Guide

Restoring buloke woodland structure

Project 1.2.2

Threatened Species Recovery Hub

National Environmental Science Programme

A guide to good practice in restoring overstorey structure in buloke woodlands of the Riverina and Murray Darling Depression Bioregions

Buloke woodlands

The buloke woodlands of the Riverina and Murray-Darling Depression Bioregions (buloke woodlands for short) are recognised nationally as an Endangered Ecological Community under the EPBC Act 1999[1].

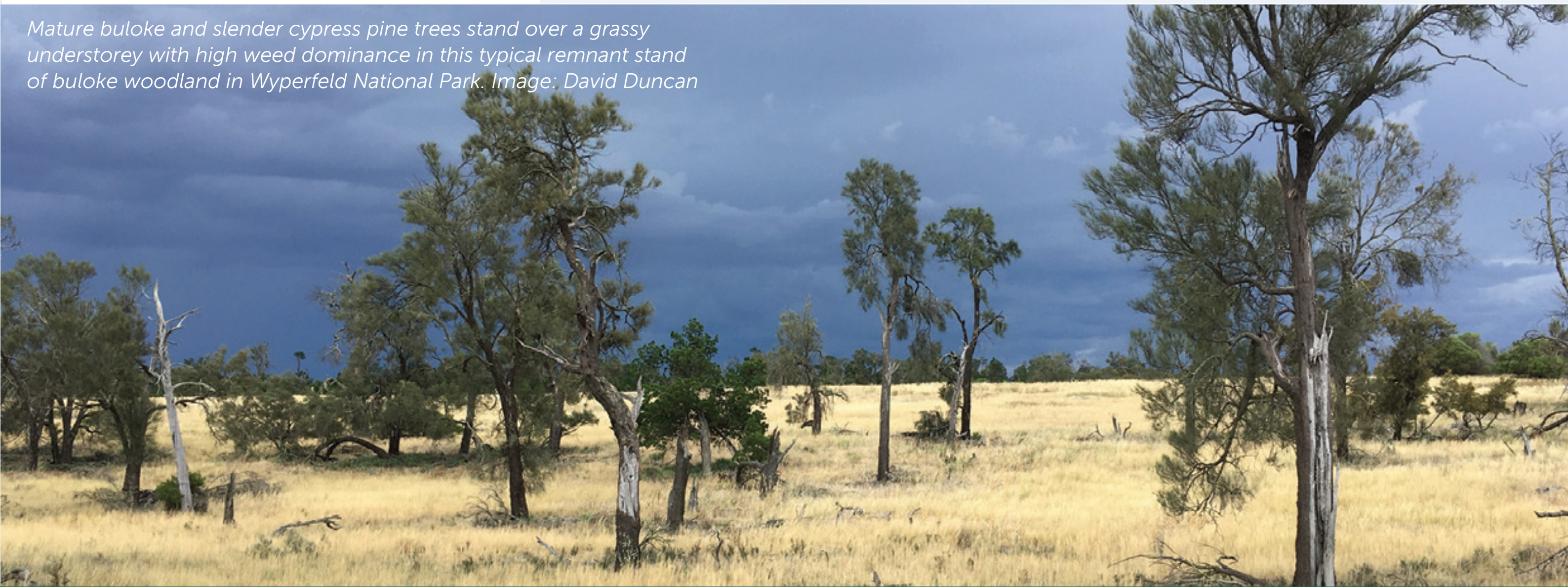
Buloke woodlands consist of a number of sub-communities that vary in species composition and dominance according to the interplay of a broad rainfall gradient (280–580 mm/yr) and the geomorphological variation between heavy soil plains and dune formations over which the buloke woodlands are distributed[2].

About this guide

This guide is designed for those working to – at a minimum – restore a degraded, simplified remnant towards an open woodland structure of mixed species dominance by buloke (*Allocasuarina luehmannii*), slender cypress pine (*Callitris gracilis*) or other locally appropriate co-dominant tree species.

