



Environment Protection and Biodiversity Conservation (Recovery Plan for the Greater Bilby *Macrotis lagotis*) Instrument 2023

We jointly make this recovery plan under subsection 269A(3) of the *Environment Protection and Biodiversity Conservation Act 1999*.

Dated 5 April 2023

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Minister for the Environment and Water (Commonwealth)

Dated

23 March 2023

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16 March 2023

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Minister for Industry, Innovation and Science

Minister for Defence and Space Industries (South Australia)

2.1A Name

This instrument is the *Environment Protection and Biodiversity Conservation (Recovery Plan for the Greater Bilby Macrotis lagotis) Instrument 2023*.

2.1B Commencement

This instrument commences the day after it is registered.

Note: This instrument replaces the recovery plan titled 'National Recovery Plan for the Greater Bilby Macrotis lagotis' adopted under *Environment Protection and Biodiversity Conservation Act 1999* - section 269A - *Instrument Adopting Recovery Plans (09/05/2007)*.

2.1C Authority

This instrument is made under subsection 269A(3) of the *Environment Protection and Biodiversity Conservation Act 1999*.



Australian Government
Department of Climate Change, Energy,
the Environment and Water

Recovery Plan for the Greater Bilby (*Macrotis lagotis*)



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Species Profile and Threats Database (SPRAT) pages for this species is available at http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=282.

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Acknowledgements

This plan represents the combined efforts of many people, including those who have directly contributed to the content of the plan, those whose site and management action information has been captured, and those who have built the knowledge and understanding on which this plan relies.

The Greater Bilby National Recovery Team would like to acknowledge the many individuals and organisations that have directly contributed significant time and resources to the development of this plan over a number of years.

Due to the vast number of individual contributors who have provided inputs to this plan representing the interests of a diverse range of stakeholder groups including Traditional Owners, land managers, land owners, conservation organisation, and government agencies, to list them would be impractical and risk missing someone unintentionally.

We extend our sincerest thanks to each and every individual and organisation that has contributed and invested effort to support the recovery of this iconic and culturally significant marsupial to remain in the Australian landscape for future generations.

Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

Image Credits

Front Cover: Ninu nyinanyi ngurrangka talingka (Bilby living in sandhill country) © Jodie and Nolia Ward

Recovery Plan for the Greater Bilby (*Macrotis lagotis*)



Department of Climate Change, Energy, the Environment and Water

Dedicated in memory of Peter McRae and Frank Manthey – The Bilby Brothers, and co-founders of the Save the Bilby Fund.



Peter McRae: Scientist and passionate advocate for outback conservation, Peter established the first bilby captive breeding facilities in Queensland and designed the fenced enclosure on Currawinya National Park. © Lonie Eckles photographer courtesy Save the Bilby Fund.



Frank Manthey OAM: Tireless crusader to promote the plight of the bilbies, and successfully lobbied the Federal Government to recognise National Bilby Day.

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Acronyms

Term	Definition
AR	Arid Recovery (UNSW)
AWC	Australian Wildlife Conservancy
BHA	Bush Heritage Australia
CPSG	Conservation Planning Specialist Group (International Union for the Conservation of Nature)
CLC	Central Land Council
DAF	Department of Agriculture and Fisheries (Queensland)
DBCA	Department of Biodiversity, Conservation and Attractions (Western Australia)
DCCEEW	Department of Climate Change, Energy, the Environment and Water (Australian Government)
DPE	Department of Planning and Environment (New South Wales)
DEPWS	Department of Environment, Parks and Water Security (Northern Territory)
DES	Department of Environment and Science (Queensland)
DEW	Department for Environment and Water (South Australia)
IPA	Indigenous Protected Area
KLC	Kimberley Land Council
NLC	Northern Land Council
NP	National Park
NPWS	National Parks and Wildlife Service, New South Wales
NRM	Natural Resource Management
WWF	World Wide Fund for Nature (Kimberley)
SCA	State Conservation Area
STBF	Save the Bilby Fund
TCSA	Taronga Conservation Society Australia
ZAA	Zoo and Aquarium Association

1 Summary

This document constitutes the national Recovery Plan for the Greater Bilby (*Macrotis lagotis*), made under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The plan aims to halt decline and support recovery of the Greater Bilby and provides for the research and management actions necessary to maximise the Greater Bilby's chances of long-term survival in nature.



Photo: Greater Bilby (*Macrotis lagotis*) © Wells, Babs & Bett (CALM) and DCCEEW.

The objectives of this plan are that by 2030:

- the size of the Greater Bilby population has grown
- the area occupied by the Greater Bilby has been maintained or increased
- the genetic diversity of the Greater Bilby has been maintained, and retains the potential for evolutionary change through adaptation and selection
- Indigenous people have a greater role in bilby conservation.

To achieve these objectives, this plan identifies both on-ground and supporting strategies, with both the research and management actions believed to be necessary to maximise the Greater Bilby's long-term chances of survival in nature.

The on-ground strategies include predator and introduced species management to promote bilby population growth, habitat management to maintain or, preferably, improve habitat condition, and to manage the Greater Bilby as a single, interconnected metapopulation to maintain genetic variability and provide insurance against loss. These activities are to occur within a monitoring framework that measures the impact of management.

The supporting strategies focus on supporting Indigenous groups and land managers, improving governance and coordination, improving monitoring and survey methods, and undertaking research to inform management.

The plan includes supporting actions to promote the role of Indigenous people and land managers in bilby conservation, provide governance and coordination, establish and maintain monitoring and survey, and undertake research to inform management.

2 Introduction

2.1 Introduction to the Greater Bilby and its conservation

The Greater Bilby, *Macrotis lagotis* (Reid, 1837), is the only remaining member of the Genus *Macrotis* and sole extant representative of the Family Thylacomyidae (Jackson & Groves 2015) and will be hereafter referred to as ‘the Greater Bilby’ when referring to the species, or as bilbies or bilby when referring to individual animals. The Greater Bilby is of high spiritual importance to Indigenous people across its present and former range. This plan acknowledges this importance and the significant role Indigenous people play in the conservation of the Greater Bilby.

The Greater Bilby once occupied more than three quarters of Australia – almost all of the drier areas. Overall, the range of the Greater Bilby had been reduced by more than 80 % with bilbies occurring as wild populations now only found in the Northern Territory (NT), central and northern Western Australia (WA), and in small, isolated populations in Queensland (Qld). Bilbies have been reintroduced to islands and enclosures (managed as fenced wild populations) and are managed in zoos and wildlife parks.

More than 70 % of the distribution of bilbies that occur as wild populations are found on Indigenous lands managed by Indigenous people, including Traditional Owners and Indigenous rangers. Training and employment opportunities for Indigenous people, improved access to traditional lands, and maintenance of culture and traditional ecological knowledge are critical for bilby conservation.

Predation by and competition from introduced and feral species, habitat loss and degradation, population size reduction and fragmentation, and changed fire regimes, all continue to threaten the Greater Bilby’s long-term chances of survival in nature.

An adaptable and flexible management approach is required to deal with the interdependence and variability of threats across the species’ range and the uncertainty about the effectiveness of individual management actions. The potential for incremental loss of traditional ecological knowledge and management in these sparsely populated, harsh and isolated locations, places emphasis on the need to support local communities to implement and coordinate actions locally, whilst exchanging knowledge at regional and national scales. Increasing temperature and extreme weather events from climate change are likely to affect the operation of threats to recovery and potentially create new unforeseen threats.

This recovery plan is based on two key documents:

- *The Greater Bilby recovery summit 2015 report and interim conservation management plan* prepared by the Save the Bilby Fund and the Conservation Breeding Specialist Group of the IUCN. This report was a product of a four-day workshop in 2015, consisting of thirty-nine experts representing twenty-nine organisations involved in recovery of the Greater Bilby. This workshop reviewed the conservation activities that had been undertaken since the publication of the Recovery Plan for the Greater Bilby 2006–2011 (Pavey 2006).
- *What did we learn from the 2016 Ninu Festival?* prepared by Rachel Paltridge. This report was informed by a three-day workshop in 2016, of 125 Indigenous rangers from 10 Indigenous land management organisations and 22 other experts representing 18 partner organisations. A second complementary report, *Bilby is part of this country and for everybody, cultural report about bilbies and the Ninu Festival, Kiwirrkura, 2016* was produced by Fiona Walsh and Custodians of the Greater Bilby and focused on more of the cultural aspects of the Ninu Festival and explored the significance of bilbies to Traditional Owners.



Photo: Sally Napurula Butler with a bilby at the Alice Springs Desert Park, 2016 © Kiwirrkura IPA.

2.2 What is different about this plan?

This plan reflects changes in social, economic, and environmental context within which it was developed that have occurred since the previous recovery plan was adopted in 2007 (Pavey 2006).

Both the Conservation Measures Partnership and the International Union for the Conservation of Nature's Conservation Planning Specialist Group (CPSG) have progressively developed conservation planning systems focussed on achieving conservation outcomes through collaborative processes.

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Increasing collaboration was identified as the solution to poor plan uptake, and to increase the cohesion and effectiveness of conservation effort. Such planning systems place equal weight on having a structured and scientifically sound foundation, and on reflecting the aspirations, constraints and capacity of the conservation partners. Combined, this results in a plan that ‘belongs’ to the collaborative partners and is therefore more likely to be implemented.

Development of this plan was commenced at a collaborative workshop (the Greater Bilby National Summit, 2015) facilitated by the CPSG, initiated by the Save the Bilby Fund, and supported by many partners. In addition to the many existing partners, the recognition of the significant role of Indigenous people required a new approach to collaborative planning that provided an opportunity for all those involved in conserving the Greater Bilby to influence the content of the plan.

Indigenous ranger projects were first funded in 2007 through the Working on Country Program and created meaningful employment, training and career pathways for Aboriginal and Torres Strait Islander people in land and sea management. There are now more than 2100 full-time, part-time and casual Indigenous rangers, many of whose country is (or was) home to bilbies. The plan includes the actions and strategies that rangers and their communities identified as important for keeping country healthy for both bilbies and people and for maintaining knowledge and culture.

[A two-way science approach](#) – where both Indigenous and western scientific knowledge are equally valued – used in developing this plan promoted knowledge exchange between the hundreds of people involved in bilby conservation, research, and land and healthy country management. The plan harvested and collated the information, ideas, and priorities of those who have participated in the Greater Bilby National Recovery Team and its sub-committees, Indigenous rangers forums and workshops, the Ninu Festival, the National Greater Bilby Summit, and numerous other bilby-specific fora during the period within which the plan was developed. The willingness to share the results of these discussions characterises the spirit of collaboration that this plan intends to promote.

Since this plan was drafted, a number of Indigenous groups involved in bilby conservation have formed, whom have not been involved in the preparation of this plan and some existing groups, who were similarly not involved. It is expected further engagement of Indigenous groups in the conservation of the bilby will occur on a site by site basis, including in Qld. Because of this, the partners lists in the plan should be considered an incomplete list of Indigenous groups that could be involved in the future.

Box 1 Two-way science

A good way to define two-way science (also known as right-way or cross-cultural science) is through the **Western Desert principle of ngaparrtji ngaparrtji** (pronounced nap-art-jee nap-art-jee) meaning ‘give and take’, ‘in return’ or ‘you scratch my back and I’ll scratch yours’. For Martu, ngaparrtji ngaparrtji science is an exchange of knowledge and a chance to learn based on mutual respect, responsibility and connectedness. It is a collaborative approach based on recognition of the value that each group brings to a project and when all groups have a shared interest in the outcomes (draft Matuwa Kurrara Kurrara IPA Two-way Science Plan).

3 Background

3.1 Purpose

A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) aims to halt the decline and to support the recovery of species listed as threatened so that its chances of long-term survival in nature are maximised.

3.2 Cultural significance

The number of Indigenous names for the Greater Bilby highlights its importance for Indigenous people across Australia. The name Bilby is derived from the Ullaroi language name – Bilba (Paltridge 2016). There are at least another twenty names used across Australia. Having a name for an animal indicates that Indigenous people recognise it as distinct and means they have an understanding of its ecology, undertake management for the species, and/or incorporate it into their cultural stories, beliefs, and law. This knowledge, and a strong connection to the species, continues for Indigenous people, even in areas where bilbies are now locally extinct.

In 2016 the Kiwirrkurra Community (WA), on behalf of the Indigenous Desert Alliance, hosted a Ninu (bilby) Festival, recognising the importance of the knowledge and support from Indigenous rangers and Traditional Owners across the Greater Bilby's range. The Ninu Festival harnessed traditional and contemporary knowledge about the Greater Bilby and processes that threaten it to produce a framework for effective and collaborative management of wild bilby populations across Australia (Paltridge 2016).

