.
- Continue to manage and minimise the spread of *P. cinnamomi* by applying phosphite at 12–24 kg per hectare to all known sites where Stirling Range Dryandra naturally occurs (DPAW 2016).
- Ensure that appropriate hygiene protocols are adhered to when entering or exiting the known locations of Stirling Range Dryandra subpopulations.
- Determine which isolates of *P. cinnamomi* are present in which subpopulations.

Invasive species (including threats from grazing, trampling, predation)

- Place and maintain cages or fencing around seedling, juvenile and translocated plants to protect against Rabbit grazing.
- Maintain the Rabbit control program to control Rabbit subpopulations. Continue baiting with 1080 oats in areas with high Rabbit subpopulations, including East Bluff, Bluff Knoll and Pyungoorup (DPAW 2016) to ensure post-bushfire population recovery.
- Assess the impact of RHDV1-K5 calicivirus on Rabbit subpopulations at two sites. The virus was released in 2017 and 2018, and post-fire in 2020 and 2021 (DBCA 2021).

Impacts of native species

- Maintain grazing enclosures on Bluff Knoll, Pyungoorup, Isongerup and East Bluff to protect against Quokka grazing.
- Maintain other smaller cages around seedlings to further protect against Quokka grazing.
- Maintain use of infrared cameras to monitor Quokka activity.

Habitat loss, disturbance and modification

- Ensure that extant subpopulations continue to be protected as part of the Stirling Range National Park as well as translocated subpopulations.
- Protect subpopulations from trampling using signage, track markers and fencing.

Stakeholder engagement/community engagement

- Liaise with land managers and Aboriginal communities. Consult with Aboriginal stakeholders to discuss issues or interests in areas where the Stirling Range Dryandra is found, as the Stirling Range National Park is in a culturally sensitive area.
- Liaise with the local community and government agencies to ensure that recent population data informs the implementation of management actions.
- Promote public awareness of biodiversity conservation and protection through dissemination of information through physical and digital media.

Survey and monitoring priorities

- Regularly monitor all extant subpopulations, including population stability, pollinator activity, growth, reproduction, recruitment and longevity. A subset of extant seedling and juvenile plants are currently tagged for monitoring in all subpopulations (DBCA 2021). Use these data to assess species' status and population recovery after the 2018 and 2019 fires.
- Monitor plants within translocated subpopulations and seed orchards. Record the number of surviving seedlings, height of seedlings, reproductive state, and general health.
- Survey for new subpopulations and possible translocation sites.
- Implement a monitoring program to evaluate effectiveness of disease management.

Information and research priorities

- Increase knowledge surrounding the ecology of the species. This includes improving understanding of factors limiting seed production and recruitment, genetic structure, minimum viable population size and genotypes resistant to dieback.
- Understand the potential influence of climate change on the long-term survival prospects of the species, due to altered temperatures, rainfall patterns, bushfires, environmental stressors and diseases by using surplus plants for controlled experimental studies off site.
- Map habitat critical to species survival. Although habitat mapping has already been undertaken for this species, updated and detailed mapping is likely required due to the changes in habitat brought about by the 2018 and 2019 fires.
- Collect climatic data (rainfall, soil and air temperatures, humidity).
- Identify potential areas of climate refugia for the species under projected climate change scenarios.
- Ensure longevity of the seed in ex situ seed banking is capable of long-term storage.

Links to relevant implementation documents

Montane Heath and Thicket of the South West Botanical Province, above approximately 900 m above sea level (Eastern Stirling Range Montane Heath and Thicket Community) Interim Recovery Plan 2016-2021

Stirling Range Dryandra (*Dryandra Montana*) Recovery Plan (2008)

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

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