A self-sustaining "open woodland" structure is a common short term restoration goal for degraded buloke woodland stands, which typically reflect a legacy of clearing, livestock grazing, grazing and browsing from wild herbivores, and the introduction of invasive weed species[2]. Short term direct indicators of success are often recruitment and survival of seedlings, as well as threat reduction measures such as managing herbivore pressure[3,4].

Some limitations to successful restoration in buloke woodlands differ in degree according to underlying variation in soil type, and soil moisture. Recruitment of tree and shrub species in buloke woodlands at higher mean annual rainfall (>400 mm/yr) can be readily achieved by excluding access by grazing livestock[5], and in some cases dense recruitment can be considered excessive. By contrast, in semi-arid areas (<350 mm/yr) lack of recruitment is a major hurdle for the survival of buloke woodlands. Because this guide is about recruitment, we focus on these drier woodlands where recruitment is hard-earned.



Mature buloke and slender cypress pine trees stand over a grassy understorey with high weed dominance in this typical remnant stand of buloke woodland in Wyperfeld National Park. Image: David Duncan

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Why focus on Allocasuarina?

The information in our guide is based on studies of *Allocasuarina luehmannii* (buloke) recruitment in buloke woodlands. Not only is buloke a functionally and structurally important element of the ecological community, its nitrogen-rich seedlings are attractive to herbivores, so strategies that adequately protect buloke will likely suffice for other characteristic shrub and tree species too. For these reasons it is legitimate to focus on buloke initially.

Recruitment in buloke can occur via sexual reproduction (seedling) and vegetative ("suckering") pathways. Suckers extend the life of adult trees, so promoting suckers could be part of a restoration strategy[6], but sexual reproduction is needed to give the species a chance to adapt to a changing climate. Management options to stimulate the two processes differ, though both are vulnerable to herbivory (see beside).