This recovery plan contains many on-ground actions for implementation in Indigenous Protected Areas and other Indigenous-managed lands. In order to maximise their effectiveness, this plan embraces the themes of:

- Keeping the Tjukurrpa (Box 2) and cultural knowledge of the Greater Bilby alive and strong.
- Increasing community awareness of the Greater Bilby – locally and more broadly.
- Strengthening and expanding Indigenous ranger support and activities.
- Increasing management efforts.
- Mapping and monitoring bilbies, threats, and management effectiveness.

Ninu helps to connect people. Across Aboriginal Australia, people connect through family, language, country and Dreamings. 'Relatedness' is a central and valued concept among Indigenous groups. This relatedness includes people's relationships to each other, to animals and their songlines (Walsh 2016).

Box 2 Tjukurrpa

Tjukurrpa has many deep, complex meanings. Tjukurrpa refers to the creation period when Indigenous ancestral beings created the world. Tjukurrpa tells of the relationships between people, plants, animals and the physical features of the land. It is the past, present and future – all at the same time. Through the Tjukurrpa, bilbies of one place are related by Tjukurrpa to bilbies in another place and another place and so on along lines that cross the country. So custodians in one place can make connections to custodians in other places. They do this through their responsibilities to look after the sites, songs and stories for the animals. Sharing these animals and their stories helps to connect people over thousands of kilometres (Walsh 2016).



The number of Indigenous names for the Greater Bilby highlights its importance for Aboriginal people across Australia. The name Bilby is derived from the Ullaroi language name – Bilba (Paltridge 2016). There are at least another twenty names used across Australia, with many of these names represented in this word cloud.

This is also symbolic of the collaborative approach that was taken to help develop this recovery plan, with more than 21 community groups and individuals from all over Australia contributing their time, knowledge and resources to the development of this plan over many years.



Photo: Matuwa Kurrara Kurrara Ranger Lena Long with Bilby Burrow. Rangelands NRM © Chris Curnow.

3.3 Cultural status

The Greater Bilby is listed as vulnerable under the EPBC Act. The main factors that are the cause of the species being eligible for listing in the vulnerable category are that it is patchily distributed and has a small area of occupancy (reduced to 20 % of its former range (Southgate 1990)); the population size is estimated to be fewer than 10,000 mature individuals and it is undergoing continual decline (Woinarski et al. 2014).

International, national and state conservation status of the Greater Bilby

Legislation	Conservation status
<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Commonwealth)	vulnerable
<i>Biodiversity Conservation Act 2016</i> (New South Wales)	extinct
<i>Nature Conservation Act 1992</i> (Queensland)	endangered
<i>National Parks and Wildlife Act 1972</i> (South Australia)	vulnerable
<i>Territory Parks and Wildlife Conservation Act 1976</i> (Northern Territory)	vulnerable
<i>Biodiversity Conservation Act 2016</i> (Western Australia)	vulnerable
<i>IUCN Red List of Threatened Species</i> (2013, international)	endangered

3.4 The Greater Bilby National Recovery Team

The Greater Bilby National Recovery Team (hereafter referred to as the recovery team) provides advice and assistance in coordinating actions described in recovery plans. It includes representatives from organisations with a direct interest in the recovery of the species, including those involved in funding and those participating in actions that support the recovery of the species. Members are committed to the conservation of the species and the achievement of recovery objectives and implementation of recovery strategies.

The recovery team provides advice and assists in coordinating the implementation of the recovery actions outlined in this recovery plan. The membership of this recovery team and associated subcommittees draws from a wide variety of individuals and organisations relevant to the conservation of the Greater Bilby, such as the Department of Climate Change, Energy, the Environment and Water (Commonwealth) (DCCEEW), the Department of Biodiversity Conservation and Attractions (WA) (DBCA), the Department for Environment and Water (SA) (DEW), the Department of Environment and Science (Qld) (DES), the Department of Planning and Environment (NSW) (DPE), the Department of Environment, Parks and Water Security (NT) (DEPWS), Save the Bilby Fund (STBF), Indigenous rangers, Northern Land Council (NLC), Central Land Council (CLC), Kimberley Land Council (KLC) Desert Wildlife Services (DWS), Ecological Horizons (EH), Arid Recovery (AR), Rangelands NRM, Envisage Environmental Services, Southern Queensland Landscapes, Territory NRM, Australian Wildlife Conservancy (AWC), Bush Heritage Australia (BHA), Zoo and Aquarium Association (ZAA), independent researchers, zoos representatives, community groups and landholders. Membership of the Recovery Team changes over time to reflect its changing role and tasks as conservation progresses.

3.5 Species description and ecology

The Greater Bilby is endemic to Australia and is an iconic species to many Australians. With the extinction of the Lesser Bilby (*Macrotis leucura*) in the 1960s, it is the only surviving member of the family Thylacomyidae (Jackson & Groves 2015).

The Greater Bilby is a medium-sized burrowing marsupial with long, soft, blue-grey fur over most of the body but white to cream fur on its underside. It has large ears, a long, pointed snout with slit-like nostrils and a crested tail, white fur for the terminal half and black for the remainder. The forelimbs have three stoutly clawed toes that enable bilbies to burrow effectively, and two un-clawed toes. The hind limbs are slender and each has four toes.

Male bilbies can grow to 550 mm head-body length, with a tail up to 290 mm, and can reach a weight of 2500 g. Females are smaller and can grow to 390 mm head-body length with a tail up to 278 mm, and reach a weight of 1100 g (Johnson 2008). Breeding varies, depending on seasonal conditions and food availability, with litters mostly of one or two, but sometimes three (McCracken 1990). The gestation period is around 12–14 days. Pouch life is about 75–80 days, with females tending their young in a burrow for another two weeks (Southgate et al. 2005). Bilbies can live up to 11 years in captivity, however most animals are unlikely to survive that long in the wild (Southgate et al. 2005). Females start breeding at five months and males at eight months. Generation time is assumed to be less than two years (Southgate pers. comm. 2019) or four years (Woinarski et al. 2014).

Bilbies are omnivores that often dig for food, disturbing soil to a depth of 250 mm. Their diet consists of invertebrates such as larvae (including those of butterfly and moth), termites, ants, grasshoppers, spiders and beetles, and other items such as seeds, bulbs, and fungi (Burbidge et al. 1988; Gibson 2001; Navnith 2009; Southgate & Carthew 2006). Some of the key food resources (including food plants) are promoted by fire such as *Yakirra australiense* (Southgate 1990b; Southgate & Carthew 2006; Southgate & Carthew 2007; Southgate et al. 2007). Root-dwelling larvae are extracted from a wide range of plant species (Paltridge 2016; Southgate et al. 2018) some of which are intolerant of fire such as the curly-barked *Acacia doreta* (Vollies' *Minni Ritchi*).

Bilbies are highly mobile and can have large foraging ranges, although their home range in many areas is still unknown. Data from tracked wild animals in the Tanami showed that an adult female occasionally moved up to 1.5 km between burrows on consecutive days while an adult male used burrows that were 2.6 km apart (Southgate et al. 2007). At Watarrka National Park (NT) adult males were regularly recorded moving 2–3 km, and up to 5 km between burrows on consecutive days (Southgate et al. 2007). Movements of these distances are far greater than most other medium-sized mammals, including other bandicoots, indicating that bilbies are well adapted to the variability of resources in the arid regions (Southgate et al. 2007).

At Arid Recovery (SA) the mean female home range was 0.18 km² and the mean male home range was 3.16 km² over an 18 month period (Moseby & O'Donnell 2003). Bilbies have been recorded using up to 18 burrows concurrently over several months, and construct on average a new burrow every two and a half weeks (Moseby & O'Donnell 2003).

In Queensland, which has a different open-plains habitat to Western Australia and the Northern Territory, a study over a period of 4–6 weeks on unfenced populations of bilbies found the mean burrow range was 1.53 km² for males and 0.3 km² for females, and the mean home range was 5.11 km² for males and 2.03 km² for females (McRae 2004). The home range movement of bilby in some areas such as the Kimberley is not known.

Bilby burrows appear to be important refuges for a variety of other fauna such as goannas, echidnas and other small mammals (Read et al. 2008; Hofstede & Dziminski 2017).

3.5.1 Interactions with dingoes

Dingo and bilby distributions have overlapped for thousands of years. Dingoes are also known to take the bilby as prey, but have not been substantially linked with the decline of the species (Southgate 1990a; Southgate et al. 2007), with the exception of Queensland (Augusteyn et al. 2021) where wild canids (including Dingoes) have been identified as a potential threat. In contrast to their response to the threat of feral cat predation, bilbies show an innate antipredator response to the threat of dingo predation (Steindler et al. 2018) – noting that this may be lost without continued exposure to predators (Jolly et al. 2018).

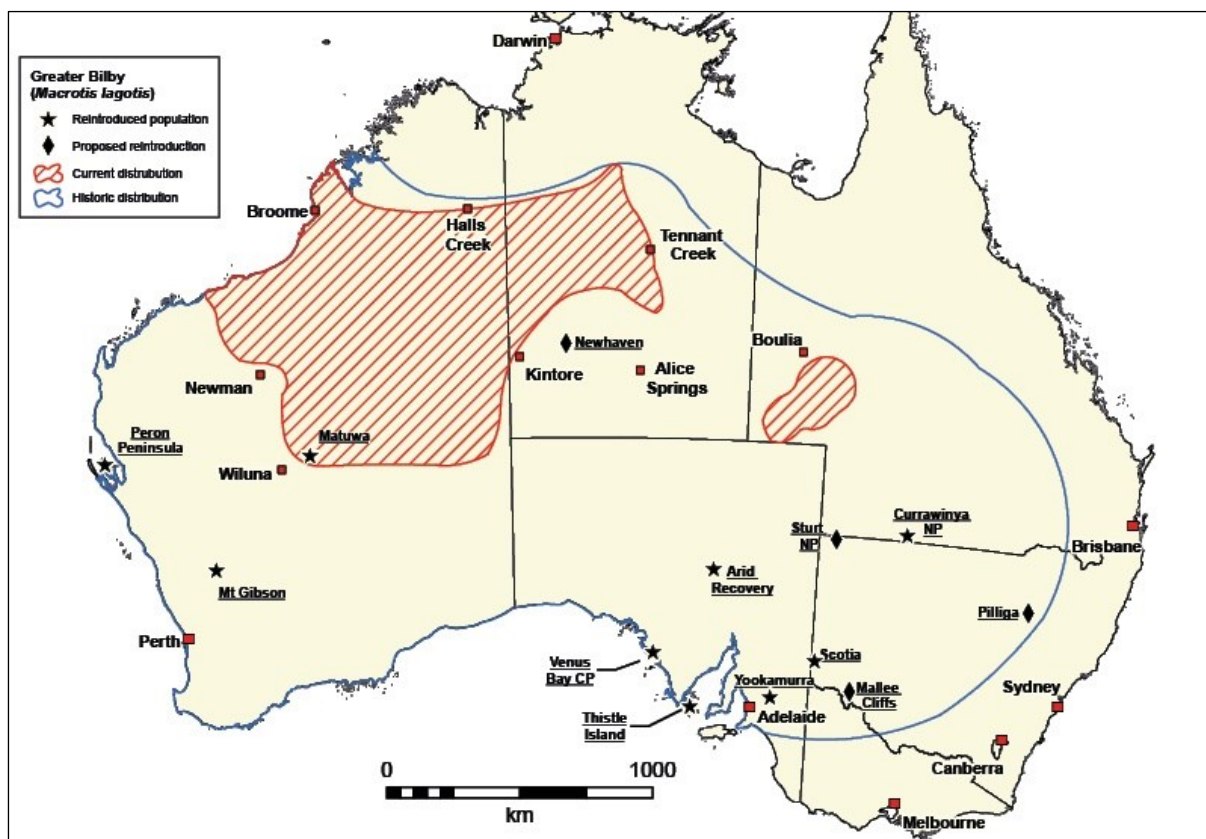
Bilbies and dingoes occur in similar environmental conditions, and the presence of dingoes may improve habitat suitability for bilbies by preying upon or displacing more effective predators such as the foxes and feral cats. The dingo is known as an important predator of feral cats in the Tanami and can possibly displace foxes (Southgate et al. 2007). At Astrebla Downs NP (Qld) feral cat remains were recorded in wild canid scats (Augusteyn et al. 2021) although it was noted that on one occasion wild canids were observed scavenging from piles of old cat carcasses. In arid areas dingoes have been

found to have positive effects on small mammals and negative effects on foxes (Letnic et al. 2009b, cited in Letnic et al. 2012). Kennedy et al. (2011) observed a negative correlation between dingo and cat activity in northern Australia, but noted the reason was less clear and may be due to cats avoiding areas where dingoes are present or due to cats being less abundant in areas where dingo density is high. However, one study in central Queensland concluded that there was no evidence that dingoes excluded feral cats (Fancourt et al. 2019). McRae (2004) reports that there is significant anecdotal but little scientific evidence that dingoes may exclude foxes from some areas, Saunders et al. (1995) suggests that dingoes may regulate fox density rather than their distribution under specific circumstances. Augusteyn et al. (2021) noted that in addition to interactions between predators, the impact wild canids have on a species may depend on how other threats interact.