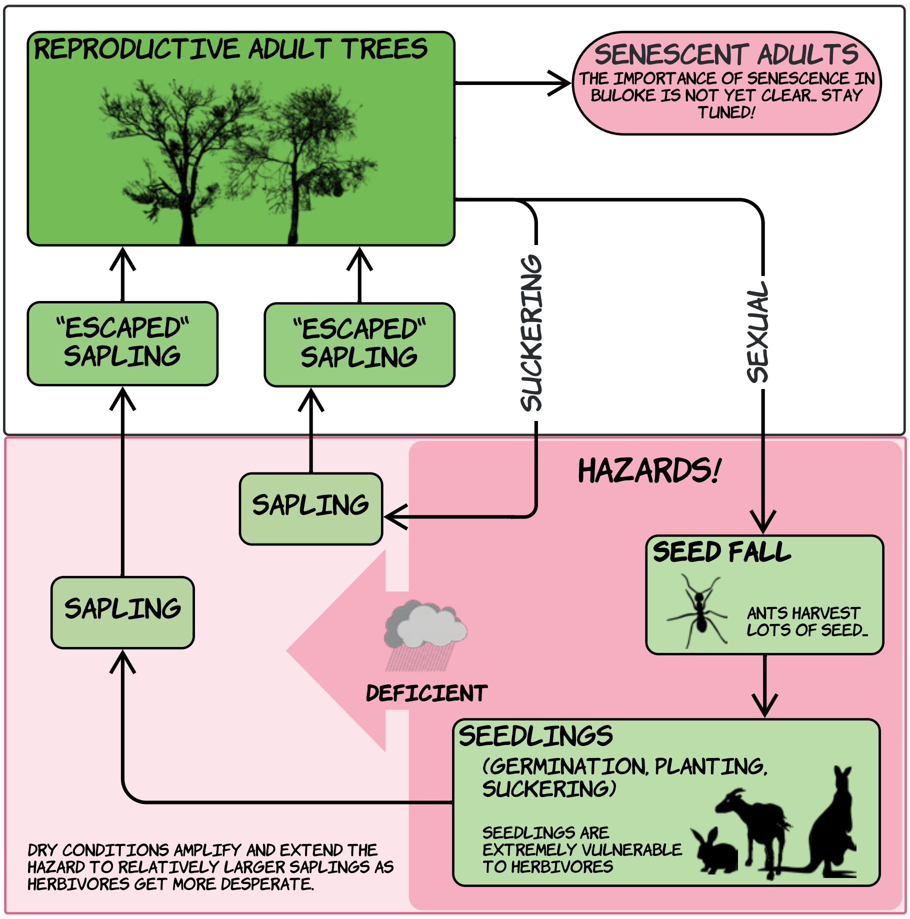

Figure 1. Life stages of buloke emphasising hazards facing seedling establishment and escape.

More than just buloke

However, *buloke woodlands* are more than just *buloke*! In fact, because buloke seedlings are highly palatable, it would be wise to evaluate restoration success using responses of other species too[7]. The community comprises hundreds of species of plants and animals. Many of those may play important functional roles in the ecology of the community and the local environment. Other species that can have important ecological functions such as the dingo (an apex predator[8]) and bettongs (a soil engineer)[9,10] are locally extinct, or nearly so.

A remnant buloke woodland stand retaining some structural complexity. Image: Chris Jones

Vital ingredients

Successful recruitment of a new cohort is a recipe of at least three simple ingredients that rarely coincide in today's buloke woodlands.

A viable seed source: either from surviving, genetically healthy adults, or imported seed or seedlings in the case of revegetation projects.

Seed viability is good for all tested shrub and tree species of buloke woodlands, except cattle bush (*Alectryon oleifolius*)[11].

Sufficient soil moisture to avoid moisture deficit in the critical first two dry seasons of a seedling's life[12]. Most of the adult trees we see around probably arose from rare unusually wet sequences of years – and before the arrival of rabbits.

Seedling recruitment is possible – though not probable – in intervening years, providing there is viable seed and negligible herbivore threat.

Protection from herbivores, via exclosure fences, plant guards, or herbivore populations reduced to low density.

Protection from grazing and browsing is required for long enough to allow seedlings to grow beyond the reach of herbivores, which could be more than a decade.

How important are guards?

Constructing fenced exclosures or installing robust plant guards costs money, but without protection, it is unlikely seedlings will survive. Individuals need to grow big enough to avoid damage from herbivore species (this is their "escape size") as quickly as possible.

On the next page we offer a prospectus for revegetation based on a large-scale experiment on buloke seedling survival.[13] Unguarded buloke seedlings had a mortality rate 2–7 times higher than guarded seedlings; depending on landscape position, and 75–97% of unguarded seedlings died in the first few years.

If the seedlings that survive continue to grow at the observed rates, no unguarded seedlings, and 20–50% of guarded seedlings are expected to reach escape size in 50 years.

Planting location was an important variable. The best survival and growth for protected seedlings was observed near the foot of dunes, perhaps due to lighter soils. Protection from herbivores is essential in those locations as they are favoured by rabbits. By contrast, in open grassy plains on heavier soils, herbivore activity was less but growth slower.

Planting inside existing buloke stands was a poor option, probably because those sites can be camps for kangaroos, and adult trees may compete for soil moisture, even from a distance.

The main herbivores in our study were rabbits and western grey kangaroos, and herbivore activity data suggest both species were at around the target densities that managers work to[3].

Mortality rates and the difference between treatments could be more stark where densities were not controlled, or where other herbivores such as goats, cattle or fallow deer are also present. The estimated time to "escape size" would also be expected to increase.

Ami Bennett and Emily Baldwin establish an experimental planting of buloke in an open grassy context. Image: Kate Cranney

Tube-stock planting prospectus

Notes on interpretation

These data summarise fates over four years of 1275 seedlings planted in different landscape contexts in Nov. 2016 (see Bennett and others[13] for details).

Seedlings were around 18 months of age at planting, with average stem diam. of 2.2 mm and average height of 31 cm (ideal size, according to Gardiner and others[14]).

‡ Guarded refers to an individual 90 cm-high graduated wire mesh guard with a 30 cm-high wire netting around the base. Data from an additional partial guard design omitted from this graph for simplicity, but see Bennett and others[13] for detail.

† Seedlings planted within existing buloke stands were planted no less than 13 m from a living adult tree, following Morgan and others[15].

* Escape size thresholds based on examination of browsing damage on self-sown seedlings at Hattah-Kulkyne NP[16].

The projected times for seedlings to reach escape size assume the continuation of annualised growth rates observed in individuals surviving to the end of the four-year observation period.

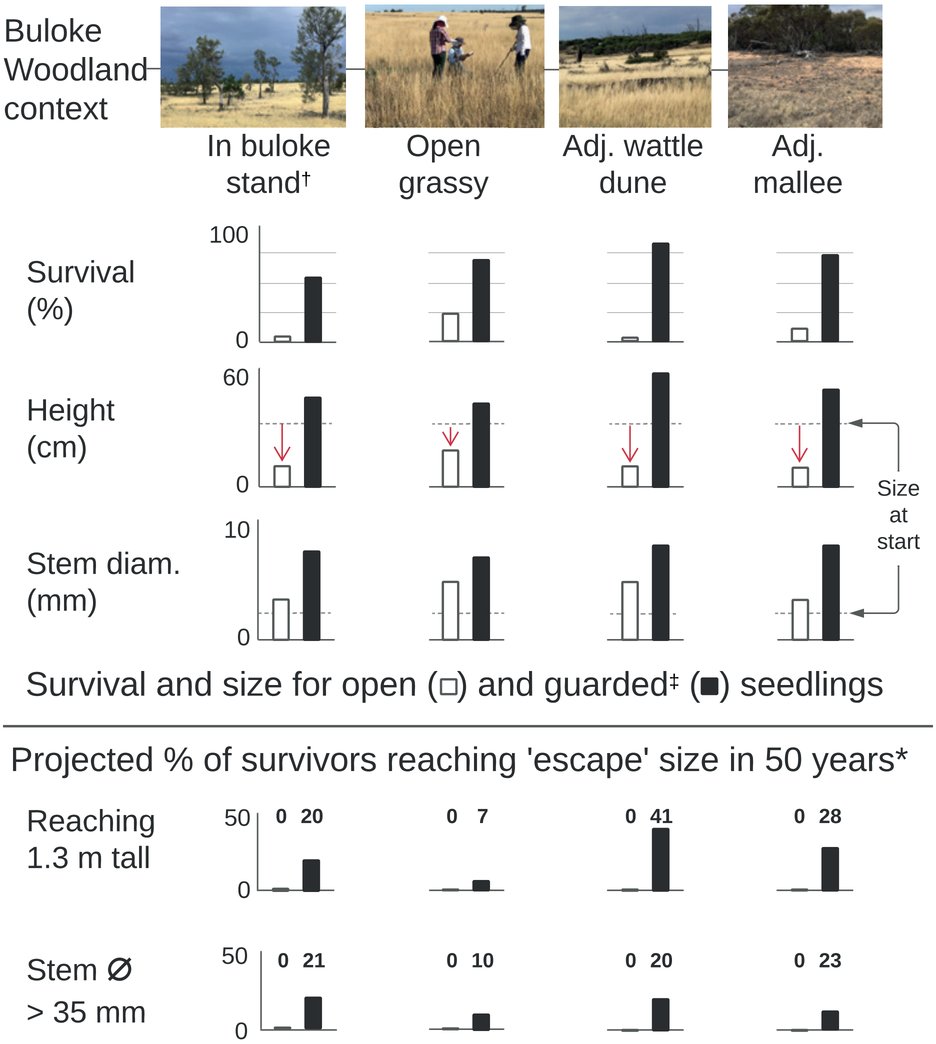

Figure 2. Average survival and growth of 1275 planted buloke seedlings over four years.