3.6 Distribution

Before European settlement, bilbies occurred over 70 % of the Australian mainland, with fossil deposits suggesting a range that also included Rockhampton in Central Eastern Queensland (Hocknull 2005; Hocknull et al. 2017). Since the late 1800s, bilbies have disappeared from approximately 80 % of their former range (Southgate 1990a), contracting into the drier and less fertile areas of its former range (Gibson & Hume 2004).

The majority of remnant, naturally occurring populations of bilbies occur on Indigenous lands managed for a variety of purposes (Bradley et al. 2015). Due to threatening processes, the range of the Greater Bilby has contracted northwards and it is unclear if this contraction is continuing. Wild bilby occurrences are restricted predominantly to current distribution in Figure 1, or identified as sites in this plan (Johnson 2008; Greater Bilby National Recovery Team pers. comm. 2015).

Figure 1 Distribution of the Greater Bilby (*Macrotis lagotis*).

The estimated current distribution of the Greater Bilby is based on information from mapping undertaken by Indigenous rangers at the Ninu Festival in 2016, database records, and expert opinion elicited at the 2015 Bilby Summit. Future mapping of bilby distribution, particularly in the NT and WA, will incorporate Indigenous knowledge arising from on-ground management and monitoring works and records from other sources. Historic distribution has been adapted from Southgate (1990a).

Box 3 What is a bilby site?

Bilbies are mobile and move within the landscape according to resource availability, and as such the term 'site' is intended to encompass the area within which a population or related group of bilbies may range over generations. 'Bilby sites' and 'sites' includes all locations where it is possible that bilbies may persist, either naturally or as a result of being reintroduced, and includes fenced wild populations (discussed further in section 3.7). Sites may include locations or areas of Indigenous ranger activity named in this plan, locations of recent records, and locations where there is evidence of suitable habitat or bilby presence. At fenced sites, 'site' can refer to the area within or outside the fence, as both bilbies and management actions may occur within or external to the fenced area. A site can encompass an area in which a number of specific sites may be identified in the future. The terms 'bilby site' or 'site' does not refer to locations where individuals are captive managed (discussed further in section 3.7).

3.7 Types of bilby management

The Draft Greater Bilby Metapopulation Management Plan describes how the bilby metapopulation will be managed at three levels with each playing a different role in achieving the metapopulation goals:

- **captive management:** receives and intensively manages genetically valuable individuals and amplifies them for distribution to fenced-wild and wild sites; engages in education and advocacy.
- **fenced-wild management:** provides long-term or permanent sites supporting bilbies as part of the managed metapopulation; provides a source of individuals for dispersal to wild and to other fenced-wild sites.
- **wild management:** provides long-term or permanent sites supporting bilbies as part of the managed metapopulation; acts as a source of wild founders for the managed metapopulation; sites receive bilbies generated through the managed metapopulation to support viability.

In addition to the extant naturally occurring wild populations of the Greater Bilby, there are a number of bilbies that are either maintained in captivity, have been reintroduced behind fences, introduced onto islands, or have been reintroduced to the wild.

Such translocated populations persist because management negates or isolates them from threatening processes such as predation from introduced predators. Each of these populations faces challenges that may require specific actions and monitoring to measure and maintain population performance. For example, the effects of low founder numbers, the potential loss of adaptation of the Greater Bilby to introduced predators, or the selective pressure a fence, site habitat, or enclosure size may impose on a population.

There is a limited understanding of how some of these factors may influence population processes. For example, the long-term impacts of restricting bilbies wide-ranging and dispersing opportunities are unknown (Moseby & O'Donnell 2003). It is assumed that the Greater Bilby co-evolved with native predators such as monitors and large pythons (Skroblin et al. 2017), so bilbies are aware of native predators and have behaviours that minimise risk of predation by those predators. It is unclear whether predator awareness training can be effective against predators such as foxes and feral cats. Evolutionary isolation from foxes and feral cats may mean that the Greater Bilby's naivety of predation risk may not be overcome as a result of predator-awareness training. Because of variation in the duration that juvenile bilbies remain with their mothers, avoidance behaviours are more likely to be passed down to those juvenile bilbies that remain with the adult for long enough to learn from their mother (Moseby et al. 2012). Results from releases of bilbies from a fenced, fox- and feral cat-free, area have shown that juveniles succumbed to feral cat predation soon after pouch exit (Moseby et al. 2012; Steindler et al. 2018).

A trial reintroduction to unfenced areas of Watarrka NP resulted in a growth in bilby numbers for a short period of above average rainfall, following which they declined and became locally extinct, most likely due to predation from dingoes and feral cats (Southgate et al. 2000; Moseby & O'Donnell 2003). The reintroduction of bilby into the Main Enclosure of Arid Recovery Reserve in 2000 was considered successful based on short and medium-term success criteria (Moseby et al. 2011).

Because of such challenges, it is acknowledged that the management of these populations requires specific management to maintain carrying capacity, health and genetic diversity. Monitoring and research is required to measure effectiveness and adapt metapopulation management to ensure the best outcomes for the conservation of the species.

3.7.1 Captive management

Bilbies are held for captive breeding in a number of enclosures and zoos. These bilbies are usually provided with supplementary food and often managed as individuals, rather than as independent populations. Monarto Zoo (SA) and Dreamworld (Qld) coordinate bilby captive breeding under the guidance of the Zoo and Aquarium Association, which sets standards and practices for bilby husbandry, biosecurity, and genetic management under the auspices of the Australasian Species Management Program (ASMP). Involvement of other institutions such as Taronga Western Plain Zoo is coordinated under the Metapopulation Plan.

3.7.2 Fenced wild management

Reintroductions

Bilbies have been reintroduced to a number of large fenced enclosures across their former range. Enclosures of up to 262,000 hectares protect bilby from introduced and feral predators, allowing animals to range freely and are exposing them to a range of natural selection pressures.

The combined population size of reintroduced populations is estimated at 3000 individuals (pers. comm. Greater Bilby National Recovery Team 2021). These populations are important as they help restore ecological processes such as soil-turnover (for example James et al. 2009) and they ensure the bilby genome is exposed to selection pressures from a suite of environments across its former range (for example Weeks et al. 2015). These populations play an important role in building genetically robust and demographically stable sources of founders for reintroductions or supplementation.

Bilby reintroductions to fenced wild sites currently include Mallee Cliffs National Park (NSW), Arid Recovery Reserve near Roxby Downs (SA), Francois Peron National Park (WA), Scotia Sanctuary (western NSW), Yookamurra Sanctuary (SA), Mt Gibson Sanctuary (WA), Currawinya National Park (Qld), Pilliga State Conservation Area (NSW) Sturt National Park (NSW), and Newhaven Sanctuary (NT).

The long-term objective at some of these locations is reintroduction ‘outside the fence’, provided threatening processes (in particular, introduced and feral predators) can be sufficiently reduced, and provided that antipredator behaviours can be maintained in fenced wild populations (Jolly et al. 2018; Ross et al. 2019).

Introductions

Captive bred bilbies were introduced to Thistle Island (SA) in 1997, a location that they did not historically occupy. Surveys undertaken on the island a decade after their release indicated that the population size had increased and occupied the entire island (Berris et al. 2019).



Photo: Christine Ellis, Australian Wildlife Conservancy Land Management Officer, with students from Nyirripi School release a Bilby into Newhaven Wildlife Sanctuary © Australian Wildlife Conservancy.



Photo: Cassandra Arkininstall and Save the Bilby CEO Kevin Bradley releasing captive-bred bilbies into Currawinya National Park in 2019 © Cassandra Arkininstall.

3.7.3 Wild management

Bilbies have been reintroduced at Matuwa (WA) into a 2,500 km² intensively managed area. This area has been collaboratively managed by DBCA and Martu Indigenous Rangers for fire and feral cats (*Felis catus*) (annual Eradicator baiting and trapping since 2004) and has been fenced to exclude domestic stock and camels since 2000. Between 2007 and 2009, 128 bilbies were reintroduced, and bilbies have since spread throughout most of the intensively managed area and has also colonised adjacent areas.

Bilbies were reintroduced to an unfenced 'Wild West Zone' adjacent to Arid Recovery Reserve in 2004 and 2007. Predators such as cats and foxes were present in this zone but their numbers controlled through baiting. While some short-term success criteria were met, none of the medium-term success criteria were met due to mortality attributed to fox and feral cat predation (Moseby et al. 2011).

As noted throughout this plan, there are many locations where the Greater Bilby persist as wild non-translocated populations. Each of these is subject to own set of specific challenges and management opportunities that places them at risk.

3.8 Important populations and populations under particular pressure

The former distribution of the Greater Bilby was effectively continuous across its former range (Abbott 2001) where suitable habitat was present, and molecular DNA analysis does not show strong genetic structure indicating that there is a single 'evolutionary significant unit' (Southgate & Adams 1993; Moritz et al. 1997). The Greater Bilby is considered a single population even though fragmentation and isolation may have resulted in local adaptation. Managing the Greater Bilby as a single genetic unit is likely to maximise conservation outcomes for the Greater Bilby (Bradley et al. 2015). The Greater Bilby largely now occurs as small groups which are fragments of the former distribution across which gene flow occurred. Each of these groups is important and under pressure.

As the Greater Bilby is intended to be managed as a metapopulation, the local cultural significance of each occurrence, and the lack of information of population structure, the concept of 'important populations' (where one occurrence of the Greater Bilby is deemed to be of more value than another) is not relevant to the overall conservation of the Greater Bilby. However, this does not preclude particular populations being considered more important for the purpose of meeting specific conservation objectives or being identified as priorities for investment by individual conservation managers. A metapopulation is a group of populations that are separated by space but consist of the same species. These spatially separated populations interact as individual members move from one population to another, noting that movement between fenced populations or isolated or widely separated populations will require translocation - human assisted movement - of bilbies.

3.9 Habitat summary

The information presented here is a small subset of the extensive information available on the habitat of the Greater Bilby. It is provided as an introductory summary for those unfamiliar with the species. For a fuller understanding of bilbies habitat, please refer to both the published literature and consult those with expertise in the species, including Indigenous experts.

Historically, bilbies occurred in a wide range of climatic zones, soil, vegetation types, and landforms across much of Australia. Vegetation types used by bilbies included eucalypt open forest and woodland in south-western WA; the South Western Slopes bioregion and the Southern Tablelands of NSW (Fleming pers. comm.); around Adelaide, SA; tall shrublands and open woodlands in semi-arid regions; and hummock grasslands across arid Australia (Abbott 2001; Southgate 1990b). The habitats used by the remaining wild bilbies vary between both sites and regions in which bilbies persist. They now occupy a range of habitats including: open tussock grassland on uplands and hills; mulga (*Acacia aneura sens. lat.*) woodland/shrubland growing on ridges and rises; and hummock grassland on plains and in alluvial areas (Woinarski et al. 2014, Skroblin et al. 2017). Bilby distribution is limited by the availability of soils suitable for burrowing, such as sandy areas, where burrow excavation is easier (Southgate 1990b; Moseby & O'Donnell 2003).

Habitats in the central desert area include salt lake margins (especially those supporting Bush onion (*Cyperus bulbosus*), areas with laterite (concreted, iron-rich rock layers), areas of rock features, and sandplains dominated by spinifex or mulga (Southgate et al. 2007; Paltridge 2016). In the Tanami Desert, bilby occurrence is strongly associated with substrate type (less abundant on dune and sand substrates than on laterite/rock features or drainage/calcrete substrates), and the positively associated with mean annual rainfall and dingo presence (*Canus lupis dingo*) (Southgate et al. 2007; Paltridge 2016).

The lateritic habitats can support shrub species such as *Acacia kempeana*, *A. hilliana* and *A. rhodophylla*, which have root-dwelling larvae (Southgate et al. 2007; Southgate et al. 2018) that provide a relatively reliable food source for bilbies. These lateritic rises also support patchy spinifex (*Triodia* spp) hummocks that provide runways between hummocks, potentially enabling easier movement and foraging (Southgate et al. 2007).

In the northern part of its range, bilbies persist in areas of habitat that have higher levels of plant cover and therefore food production. Habitat types in these areas comprise closed coastal tussock grasslands and *Acacia bivenosa* shrublands, *Acacia* dominated woodland, shrubland and thickets on pindan sandplain, comprising species such as *A. eriopoda*, *A. monticola*, *A. stellaticeps* and *A. tumida*. Bilbies may have persisted in the most northern parts of these areas because of fewer foxes (*Vulpes vulpes*) (Southgate et al. 2007).

In the north of WA, suitable habitat for the bilby includes: woodlands (<10 m) with *Eucalyptus* and *Acacia* spp., Pindan woodlands with hummock and tussock grass, on coarse sand to light medium clay; low shrub cover of *Acacia* spp. over hummock and tussock grasses, on sandy soils, loams and red earth; spinifex grasslands with low shrub cover of *Acacia* and *Melaleuca* spp. on sandy and sandy loam soils (Cramer et al. 2016).

Greater Bilby habitat in Queensland is open clayey and stony plains that often have less than 10 % ground cover, with the dominant vegetation being chenopods and grasses (McRae 2004). A survey in western Queensland in 2018 found signs of bilbies in dune fields, a land type that was previously only historically occupied by bilbies in Queensland (Southgate pers. comm. 2019).

Fire, at least in part due to its influence on the type and availability of food resources and exposure to predators, may play a role in improving habitat favourability for bilbies in parts of the Greater Bilby's range. This is demonstrated in areas of the Tanami Desert (Southgate et al. (2007)) where

bilby occurrence was associated with the close proximity to recently burnt habitat and areas with high fire heterogeneity.



Photo: Bilby diggings and habitat at Diamantina National Park, Qld © Simon Nally 2018.

3.10 Habitat critical to survival

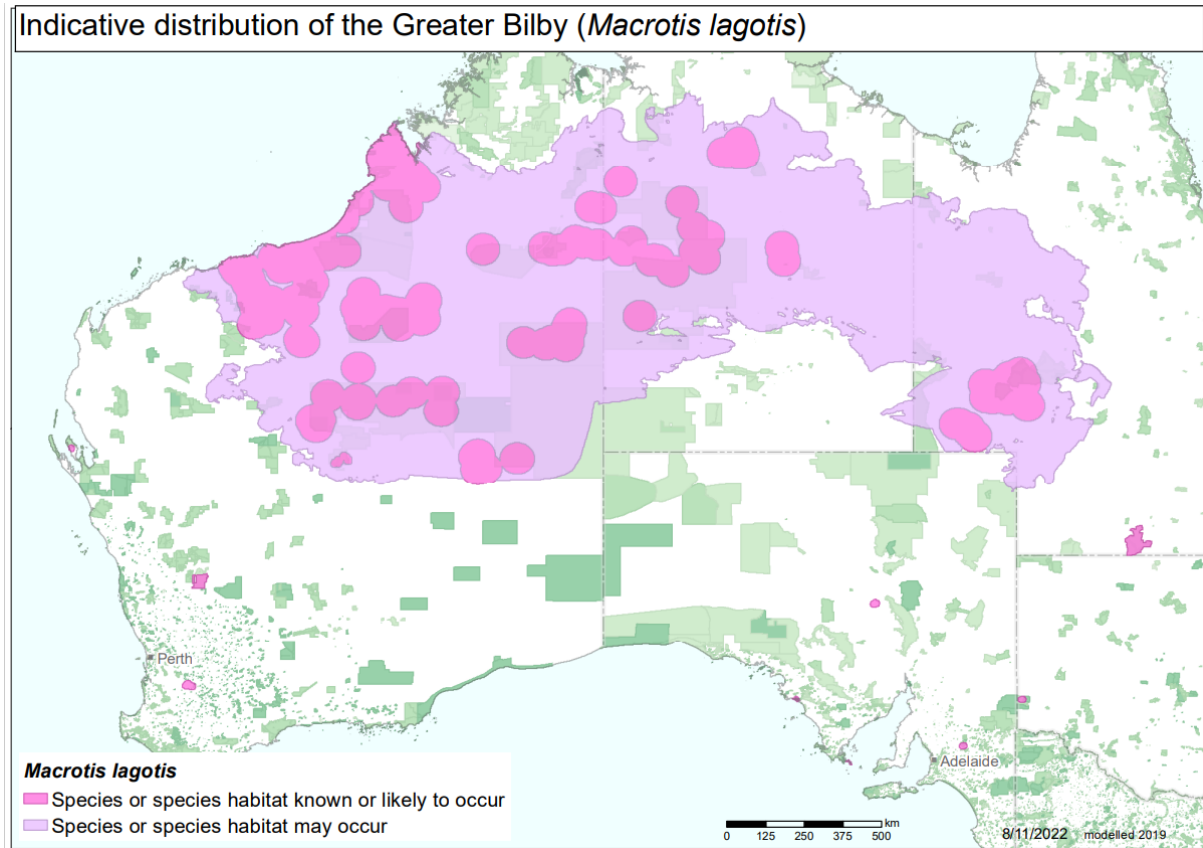
The habitat, or biophysical environment, of the Greater Bilby varies across its range (see section 3.9), so it is not possible to generate one description or definition of habitat critical to survival. The habitat critical to the survival of the Greater Bilby may be more usefully defined at a bioregional scale that describes the combination of plants, animals, geology, landforms, and climate that is relevant to a geographical unit. However, any categorisation of habitat critical to survival must acknowledge that it exists as a continuum, with carrying capacity fluctuating with seasonal or episodic food availability and effects of threats. A set of comprehensive habitat descriptions to define habitat critical to survival was unavailable at the time of drafting this plan.

As an interim guide, habitat critical to the survival of the Greater Bilby can be considered to include:

- Any area where the species is known or likely to occur as shown on the distribution map on the [greater bilby SPRAT profile](#). Figure 2 is indicative of these areas at the time of publication, but should not be relied upon.
- Any location outside the known or likely distribution where bilbies are found to occur.
- Any area, between the areas noted above, that may be periodically occupied by bilbies.
- Any area which bilbies may naturally colonise or may feasibly be reintroduced.

Habitat critical to the survival of the species occurs in a wide range of tenures and land ownership arrangements, including on Indigenous owned or managed land, private land and leaseholds, travelling stock routes, unallocated crown land, national parks and nature conservation reserves, and other lands managed for conservation.

Figure 2 The modelled current distribution of the Greater Bilby (*Macrotis lagotis*).



Note: The distribution shown is generalised from the Department's *Species of National Environmental Significance* dataset. This is an indicative map of the present distribution at time of publication and is currently under review. Modelling is based on observation data from the period 2007-2018.

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.



Photo: Birdsville Bilby survey site sand dune © Save the Bilby Fund Kevin Bradley 2018.



Photo: Senior Ranger Rita Cutter pointing out a bilby burrow on Birriliburu country in the Little Sandy Desert, WA © Vanessa Westcott.



Photo: Albert Wiggan pointing out a bilby burrow on Nyul Nyul country in the Kimberley, WA © Vanessa Westcott.

3.11 Climate change

Predicted changes to climate are likely to affect the distribution and recovery of the Greater Bilby. Climate modelling (CSIRO & BOM 2020) indicates that there is a very high confidence in increased mean, maximum and minimum temperatures, including an increase in days and spells of high temperature across the Greater Bilby's current and former distribution.

For the majority of the Greater Bilby's current distribution, changes to summer rainfall cannot be confidently projected, but in the southern part of its distribution there is a high confidence that winter rainfall will decrease. There is high confidence in an increase in the intensity of extreme rainfall events, and a medium confidence in an increase in the period of drought.

Climate change predictions (CSIRO & BOM 2020) show that for the majority of the Greater Bilby's current distribution (except areas affected by monsoonal weather) bushfire depends highly on fuel availability, which mainly depends on rainfall. A tendency toward increased fire weather risk is expected in future, due to higher temperature and lower rainfall, but there is low confidence in the magnitude of fire weather projections. For Greater Bilby occurrences in areas influenced by monsoonal weather, changes to future rainfall will be the determining factor of change to fire frequency. When fire does occur, there is a high confidence that fire behaviour will be more extreme.

The effects of climate change on the Greater Bilby may be direct; for example, as a result of changes to food sources and habitat suitability, as well as indirect; for example, a change in the behaviour of competing herbivores and predators as they adapt or respond to the effects of climate change.

While addressing the causes of climate change is not within the scope of this plan, it is important to anticipate changes to the ecology of bilbies and species that compete or predate on bilby and implement conservation actions in a way that reflect the predicted changes to climate.

4 Recovery objectives

The Greater Bilby Recovery Summit 2015 Report and Interim Conservation Management Plan (the interim plan) (Bradley et al. 2015) included the following vision:

VISION

‘In 2040, the Greater Bilby and its cultural and spiritual significance to Traditional Owners is valued and embraced by all Australians and by the global community. Together we engage through effective partnerships providing legislative, management and stewardship frameworks that support a secure, viable and self-sustaining population of bilbies in the wild, across an extended range.’

This vision, the goals and outcomes of the interim plan and the findings of the 2016 Ninu Festival (Paltridge 2016) have been used to frame the objectives, strategies and actions in this recovery plan. The objectives and actions included in this plan also represent a continuation and extension of the conservation framework laid out in the preceding recovery plan (Pavey 2006).

More than 70 % of the distribution of naturally occurring wild bilbies are found on Indigenous-managed lands. Training and employment opportunities for Indigenous people, access to traditional lands, and maintenance of culture and ecological knowledge are critical for the conservation of wild bilby populations.

4.1 Objectives and performance criteria

The EPBC Act requires a recovery plan to provide for the research and management actions necessary to stop the decline and support the recovery of the Greater Bilby so that its chances of long-term survival in nature are maximised. The chances of long-term survival in nature are affected by:

- the levels of mortality; longevity, and rate of reproduction
- the extent and quality of habitat, and
- the size of and connectivity between populations.

These parameters are influenced by threatening processes and affect the Greater Bilby’s ability to be resilient to stochastic events and threatening processes.

This plan is designed to operate for ten years. The ecological priorities within this period are to increase the population size and extent, prevent local extinction, and to maintain genetic diversity. The social priority is to increase the involvement of Indigenous people in bilby conservation.

The objectives describe the state of the species and the level of involvement of Indigenous people in 2030.

Objective 1: The size of the Greater Bilby population has grown.

Performance criterion 1: In 2030, an index of abundance derived from a sample of sites indicates population growth compared to 2020. Parameters such as sample site representativeness, survey frequency, and whether site data is indicative of absolute or relative bilby abundance will be considered by the recovery team.

This objective focuses effort to reversing the suspected recent trend of decline. By increasing the Greater Bilby population, it becomes more resilient and the species is at lower risk of extinction.

Objective 2: The extent of occurrence and area of occupancy of the Greater Bilby has been maintained or increased.

Performance criterion 2(a): In 2030, the combined area of occupancy of the Greater Bilby across a set of sample sites has been maintained or increased. To be calculated through resurvey of previously sampled sites including; Sangsters Bore (NT), Matuwa (WA), Warburton (WA), Kiwirrkurra (WA), Astrebla Downs (Qld), Katjarra (WA) and any other representative site identified by the recovery partners.

Performance criterion 2(b): In 2030, the extent of occurrence of the Greater Bilby has been maintained or increased since 2020. To be calculated through the collation of presence-only and presence-absence data.

This objective focuses effort to preventing any trend of progressive local extinction, or any incremental reduction in the extent of habitat occupied, both of which reduce resilience and increase the chances of extinction.

Objective 3: The genetic diversity of the Greater Bilby has been maintained and retains the potential for evolutionary change through adaptation and selection.

Performance criterion 3: In 2030, genetic diversity is estimated to be equivalent to that present in 2020. The measure is to be defined by the recovery team.

This objective focuses effort to maintaining the evolutionary potential and resilience of the Greater Bilby.

Objective 4: Indigenous organisations, communities, and individuals have a greater role in bilby conservation.

Performance criterion 4: In 2030, there has been an increase in the number and locations of Indigenous people who are actively engaged in Greater Bilby recovery, from leadership and agenda setting to on-ground works.

This objective acknowledges the critical role of Indigenous people and their land in the conservation of the Greater Bilby at many locations.

Sites used for performance measurement are expected to be a combination of opportunistic and selected sites based on the priorities and capacity of recovery partners. The recovery partners will identify potential sites and associated data that may be available for performance reporting by the recovery team.

The Commonwealth and state and territory governments, and the recovery team will be involved in evaluating the performance of the recovery plan.