Informal protection

Robust guards are a secure bet, but seedlings are sometimes found emerging from under fallen branches, or from inside a *Triodia* hummock. Managers can mimic this, opportunistically placing objects around or over seedlings to act as a temporary deterrent to herbivores. To ensure their survival longer term, it is advisable to install guards or fencing around such serendipitous seedlings.

Slender cypress pine sapling established under the protection of a Triodia hummock at Hattah-Kulkyne NP. Image: Dylan Osler

Cost-effective restoration strategies

Our study provides insight into spatial variation in seedling survival and herbivore activity. These data can be combined with restoration project parameters, plant and herbivore species profiles, and cost information in formal analyses to identify cost-effective strategies for prospective projects [e.g., 17].

The schematic here illustrates the main dimensions of such an analysis for the question of herbivore protection for revegetation activity.

Each cell in the table could contain further variation according to species being planted. Spatial variation according to buloke woodland contexts could be introduced to produce a spatially explicit strategy, and additional options or criteria could be introduced (indicated by ellipses…).

Restoration is a developing science so monitoring of outcomes and experimentation with new techniques continue to be important in learning how to restore buloke woodlands.

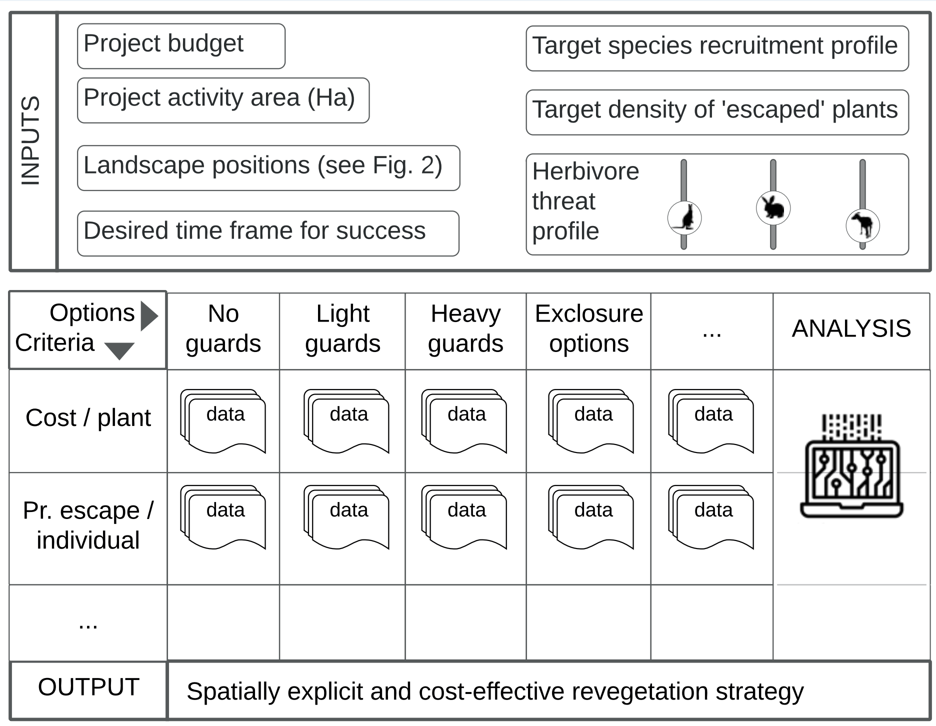

Figure 3. Indicative structure of a cost-effective analysis for buloke woodland restoration.

Adaptable strategies, proposals and projects

The dynamics of buloke woodlands were and still are shaped strongly by weather; the availability of resources that support plant germination and growth, and that drive herbivore population dynamics. Major investments can completely fail if the conditions are not appropriate.

Recent research from northern Australia has shown that a model with seasonal forecasts could predict project failures related to low rainfall or extreme temperatures[18].

To make the most of scarce resources and maximise the probability of successful regeneration of buloke woodlands, it makes sense that restoration strategy be adapted to the climate outlook[e.g., 19]: go big in years with favourable outlook and focus effort at other times on preparing sites and 'banking' resources for the next opportunity.