5 Threats

This section describes the known and potential threats that affect the achievement of the recovery objectives. Threat prevalence and intensity vary across the range of the Greater Bilby. Members of the recovery team (pers. comm. 2015) have identified some of these variations:

- In the absence of traditional burning practices, fires in the monsoonal Kimberley occur as smaller frequent wildfires in early summer, compared to the Pilbara and deserts of WA and NT where comparatively infrequent episodic late summer wildfires risk burning extensive areas of habitat, and both represent threats to habitat quality due to a reduction in the patchiness or heterogeneity of habitat distribution, age, and structure. Fire size, frequency, intensity, and extent varies according to climate, and biogeography.
- Where established, foxes have eliminated and constrain the re-establishment of bilbies. In areas where foxes are not well established, predation by feral cats remains a significant risk to persistence and re-establishment. Wild canids (dogs), under some circumstances, may also present a risk to the persistence of bilbies. The distribution and effect of introduced predators varies with historical and current land-use, water availability, climate, and biogeography.
- The risk of habitat loss or fragmentation from activities such as agriculture or mining related land use, varies with development pressure, weed and pest species, geology, biogeography, and climate.

There is significant interaction between threats. For example, livestock grazing can negate the benefits of fire management for small mammals in Australian tropical savannas (Legge et al. 2019). Fire and grazing can reduce the height and size of vegetation allowing predators to catch prey more easily (McGregor et al. 2015). After extensive fires vast areas of homogeneous regrowth following extensive wildfire may limit foraging, dispersal and re-colonisation by bilbies (Bradley et al. 2015).

This plan includes governance and monitoring actions that aim to minimise the risk of inappropriate conservation actions, rather than identify such activities as a potential threat. Consideration of any possible perverse outcomes from management actions is outside the scope of this plan, but may be considered by the recovery team, governments and land managers when planning and monitoring actions.

5.1 Predation by foxes and feral cats

Evidence suggests that foxes may have had the single largest negative effect on the conservation of the Greater Bilby (Abbott 2001). Fox predation is a major cause of mammal extinction and decline in Australia (Kinnear et al. 2002), and the presence of foxes is negatively correlated with the presence of bilbies (Southgate 1990a). Foxes are established and more common in the southern part of the Greater Bilby's former range where they exerted more predation pressure than in the central and northern part of the Greater Bilby's range. An abundance of rabbits (*Oryctolagus cuniculus*) leads to elevated predator densities and consequential increased predation of bilbies and rabbits are largely restricted to the southern part of the Greater Bilby's current distribution (Southgate 1990a; Cox et al. 2013). The early spread and establishment of foxes was closely linked to the spread of rabbits (Saunders et al. 1995). Bilbies may have persisted in the most northern parts of its range because of fewer foxes (*Vulpes vulpes*) (Southgate et al. 2007).

It is not known whether the fox is continuing to expand its range north and west in the NT and WA, or whether expansion and contraction of the range of foxes is solely due to seasonal and climatic fluctuations (Saunders et al. 1995).

Feral cat predation is another major factor associated with the decline of bilbies. With less than 200 years of evolutionary exposure to feral cats, bilbies do not seem to have developed innate antipredator behaviours in response to the threat of feral cat predation (Steindler et al. 2018). The range of the feral cat overlaps with that of the current range of the Greater Bilby and has done for some time, so it is unlikely that the feral cats alone are responsible for the decline of the Greater Bilby across its range (Southgate 1990a).

At some locations and following particular seasonal conditions, feral cats can significantly limit and, at times, cause local extinction of bilbies. Predation by feral cats has been recorded at Dryandra (WA), Arid Recovery (SA), Matuwa/Kurrara Kurrara Indigenous Protected Area (ex Lorna Glen and Earraheedy pastoral leases) (WA) (Morris pers. comm., cited in Woinarski et al. 2014), Venus Bay (SA) and in the Tanami Desert (Tennant Creek and Kintore (NT)) (Paltridge 2002). Predation by feral cats can be severe in Qld (McRae pers. comm., cited in Woinarski et al. 2014) and requires ongoing feral cat control on Astrebla Downs and Diamantina National Parks (Qld) (Rich et al. 2014). Feral cats have led to the failure of bilby reintroductions outside fenced enclosures (Moseby et al. 2011) and within the enclosure at Currawinya National Park (Qld) when the perimeter fence deteriorated and feral cats entered the enclosure. At Arid Recovery (WA), bilbies exposed to low densities of feral cats over an extended period exhibited behavioural changes that increased their chance of survival (Ross et al. 2019). However, it is assumed that feral cat predation is likely at most locations, and along with fox predation may be the key impediments to reintroduction at many sites.

Artificial watering points for domestic livestock may contribute to the expansion in the range of introduced predator such as fox (James et al. 1999; Davies et al. 2010), however fox may also avoid water points when dingoes are present (Brawata & Neeman 2011).

5.2 Predation by wild canids in Queensland

In western Queensland, wild canids (dingoes, wild dogs (*Canis familiaris*), and their hybrids) are known to predate on bilbies and may potentially threaten bilby population resilience at Astrebla Downs National Park (Augusteyn et al. 2021). A study at Astrebla Downs NP (Qld) between 2012 and 2019 (Augusteyn et al. 2021) showed that of 723 canid scats collected over the period, on average 43 % of the scats contained bilby remains of an average 84 % volume. There was considerable variation across years and seasons with the frequency of occurrence of bilby remains in canid scats ranging from 13 to 85 % and volume ranging from 20 to 100 %.

5.3 Habitat loss, degradation and fragmentation

Land clearing leads to loss of habitat, degradation of surrounding habitat, increased predation and fragmentation effects (Bradley et al. 2015). Bilbies did not persist in unfragmented landscapes such as those found in western Victoria (Abbott 2001), so even in largely unfragmented landscapes extinction debt due to stochastic loss of small populations (for example groups of bilbies) results in delayed extirpation (Loehle & Li 1996).

Roads, rail lines fences, dams, mines and associated camps, pipelines and other industrial structures, agriculture, and settlements may threaten bilbies through vegetation clearance, increased risk of road kill, creating barriers to dispersal and gene flow, and elevated predator densities resulting from increases in food and water resources (Bradley et al. 2015). The development of large-scale pivot irrigation agriculture in the Pilbara and Kimberley in the WA, and areas of central NT, may contribute to these effects.

The construction of and upgrading of roads in areas where road access has previously been limited is likely to increase the threat of mortality or injury of bilbies on roads. There are areas in the north Pilbara and Kimberley where numerous road mortalities of bilbies have been reported over the last decade, with medium to longer term impacts on bilbies unknown.

Buffel grass (*Cenchrus ciliaris*) and couch grass (*Cynodon dactylon*) have been recorded in bilby habitat. Sandy soils are preferred by buffel grass in Central Australia (DENR) where it presents a threat to affected habitat by changing fire intensity and regimes, altering vegetation composition and demography (Clarke et al. 2005) and by competing with bilby food plants (PWCNT 1998). Other unspecified weeds have also been reported from bilby sites in WA and the NT.

5.4 Domestic and other introduced species

Bilby distribution is associated with an absence or low density of rabbits and low domestic herbivore stocking rates (Southgate 1990a; McDonald et al. 2015). Introduced herbivores degrade habitat by removing vegetation cover and cause soil compaction and erosion, effects that are greater closer to water points. Water points also alter the dynamics of native herbivores which can also impact vegetation and predator dynamics (James et al. 1999).

Herbivores also congregate along drainage lines, which are often inhabited by bilbies in the Pilbara, Great Sandy and Tanami Deserts (Bradley et al. 2015). Rabbits and bilbies share important food plants, such as bush onion, and rabbits support higher densities of feral cats, wild canids (including dogs) and foxes. It is also assumed that rabbits take over and exclude bilbies from burrows (Paltridge 2016).

At NT and WA locations, trampling and herbivory from donkeys (*Equus asinus*), horses (*Equus caballus*), and camels (*Camelus* spp.) is assumed to be degrading habitat. While there is no published information on the adverse impacts caused by these species on bilbies, the earliest decline of bilbies in Qld occurred in the more intensively grazed landscapes. Cattle trampling also affects bilby burrows, sometimes causing their collapse (Bradley pers. comm. 2016). Trampling and grazing is particularly damaging in areas where vegetation is regenerating in the first year after fire and there is naturally low vegetation cover and fragile soils.

Domestic cattle stocking rates and herd sizes in northern Australia have increased (Thompson & Martin 2014), and more watering points have spread grazing pressure across larger areas (Walsh & Cowley 2016). Cattle breeds more suitable to northern Australia were introduced to provide greater economic returns from cattle grazing (Thompson & Martin 2014) Between 2009–10 and 2011–12 cattle stocking rates on farms producing beef in northern Australia were the highest in 20 years (Thompson & Martin 2014). The expansion and intensification of agriculture and cattle grazing within the Kimberley in WA, where there is a trend for clearing of land for irrigated agriculture and irrigated cattle fodder production, is likely to affect bilbies.

As the cane toad (*Rhinella marina*) progressively invades the Kimberley from the east, it is likely to invade some areas used by bilbies. If this occurs, there is the potential that bilbies will consume toadlets and/or toads. Although not identified as a specific threat, actions are included to detect and monitor adverse effects from the presence of the cane toad.

5.5 Unmanaged fire and inappropriate fire regimes

The relationship between the Greater Bilby and fire over much of its range is complex, and the absence of active fire management or the prevailing fire regime of an area can determine its suitability as habitat for bilbies. Fire can promote the growth of bilby food plants, can influence vegetation density by making it more, or less, suitable for bilbies, and may influence predator behaviour and predation. However, for wild populations of the Bilby in Queensland, fire is not considered a threat (Page pers. comm. 2019). Bilby habitats, such as those in Astrebla Downs National Park are unlikely to carry fire due to low fuel loads occurring during fire seasons (NPRSR 2013). Fires started by natural events (for example lightning strikes) are unlikely to burn large areas and are likely to naturally extinguish. This is likely to create a natural burn mosaic.

Bilbies responded well to fires in the central and northern Tanami (NT), where fire is frequent, due to regeneration of major food plants (Southgate & Carthew 2006; Southgate & Carthew 2007). Similarly, bilbies have persisted in areas around Indigenous communities where a traditional fine-scale mosaic of smaller and less intense fires prevails (Paltridge pers. comm. 2016). Although some food plants used by the bilby are promoted by fire, fire can also destroy shrubs that can harbour root-dwelling larvae, an important food source.

Short-term changes to vegetation structure, such as that immediately after an intense fire, and long-term changes in vegetation structure from increases or decreases in fire interval may influence habitat suitability. For example, regrowth in extensively burnt areas can become increasingly impenetrable and unsuitable for medium-sized species like the Greater Bilby (Southgate pers. comm. 2016). Vegetation structure may also influence predation pressure on bilbies. In the Kimberley, intense fires created conditions that are favoured by cats, probably because their hunting success is

improved (McGregor et al. 2014). Removal of ground cover from intense fires in savannah resulted in increased predator activity where small mammals were left more exposed to predation and there was an increase in mortality from predation (Leahy et al. 2016).

Fire weather risk is difficult to predict over much of the Greater Bilby's range (CSIRO & BOM 2020) however for areas influenced by monsoonal weather fire behaviour will be more extreme.

Planting and invasion of habitat by buffel grass is believed to be a significant threat to habitat by changing fire intensity and regimes (DotE 2015), affecting food availability, structural suitability, predator behaviour, and susceptibility to predation.

In pre-colonial times evidence suggests that the use of fire was primarily intensive, controlled and focussed, while the transition to European fire regimes has resulted in more widespread fires. During this transition, the size of fires across the spinifex-dominated deserts of central and western Australia have increased. The effect of increased fire size in the spinifex deserts and trend towards landscape fire age homogeneity is linked with the broad decrease in desert biodiversity (Catt 2013). Where there was consistent use of fire, associated with indigenous occupation of country, maintained pyro-diversity and buffered landscapes against severe wildfire impacts. The size of fires continues to increase, with one fire in the Great Sandy Desert in 2017 reaching approximately 3.8 million hectares (Gareth Catt pers. comm. 2020).

Fire regimes that cause biodiversity decline has been nominated as a key threatening process under the EPBC Act (DAWE 2020). In the context of predation from foxes and feral cats, altered fire regimes and reduction in pyro-diversity are a threat to the Greater Bilby.

5.6 Loss of Traditional Owner knowledge and land management

The majority of wild bilby occurrences in the NT and WA are on Indigenous-managed lands (Walsh and Custodians of the Bilby 2016; Bradley et al. 2015). The application of traditional ecological knowledge by Indigenous people managing their country, particularly fire, may influence the local persistence of bilbies. Loss of this knowledge, or reduction in traditional management, may therefore contribute to the local extinction of bilbies and management actions have the potential to be less effective if this local and traditional knowledge is not incorporated.

Indigenous people who have both experience of local environmental conditions and traditional ecological knowledge of bilbies also have capacity for research and management and can inform management actions to make them more locally effective. It is therefore critical to the conservation of the Greater Bilby that plans, policies and programs encourage the inter-generational retention of traditional ecological knowledge and facilitate increased land management by Indigenous people.



Photo: Bilby footprints © Rick Southgate 2018.

5.7 Reduction in population resilience and genetic fitness in wild and intensively managed populations

A species whose population size is small and fragmented is more susceptible to extinction than a species whose population size is large and inter-connected. This elevated extinction risk is the result of several different factors:

- Small populations are more susceptible to chance events that can cause local extinction, which cumulatively can result in species extinction. They are also less resilient to fluctuation in death and reproduction rates.
- Small populations can have low genetic diversity and are subject to progressive loss of genetic diversity. Less genetic diversity reduces opportunities for evolutionary adaptation and ability to adapt to changes in the environment.
- A large population that consists of small isolated sub-populations that do not exchange genes is similarly subject to the loss of genetic diversity and its potential consequences.

The factors can combine or operate in isolation to result in an extinction vortex, where the factors reinforce themselves and accelerate a spiral into extinction.

Human-mediated threats have combined to eliminate bilbies over large areas and in other areas to create fragmented or isolated sub-populations, sometimes of unviable size, and likely to contain only a subset of previous genetic diversity. Such sub-populations are less resilient to threats and have a low capacity to adapt and respond to change.

The factors apply to captive, fenced wild and wild populations, but their effect is influenced by the specific circumstances and the nature of management actions. There are a substantial number of

bilbies in reintroduced populations and in captive-breeding facilities. These populations vary in their exposure to the pressures of natural selection processes such as predation. Populations on islands or in large fenced areas are protected from fox and feral cat predation, but are otherwise free-living (in other words reliant on their own foraging for survival, exposed to a range of native predators and other environmental stresses); populations in captive breeding facilities are usually protected from predators and environmental extremes, and provided with food and water. Management of these populations includes activities aimed at maintaining genetic diversity (including management of overabundance and assisting long-term gene flow) and adaptive potential (Hayward et al. 2014).

5.8 Disease

Disease has not been recorded as a threatening process for this species, however disease is identified as a potential obstacle to the recovery of the Greater Bilby (Bradley et al. 2015). Monitoring for disease can be undertaken during normal health checks and when bilby are handled and is required to ensure early disease detection. If disease is detected relevant state and territory protocols and standard operating procedures should be followed. In addition, [Wildlife Health Australia](#) maintains an updated contact list for reporting unusual wildlife disease events in each state and territory.



Photo: Zecharia Spencer conducting traditional burning on the Kiwirrkurra IPA © Kiwirrkurra IPA.

6 Strategies and actions

The recovery of the Greater Bilby requires on-ground (or direct) strategies to minimise or compensate for the threats to the objectives (Section 5). Supporting strategies provide for governance to coordinate actions and make the best use of available resources, including assistance to Indigenous and other land managers such as graziers, pastoralists and mining companies. Supporting strategies also provide for research to improve the effectiveness of actions, monitoring and survey methods, data analysis and reporting, so that progress can be consistently measured and management actions adapted.

A strategy outlines the way a threat to the objectives, or set of related threats, will be eliminated, reduced, or compensated for. A strategy can also be considered a sub-plan that groups related actions together. Actions describe what will be done, and to the extent practicable, where it will be done and by whom.

Strategies and actions in this plan have been identified on the basis of:

- Effect on objectives – it is believed that if an action is implemented, it will contribute to achieving the objectives either directly, or indirectly by reducing the effects of a threat to recovery.
- Feasibility – it is believed that partners are willing to act, have the skills and experience to act, and have existing capacity or capacity that can be improved with additional resources.

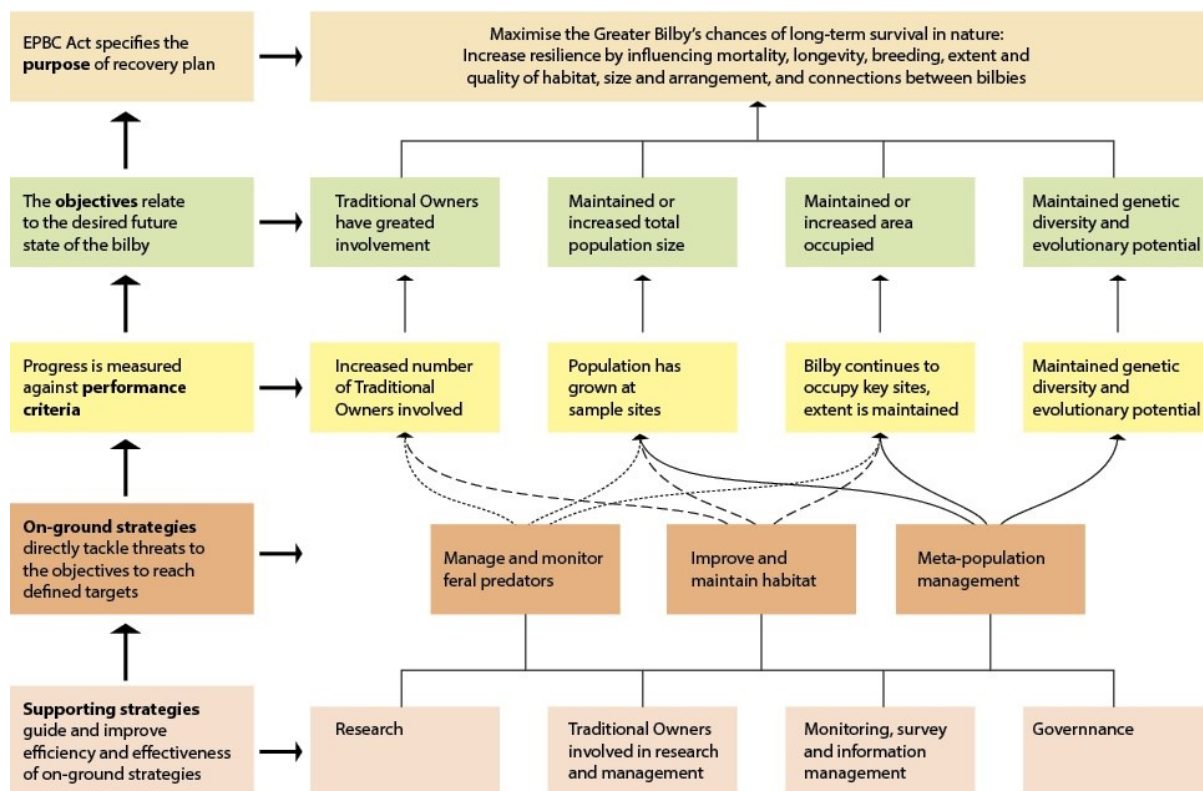
Bilbies mainly persist in areas that have a sparse human population density where it is difficult and expensive to implement works without using the experience and capacity of local communities and local land managers. Local communities, landholders and land managers are likely to have the best understanding of local constraints, and can adapt activities to respond to local conditions. In particular, the skills, expertise, experience, connection to Country and capacity of Traditional Owners and Indigenous land managers are likely to be critical to the protection and recovery of the Greater Bilby.

For these reasons, on-ground actions are more feasible in the least-populated areas when targeted to local communities, using the locally effective techniques and practices most familiar to the community. It is further recognised that, given over 70 % of the distribution of bilbies occurring as wild populations occur on lands managed by Indigenous people and organisations, the continued survival of the species is likely to be intrinsically linked to healthy and resilient Indigenous communities managing and exercising their traditional custodianship of the land.

To allow local communities and land managers to influence how, where, and when actions are implemented, actions in this plan are framed to allow a flexible approach to implementation that will suit the local conditions, resources and skill base.

The relationship between supporting strategies, on-ground strategies, performance criteria and objectives can be found at Figure 3.

Figure 3 Flow chart of recovery plan purpose, objectives, performance criteria and on-ground and supporting strategies.



6.1 On-ground and supporting strategies

All strategies identified in this plan are necessary for the conservation of the Greater Bilby. On-ground strategies directly tackle biological threats to the objectives for the conservation of the Greater Bilby, while the supporting strategies establish the systems needed to ensure effective on-ground action. Generally, on-ground strategies relate to the specific actions needed at different sites, while supporting strategies will be implemented across many sites, or are not directly spatial in nature.

The threats relate to three key biological factors – the effect of predators, the extent and condition of habitat (including habitat loss, and habitat degradation arising from fire, weeds, grazing, fragmentation), and population resilience. Accordingly, the on-ground strategies focus on these factors:

- Manage introduced predators.
- Improve and maintain habitat.
- Establish and maintain a Greater Bilby metapopulation that maintains genetic diversity and insures against extinction in nature.

These on-ground strategies are complemented by supporting strategies aimed at ensuring successful implementation of this recovery plan. Supporting strategies are:

- Research strategy – to ensure management actions are underpinned by rigorous research.

- Recovery governance – to ensure efficient, effective, and timely implementation of recovery actions.
- Monitoring, survey and information management – to measure management impact and report on progress.
- Traditional Owner research and management – to provide for Indigenous land managers, including Traditional Owners and Indigenous rangers, to plan and implement research and management actions.



Photo: Birriliburu rangers mosaic burning practices Mungarlu priority management zone © Jessica Chapman.

6.2 Priority setting and costs

Actions are not prioritised in this recovery plan, for the following reasons:

- It is necessary to implement all actions in this plan to maximise the Greater Bilby's chances of long-term survival in nature. All actions are important.
- Maximum investment in local, on-ground action is likely to be achieved where communities and land managers can choose and tailor actions to respond to local conditions, resources and capacity.
- The risk presented by each threat varies across the distribution of the Greater Bilby and between locations where bilbies persist, hence the priority for actions varies for each location.
- Priorities at some locations are likely to change within the life of this plan and over-prescribing priorities may reduce plan effectiveness.

Costs are not identified in this plan. Although the additional cost of some actions can be calculated, the cost of most actions is dependent on local priorities for action, the feasibility of actions, whether it is a new or a modification of an existing activity, and the existing capacity that is available to undertake the action. The plan aims to avoid being prescriptive and inflexible, and aims to encourage local adaptation and autonomy by land managers when implementing actions. The recovery team can be contacted to provide up-to-date advice on the prioritisation of funding and resources.

6.3 Actions

This plan aims to ensure that lack of scientific certainty is not used as a reason to delay on-ground action. It is acknowledged that the effect of each action will not be known without monitoring and analysis, and the combined effectiveness of actions requires research and governance through an adaptive management framework. It is also acknowledged that negative effects may occur and may remain undetected where such systems are not in place. However, if there are sufficient resources available to undertake the necessary research, these actions should not be delayed until the associated research is completed.

Actions have been framed at a high level to allow an adaptive and flexible approach to implementation that responds to variation in conservation needs across the range, as well as new information as it becomes available.

Partners identified as having an interest in contributing to the implementation of an action are listed against each action. Inclusion in this list means that the partner either intends to consider implementing the action provided they have access to adequate resources, capacity and support partnerships, or otherwise has an interest in contributing to the action.

Note: As bilbies are mobile and move within the landscape according to resource availability, the term 'site' is intended to encompass the area within which a population or group of bilbies may range over generations. For a full explanation of the term 'site', see Box 3 What is a bilby site?

Bilby sites and partners have only been identified to the extent practicable during the development of this plan. It is expected that further bilby sites will be identified during the life of this plan, and the land manager, with assistance from the recovery team, will identify relevant recovery actions for those sites. Ongoing consultation with conservation organisations, Traditional Owners, Indigenous rangers, state and territory government conservation agencies, and other land managers is necessary to identify further sites relevant to this plan.

Sites identified in the plan are shown on maps available with this plan. The recovery team may revise these maps during the life of the plan, to reflect new information about the need for the implementation of actions at identified or additional sites.

The partner/s who have an interest in implementing each action have been identified in the action tables (Table 1 to Table 8). Depending on the action, a partner may be an individual group or organisation, or a term used to describe a sector or type of organisation, for example conservation organisation.

6.3.1 Supporting Strategy: Survey, monitoring, and information management

The actions required to conserve the Greater Bilby vary at each site according to local conditions and the way the threats interact. The effectiveness of actions at a local scale may be reliant on adapting actions to those circumstances, including for example the way threats, such as predator distribution and abundance, change due to impacts of climate change. Monitoring provides the ability to test the impact of management actions and modify or change actions if required. Monitoring is also required to measure performance against the objectives of the plan.

Although survey and monitoring methods are expected to vary across the distribution of the Greater Bilby in order to accommodate local ecological conditions, skills and capacity, it is intended that standardisation of simple and repeatable methods over time will improve the consistency and comparability of the data available for analysis.

While not specifically identified as an action, it is important that existing traditional ecological knowledge be considered when implementing this strategy (Table 1).