Figure 4 (overpage) explores how both preceding soil moisture data and the Bureau of Metereology's quarterly outlook for autumn–winter might be used in combination to select amongst or modulate allocation to candidate activities.

The activities that the diagram highlights according to rainfall outlook in a given cycle could be considered as major priorities, rather than exclusive choices.

Some activities, like controlling herbivore populations, may be required to some extent every year, whilst others could be drafted in or left out according to the seasonal outlook. This process would be iterative; past decisions, and the status of "banked" resources would be considerations to the next decision cycle.

This guide was prepared by David Duncan with input from participants at an expert workshop hosted by the NESP Threatened Species Recovery Hub in April 2020: Libby Rumpff, Megan Good, Ami Bennett, Peter Vesk, Graeme Coulson and Michael Whitney (University of Melbourne); Doug Robinson (Trust for Nature), Fiona Murdoch, Sally Kenny, Matt White and Claire Moxham (Vic. DELWP); Brendan Rodgers, Kathryn Schneider, Lorraine Taylor, and Marie Keatley (Parks Victoria); David Cheal, Ian Sluiter (Ogyris Ecological Research), Mark Bourne (DAWE), David Parker and Heidi Zimmer (NSW DPIE), Catherine Ross (ANU), Dan Rogers (SA DEW) and Trish Fleming (Murdoch University).

Further information

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Adaptable strategies, proposals and projects (continued)

Many restoration practitioners would recognise the logic of the decision tree but consider that they lack the authority to implement it.

Inflexible project funding timelines combined with the need for transparent accounting requires that the intention to adapt strategy to climate be clearly signalled and justified in line with project objectives.

Studies simulating outcomes from adaptive and non-adaptive restoration projects should help build support from government and other investors for this more agile approach.

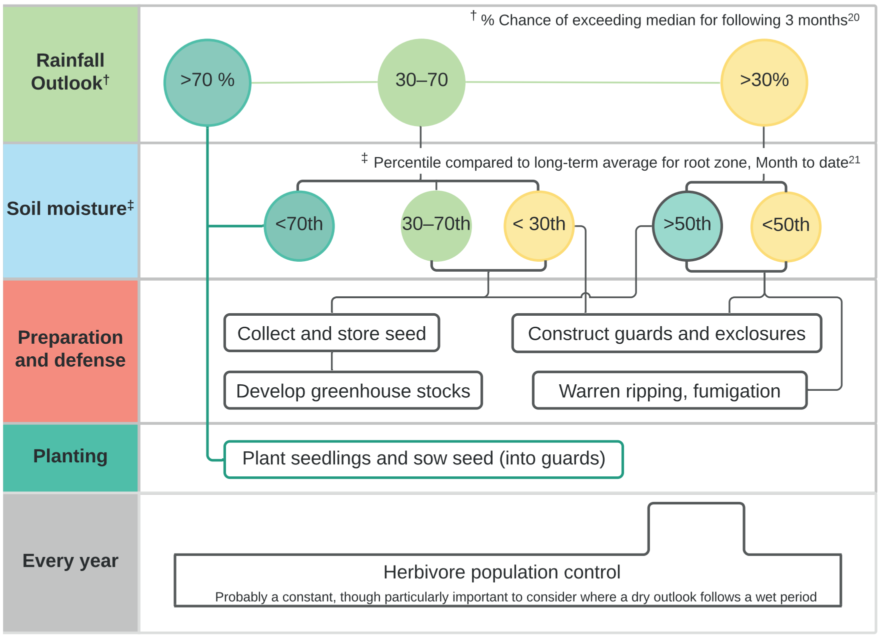

Figure 4. Decision tree for choosing restoration activities under climate outlook information