Table 1 Strategic actions for survey, monitoring and information management

Action	Description	Partners
1a	<p>In collaboration with land managers, survey for bilbies to identify further sites for management or monitoring. Priority areas include pastoral and other privately-managed lands in</p> <ul style="list-style-type: none"> • Western Queensland west and south of Pullen Pullen to Birdsville, • North-western Western Australia, including the Pilbara, Gascoyne, Dampierland, and Ord Valley Plain IBRA regions, and • Western Northern Territory <p>These areas are shown on the maps associated with the recovery plan as survey and liaison areas.</p>	<p>State and territory government conservation agencies, Save the Bilby Fund, other land managers, Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners</p>
1b	<p>Continue or start bilby monitoring and bilby surveys to establish baseline and measure management impact:</p> <ul style="list-style-type: none"> • Facilitate and coordinate monitoring and surveys, including through initiatives such as the Bilby Blitz Programme. • Promote regular (annual and five-yearly) surveys of bilby sites by local communities using methods that generate comparable data. • Include sites necessary to measure against recovery plan performance criteria. • Where desired, support the development of community-based surveys that harness existing land manager and community on country activities and generate quality data to inform land management actions. • Use methods relevant to the purpose, circumstances, and conditions, such as sign or track plots, burrow visits, cameras, thermal imaging, drones, detection dogs. • Collate, analyse and report on data generated from monitoring and surveys. 	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, Save the Bilby Fund, other land managers, state and territory government conservation agencies, AWC and species experts.</p>

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Action	Description	Partners
1c	Identify sample sites at which changes in the bilby presence will be measured (see performance criterion 1) within 12 months.	Recovery team, Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, other land managers, state and territory government conservation agencies, species experts, AWC.
1d	Identify any other sites for occupancy survey necessary for reporting against performance criterion 2(a).	As Action 1c Partners
1e	Develop and publish monitoring and survey protocols.	As Action 1c Partners
1f	Standardise and implement a set of simple and repeatable occupancy/habitat survey methods for bilbies, predators and herbivores across the range of the bilby, including those that are suitable to determine change in bilby population parameter trends and the effect of management.	As Action 1c Partners
1g	Investigate and establish, if feasible, a 'national database' or 'national map', combining data from all sources (records from research and surveys, mapping and so on) to enable on-ground recovery actions. Include layers/data on climate, vegetation, geology and fire frequency mapping.	Recovery team, DAWE, state and territory government conservation agencies.



Photo: Bilby monitoring – bilby scats © Jessica Chapman

6.3.2 Supporting Strategy: Traditional Owner research and management

The majority of wild bilbies occur on Indigenous-managed land in WA and the NT, yet until recently the development of bilby conservation plans and strategies did not usually involve effective consultation with Indigenous people. The future of the Greater Bilby relies on the skills, expertise, experience, connection to Country, and capacity of Indigenous land managers, including Traditional Owners and Indigenous rangers.

The Greater Bilby persists in areas where Indigenous rangers can implement management and monitoring activities, and where some traditional land management activities are still carried out. Increased capacity and support for local communities reduces the expense of management activities in otherwise remote and sparsely populated areas. The harsh environments and substantial distances make the use of non-local workers and resources inefficient, as transport and accommodation costs reduce the proportion of resources invested in on-ground actions. In addition, local people, landholders and land managers are likely to have the best understanding of local constraints and can adapt activities to respond to local conditions.

In 2016, the Kiwirrkurra Community (WA), on behalf of the Indigenous Desert Alliance, hosted a Ninu (Bilby) Festival, recognising the importance of the knowledge and support from Indigenous rangers, Traditional Owners, and other Indigenous groups, communities, and individuals operating in areas where bilbies are or used to be. The Ninu Festival harnessed traditional and contemporary knowledge about the Greater Bilby and threats to its' persistence, and produced a framework for effective, collaborative management of wild bilby populations. It was emphasised that the motivation to protect the Greater Bilby is based on the cultural connection, and that it is essential to maintain this connection (Paltridge 2016).

Loss of traditional ecological knowledge and Indigenous land management activities are a significant risk to the conservation of the Greater Bilby. The actions in Table 2 are designed to ensure that this traditional ecological knowledge and land management capabilities are supported and celebrated.

While not specifically identified as an action, it is important that existing traditional ecological knowledge be considered when implementing this strategy.

The actions in Table 2 also support the achievement of the conservation Vision (see section 4 Recovery Objectives) generated at the Greater Bilby Recovery Summit (Bradley et al. 2015).

Table 2 Strategic actions for Traditional Owner research and management

Action	Description	Partners
2a	<p>Continue to facilitate awareness-raising activities in order to maintain focus on both the cultural significance of the bilby, and traditional ecological knowledge and skills in bilby management:</p> <ul style="list-style-type: none"> • Conduct events to celebrate and share knowledge about bilby significance and conservation. • Provide opportunities to exchange knowledge and experience on feral cat control techniques between Traditional Owners, land managers and species management experts. • Share stories, reports and knowledge about the Greater Bilby and information about ranger and Indigenous organisation conservation activities through school activities, traditional media and social media. 	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, Save the Bilby Fund, state and territory government conservation agencies, relevant NRM organisations.</p>

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Action	Description	Partners
2b	Facilitate Indigenous leadership and involvement in the recovery team through the Indigenous sub-committee (or other means), and professional development opportunities in Recovery Team policy and governance. This will ensure extant populations are managed, and maintain a focus on the cultural significance, traditional ecological knowledge and Indigenous land management skills in bilby conservation.	Recovery team and Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, state and territory government conservation agencies.
2c	Build the knowledge, awareness and passion for bilbies in the younger generation, for example through junior Indigenous ranger activities, that facilitates both intergenerational knowledge transfer and training in management.	Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, state and territory government conservation agencies, relevant NRM organisations.
2d	For each actively managed site, develop a spatially explicit and plain language annual or multi-year action plan tailored to the needs of the land manager based on the recovery plan, suitable for use in the field by land managers.	Indigenous rangers, Traditional Owners and Indigenous land managers, Save the Bilby Fund, state and territory government conservation agencies relevant NRM organisations.
2e	Based on annual action plan consider including bilby recovery actions in relevant work plans.	Indigenous rangers, Save the Bilby fund, Traditional Owners and Indigenous land managers, relevant NRM organisations.
2f	Provide support for Indigenous rangers to monitor bilbies, for example data collection and management, for example, through the Bilby Blitz Programme.	State and territory government conservation agencies, relevant NRM organisations, key independent experts.



Photo: Bilby food – Lunki – edible grub found inside roots some Acacia species © Jessica Chapman.

6.3.3 Supporting Strategy: Recovery governance and communication

Bilby conservation activities are undertaken by individuals, communities and organisations such as Indigenous land managers and organisations (including Indigenous rangers and Traditional Owners, and remote Indigenous communities), pastoralists and other landholders/managers, state and territory government conservation agencies, conservation organisations, researchers, mining industry and other industry organisation. Combined, this represents a significant investment in the conservation of a species.

Governance can help connect and establish a common purpose between partners, learning from each other's experience and efforts, sharing resources and capacity, and coordinating bilby management and research actions that are being, and/or need to be, undertaken. Governance can also assist in establishing systems to communicate between partners and to collate information that can be used for reporting at different scales.

While not specifically identified as an action, it is important that existing traditional ecological knowledge be considered when implementing this strategy (Table 3).

Table 3 Strategic actions for recovery, governance and communication

Action	Description	Partners
3a	Recovery team to establish governance arrangements including: <ul style="list-style-type: none"> • Indigenous subcommittee, working groups, and/or Indigenous participation in the recovery team (to facilitate leadership opportunities and involvement of Traditional Owners and Indigenous rangers). • Science subcommittee (responsible for identifying, advising of priorities and coordinating research). • Metapopulation subcommittee (responsible for planning for bilby genetic integrity, insurance, and metapopulation management). 	All.
3b	Establish a bilby recovery coordinator, including to ensure effective and transparent communication between subcommittees and partners.	Commonwealth, State and Territory conservation agencies, recovery team.
3c	Provide annual reporting on progress against recovery actions.	Recovery team.
3d	Review the recovery plan five and ten years after making.	Recovery team, Commonwealth, state and territory government conservation agencies.



Photo: Greater Bilby in captivity © Department of Environment and Heritage – Qld.

6.3.4 On-ground Strategy: Manage and monitor predators

Predation by foxes, feral cats and in some circumstances wild canids (dogs and/or Dingoes) has the potential to prevent population size growth and to cause local extinction, preventing the plan's objectives from being achieved. Directly controlling feral cats, is necessary at many bilby sites across its distribution, controlling foxes is necessary where foxes present a threat to persistence or reintroduction, and controlling wild canids (dogs) may be necessary under specific circumstances in some locations. However, predation levels and the impact of feral cats is often dependent on population resilience, fire regimes, water availability, and the condition of habitat, so control should be integrated with other site management actions.

The actions in Table 4 are indicative of the types of predator management relevant to each site. Where possible, the implementation of specific actions at sites should reflect current best practice pest management practices. This includes:

- establishing monitoring to determine current levels of predator abundance/occupancy
- identifying when and where predators are causing impact to determine optimal time, place to manage predators
- Monitoring predator densities and prey numbers to plan predator control to avoid increased predation pressure from prey-switching due to decreases in prey availability
- implementing predator control measures for an extended period (>2 years) combined with monitoring to determine both the effect on reducing predators and predation and the response of the bilby population compared to sites (or regions) where no predator management is occurring
- adapting actions to maximise management effectiveness
- establish long-term or threshold-driven predator-management action programs.

While not specifically identified as an action, it is important that existing traditional ecological knowledge be considered when implementing this strategy.

Table 4 On-ground strategic actions to manage and monitor predators

Action	Description	Relevant site/s	Partners
4a	Implement feral cat control measures: <ul style="list-style-type: none"> • Undertake feral cat control using techniques applicable to the circumstances and local conditions, for example baiting, trapping, hunting, shooting, grooming traps. Ensure that potential impacts on non-target species are considered and managed. • Schedule control activities to account for bilby and feral cat breeding cycles, prey availability, potential interactions with wild canids. • Facilitate and encourage the exchange of information, advice and training between landowners and managers, for localised feral cat 	All relevant sites. Currently sites identified by partners include Diamantina NP (Qld), Pullen Pullen (Qld), Astrebla Downs NP (Qld), Currawinya NP (Qld), Haasts Bluff (NT), Hanson River (NT), Illeuwurru (NT), Mungalawurru (NT), NTIPA1-NTIP4, Kurrawarra Nyura Mala (NT), Kalumpurlpa (NT), Karlantijpa North (NT), Kintore (NT), Kurrara Kurrara (WA), Peron Peninsula (WA), Maruwa (WA), Ngururpa (WA), Nyangumarta (WA), Waylarta (WA), Mina Mina (NT), Matuwa (WA), Gooniyandi (WA), Kiwirrkurra (WA), Yawuru (WA), Katjarra (WA), Nyirripi (NT), Railway South Tck, STIPA Central (NT), Purta and Mt Frederick ALT	Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, Save the Bilby Fund, state and territory government conservation agencies, WWF, AWC, Wild Deserts (UNSW), BHA, local NRM organisations.