Cited sources

1. Department of the Environment and Energy. Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions. *Department of the Environment and Energy* http://www.environment.gov.au/
2. Cheal, D., Lucas, A. & Macaulay, L. National *Recovery Plan for Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions*. (2011).
3. Taylor, L. & Pegler, P. *Total Grazing Management Plan for the restoration of Semi-arid Woodland and Floodplain Vegetation Communities in North-western (Mallee) Parks* 2016–2021. Parks Victoria: Melbourne, Australia. (2016).
4. Parks Victoria. *Conservation Action Plan for parks and reserves managed by Parks Victoria: Mallee*. Parks Victoria: Melbourne, Australia. (2019).
5. Duncan, D. H., Moxham, C. & Read, C. *Effect of stock removal on woodlands in the Murray Mallee and Wimmera Bioregions of Victoria. An unpublished report to the North Central and Mallee Catchment Management Authorities.* (2007).
6. Murdoch, F. A. Restoration ecology in the semi-arid woodlands of north-west Victoria [PhD Thesis]. University of Ballarat. (2005).
7. Kenny S. & Moxham C. Monitoring framework for assessing semi-arid woodland condition. Victorian Department of Environment, Land, Water and Planning (2017).
8. Derham, T. T., Duncan, R. P., Johnson, C. N. & Jones, M. E. Hope and caution: rewilding to mitigate the impacts of biological invasions. *Philos. Trans. R. Soc. B Biol. Sci*. 373, (2018).
9. Fleming, P. A. *et al.* Is the loss of Australian digging mammals contributing to a deterioration in ecosystem function? *Mammal Rev*. 44, 94–108 (2014).
10. Munro, N. T. *et al.* Returning a lost process by reintroducing a locally extinct digging marsupial. *PeerJ* 7, e6622 (2019).
11. Callister, K. E., Florentine, S. K. & Westbrooke, M. E. An investigation of the soil seedbank and seed germination of perennial species in Belah (*Casuarina pauper*) woodlands in north-west Victoria. *Aust. J. Bot.* 66, 202 (2018).
12. Macaulay, L. & Westbrooke, M. E. *Guidelines for the management and rehabilitation of the Wimmera Buloke Woodlands of Western Victoria*. Centre for Environmental Management, University of Ballarat. (2003).
13. Bennett, A., Duncan, D. H., Rumpff, L. & Vesk, P. A. Disentangling chronic regeneration failure in endangered woodland ecosystems. *Ecosphere* 11, e02998 (2020).
14. Gardiner, R., Shoo, L. P. & Dwyer, J. M. Look to seedling heights, rather than functional traits, to explain survival during extreme heat stress in the early stages of subtropical rainforest restoration. *J. Appl. Ecol*. 56, 2687–2697 (2019).
15. Morgan, J., Kviecinskas, P. & Maron, M. Effect of proximity of buloke (*Allocasuarina luehmannii*) trees on buloke early sapling survival in a semiarid environment. Aust. *J. Bot*. 61, 302–308 (2013).
16. Murdoch, F. A. *Evaluating the effects on Buloke regeneration of increased browsing by rabbits – Hattah Kulkyne National Park*. 54 (2007).
17. Cooke, B., Jones, R. & Gong, W. An economic decision model of wild rabbit *Oryctolagus cuniculus* control to conserve Australian native vegetation. *Wildl. Res*. 37, 558–565 (2010).
18. Hagger, V., Dwyer, J., Shoo, L. & Wilson, K. Use of seasonal forecasting to manage weather risk in ecological restoration. *Ecol. Appl*. 28, 1797–1807 (2018).
19. Kimball, S., Lulow, M., Sorenson, Q., Balazs, K., Fang, Y.-C., Davis, S. J., O'Connell, M., & Huxman, T. E. Cost-effective ecological restoration. (2015). *Restoration Ecology*, 23(6), 800–810.
20. Australian Government Bureau of Meteorology. Australian climate outlook. URL: http://www.bom.gov.au/climate/outlooks/#/rainfall/summary. (2020).
21. Frost, A.J, Ramchurn, A, & Smith, A. The Australian Landscape Water Balance model (AWRA-L v6). Technical Description of the Australian Water Resources Assessment Landscape model version 6. Australian Government Bureau of Meteorology. (2018).

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