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Action	Description	Relevant site/s	Partners
	<p>management.</p> <ul style="list-style-type: none"> Continue refining and trialling new baits, attractants and other methods to develop effective feral cat control techniques for arid areas that don't affect other native species, for example quolls and kowaris. Provide opportunities to exchange knowledge and experience on feral cat control techniques between Traditional Owners, land managers and species management experts and predator management practitioners. Ensure, where possible, that monitoring is established to determine an appropriate baseline and measure management impact. 	(NT), STIPA Lander River (NT), Sangsters Bore (NT), Tanami Downs (NT), The Granites (NT), Mallee Cliffs NP (NSW), Pilliga SCA (NSW) and Sturt NP (NSW).	
4b	<p>Reduce predator impacts on bilbies at the southern edge of bilby range and other identified sites:</p> <ul style="list-style-type: none"> Conduct localised feral cat and fox control at bilby sites on edges of the range, including trialling of new techniques and utilising existing control activities for example shooting, baiting, or trapping. Ensure that potential impacts on non-target species are considered and managed. In Qld implement and test control techniques (primarily baiting, grooming trap, shooting, training rangers and neighbouring pastoralists to trap). In NT and WA implement and test control techniques (traditional hunting, fox and feral cat-specific baiting, trapping, grooming trap, shooting). Encourage existing shooting activities (for example for kangaroos) to include foxes and feral cats as targets, and to record and report sightings. 	<p>All relevant sites.</p> <p>Currently sites identified by partners include Mina Mina (NT), The Granites (NT), Sangsters Bore (NT), Tanami Downs (NT), STIPA Central (NT), STIPA Lander River (NT), Matuwa (WA), Warburton (WA), Kiwirrkurra (WA), Marruwa (WA), Haasts Bluff (NT), Hanson River (NT), Kintore (NT), Illeuwurru (NT), Astrebla Downs NP (Qld), Pullen Pullen (Qld), Kurrara Kurrara (WA), Nyirripi (NT), Railway South Tck (NT), Currawinya NP (Qld) and other sites identified by the recovery team.</p>	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, Save the Bilby Fund, state and territory government conservation agencies, Rangelands NRM, Southern Queensland Landscapes, AWC, BHA.</p>
4c	<p>Proactively control feral cats and wild canid predation pressure associated with boom-bust prey events:</p> <ul style="list-style-type: none"> Undertake feral cat and wild canid control where booms in prey species have increased predation pressure and during drought years when bilby population sizes are relatively high. Integrate with rabbit control where feral cat predation may control rabbit numbers. Undertake rabbit control to prevent fluctuations in rabbit numbers. Test isolated rabbit occurrences in bilby areas for RHDV and release new strains, if necessary. 	<p>All relevant sites.</p> <p>Currently sites identified by partners include Astrebla Downs NP (Qld), Peron Peninsula (WA), Diamantina NP (Qld), Illeuwurru (NT), Kalumpurlpa (NT), Haasts Bluff (NT), Hanson River (NT), Karlantijpa North (NT), Kintore (NT), Kiwirrkurra (WA), Kurrawarra Nyura Mala (NT), Marruwa (WA), Mina Mina (NT), Nyirripi (NT), Mungalawurru (NT), NTIPA1-NTIP4, Purta and Mt Frederick ALT (NT), Railway South Tck, Sangsters Bore (NT), STIPA Central (NT), STIPA Lander River (NT), The Granites (NT), Yawuru (WA), Tanami Downs (NT), Gooniyandi (WA).</p>	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, other land managers, Save the Bilby Fund, state and territory government conservation agencies, AWC.</p>

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Action	Description	Relevant site/s	Partners
	<ul style="list-style-type: none"> Monitor indicators of prey density (such as small mammals and rabbits). Monitor indicators of immigration likely to increase feral cat and wild canid density. Monitor indicators of prey-switch timing (for example when prey such as small mammals or rabbits decline in availability) and establish threshold triggers that ensure feral cat and wild canid control actions are implemented before prey-switching escalates. 		
4d	<p>Establish baseline monitoring of bilbies and predators using agreed monitoring techniques:</p> <ul style="list-style-type: none"> Monitor factors/circumstances of predation that results in local extinctions. Establish arrangements for data sharing and intellectual property management. Establish local and centralised data management, analysis and reporting systems. 	<p>All sites identified by partners. Currently sites identified by partners include Mallee Cliffs NP (NSW), Pilliga SCA (NSW), Sturt NP (NSW), Kalumpurlpa (NT), Haasts Bluff (NT), Kintore (NT), Karlantijpa North (NT), Kurrawarra Nyura Mala (NT), Hanson River (NT), Munglawurru (NT), Railway South TCK (NT), Illeuwurru (NT), NTIPA 1 – 4 (NT), Purta and Mt Frederick ALT (NT), Tanami Downs (NT), The Granites (NT), Nyirripi (NT), Sangsters Bore (NT), STIPA Central (NT), STIPA Lander River (NT), Mina mina (NT), Astrebla Downs NP (Qld), Currawinya NP (Qld), Diamantina NP (Qld), Katjarra (WA), Mungarlu (WA), Pullen Pullen (Qld), Peron Peninsula (WA), Walyarta (WA), Gooniyandi (WA), Barumba track (WA), Mankarr mulga place (WA), North East Jigalong (WA), Pinpi Road (WA), Puntawarri (WA), Kiwirrkurra (WA), Marruwa (WA), Ngururpa (WA), Nyangumarta (WA), Walyarta (WA), Nyul Nyul (WA), Paruku (WA), Copper Hill Road (WA), Near Jiwal Jiwal and Jurrar (WA), Near Yulpu (WA), Road to Ruddal River (WA), Talawana Track (WA), Warntili (WA), Jarntinti and Karlamilyi (WA), Telfer Road North Section (WA), Punmu and Lakeside (WA), Walpet Track (WA), Punmu (WA), Kurrara Kurrara (WA), Matuwa (WA), Yawuru (WA).</p>	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, Save the Bilby Fund, state and territory government conservation agencies, AWC, BHA.</p>
4e	<p>Support training of Indigenous land managers, including Traditional Owners and Indigenous Rangers to establish or refine introduced predator control and management activities, including:</p> <ul style="list-style-type: none"> Standardised methods. Data management and reporting systems. 	<p>All relevant sites as identified by partners.</p>	<p>State and territory government conservation agencies, Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners.</p>
4f	<p>Investigate and, if technically feasible, develop and make available baseline distribution data and maps of threats (feral cats, foxes, rabbits, cattle,</p>	<p>For all relevant sites, including sites that are subject to active management.</p>	<p>DCCEEW, data set owners.</p>

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Action	Description	Relevant site/s	Partners
	horse/donkey, camel, key weeds and fire histories) that can be used at a national scale for a general overview, and at a local site scale, so Indigenous rangers can check and update the veracity of available data.		
4g	Use results from action 4f to develop regional predator or threat management strategies (for example Tanami, southern WA, northern WA, south western Qld).	For all sites falling within regional predator or threat strategies.	State and territory government conservation agencies, relevant NRM organisations.
4h	Determine tolerable levels of feral cat occupancy and in Queensland, wild canid occupancy relevant to identified sites by monitoring locations where bilby colonies persist and compare to localities (with similar conditions) where bilbies are absent. Identify thresholds that require the commencement of feral cat and wild canid control/management to prevent extinction or maintain population condition. Thresholds should be set according to environmental conditions that influence interactions between bilbies and feral cats and wild canids.	All relevant sites. Currently sites identified by partners include Currawinya NP (Qld), Newhaven (NT), Pilliga SCA (NSW), Mallee Cliffs NP (NSW), Sturt NP (NSW), Nyul Nyul (WA), Yawuru (WA), Gooniyandi (WA), Mt Gibson (WA), Peron Peninsula (WA), Matuwa (WA), Kiwirrkurra (WA), Katjarra (WA), Astrebla Downs NP (Qld), Diamantina NP (Qld), Pullen Pullen (Qld).	Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, state and territory government conservation agencies, Save the Bilby Fund, WWF, AWC, local NRM organisations, Wild Deserts (UNSW), BHA.
4i	Determine the climatic conditions, weather conditions, and key habitat and prey resources that affect fox extent of occurrence and levels of occupancy.	All relevant sites. Currently sites identified by partners include Gooniyandi (WA), Yawuru (WA).	State and territory government conservation agencies, relevant NRM organisations.
4j	Determine if foxes are extending their range in WA.	At sites near margins of permanent fox occupation. Currently sites identified by partners include Matuwa (WA), Warburton (WA), Kiwirrkurra (WA), Gooniyandi (WA), Jarntinti and Karlamilyi (WA), Karajarri (WA), Yawuru (WA), Barumba Track (WA), Copper Hill Road (WA), Nyul Nyul (WA), Mankarr mulga place (WA), Nyikina Mangala (WA), Paruku (WA), Ngurrara (WA), Marruwa (WA), Near Jiwal Jiwal and Jurrar (WA), Near Yulpu (WA), North East Jigalong (WA), Nyangumarta (WA), Nyikina Mangala (WA), Pinpi Road (WA), Punmu and Lakeside (WA), Puntawarri (WA), Road to Ruddal River (WA), Talawana Track (WA), Telfer Road North Section (WA), Walpet Track (WA), Walyarta (WA), Warburton (WA), Warntili (WA), Yawinya (WA), South of 33 (WA), Jenkins Track (WA), East of 33 (WA), Pangkapirni and east (WA).	WA Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, state and territory government conservation agencies, relevant WA NRM organisations, KLC.
4k	Determine the factors or conditions that influence the persistence of bilbies in circumstances where they co-exist with predators.	All relevant sites. Currently sites identified by partners include Karajarri (WA), Yawuru (WA), Nyul Nyul (WA), Nyikina Mangala (WA), Paruku (WA), Ngurrara (WA), South of 33 (WA), Jenkins Track (WA), East of 33	Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, state and territory government

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Action	Description	Relevant site/s	Partners
		(WA), Pangkapi and east (WA), Katjarra (WA), Matuwa (WA), Kurrara (WA), Mungarlu (WA), Sturt NP 'Wild Training Zone' (NSW).	conservation agencies, relevant NRM organisations, Arid Recovery, WWF, KLC, CLC, Wild Deserts (UNSW).
4l	Improve understanding of immigration corridors, source populations and feral cat movement/ occupancy associated with prey irruption events in south western Qld, to enable effective scale and timing of control activities.	All relevant sites. Currently sites identified by partners include Astrebla Downs NP (Qld) and Diamantina NP (Qld) and adjoining lands.	AWC, DAFF, University of Queensland (UQ), Save the Bilby Fund.
4m	Investigate the interaction between feral predators and dingoes, including determining whether dingoes suppress foxes and feral cats and if so, under what conditions.	All relevant sites as identified by partners.	Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, state and territory government conservation agencies, relevant NRM organisations.

6.3.5 On-ground Strategy: Improve and maintain habitat

For the Greater Bilby population size to grow, and for the species to persist at sites where it currently occurs, bilbies need food, shelter, protection from predators, and the opportunity to connect with other bilbies. The ability for habitat to provide for bilbies is often related to fire regimes (Table 5), land uses that fragment or reduce the amount of habitat present (Table 6), and habitat degradation resulting from introduced species (Table 7). A changing climate is expected to influence habitat quality, and the nature and effectiveness of habitat management actions. While addressing the causes of climate change is not within the scope of this plan, it is important to anticipate changes to the ecology of bilby habitat, respond to changes in knowledge about climate change and implement habitat management actions accordingly.

While not specifically identified as an action, it is important that existing traditional ecological knowledge be considered when implementing this strategy.

Table 5 Manage fire

Action	Description	Relevant site/s	Partners
5a	Define, promote and implement region-specific fire management to minimise large-scale fires and promote increased patchiness or mosaics, using traditional ecological burning and traditional Indigenous knowledge: <ul style="list-style-type: none"> Undertake burning (including patch burning, traditional burning, linear fire breaks) at each known site. Adapt fire management based on long-term bilby population size response. Undertake landscape-scale fire management and limit the extent and spread of wildfires to protect 	All sites with active management, except sites in Queensland where fire management is not required.	Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, researchers, state and territory government conservation agencies, WWF, relevant NRM organisations AWC.

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Action	Description	Relevant site/s	Partners
	<p>sites and bilby habitat from unmanaged fire following high rainfall events. Consider aerial burning after extensive rainfall events that are likely to create conditions that result in widespread fires. Adapt fire management in response to effect of management on reducing large-scale fires and increasing patchiness.</p> <ul style="list-style-type: none"> • Develop fire management guidelines that protect specific habitat elements, such as key food resources (for example witchetty grubs). • Develop fire management guidelines for the following areas: the Pilbara, Lancewood (NT) and Dampierland (IBRA). 		
5b	<p>Undertake the action 5a burns at selected sites across habitat types, and:</p> <ul style="list-style-type: none"> • Collate and share traditional ecological knowledge on the effect of burning on key bilby food sources. • Monitor and analyse effects on the availability of key bilby plant food, for example to test and refine the fire-rainfall-<i>Yakirra</i> model. • Determine whether fire plays a role in promoting key food resources in the Pindan and savannah areas of the Kimberley / Dampierland (IBRA). • Test the response of bilbies (including habitat quality, food availability, predators, dingoes) to experimental fire manipulation in five different bilby population fragments in sand plain habitat. 	<p>Sites to be selected by recovery team across sand-plain, Pindan and savannah areas. Consider:</p> <p>Newhaven (NT), Pilliga SCA (NSW), Mallee Cliffs NP (NSW), Sturt NP (NSW), Nyul Nyul (WA), Karajarri (WA), Nyikina Mangala (WA), Kintore (NT), Kiwirrkurra (WA), Marruwa (WA), Katjarra (WA), Mungarlu (WA), Matuwa (WA), Kurrara Kurarra (WA), Yawinya (WA).</p>	<p>Recovery team Science subcommittee, relevant Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, researchers, state and territory government conservation agencies, WWF, relevant NRM organisations.</p>

Table 6 Improve habitat connectivity and maintain habitat extent

Action	Description	Relevant site/s	Partners
5c	<p>Compile traditional ecological knowledge about links between habitat, fire patterns and key bilby food availability.</p>	<p>For all relevant sites as identified by partners.</p>	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners.</p>
5d	<p>Ground-truth and refine bilby habitat model within the separate regions (for example using 2 ha plot and occurrence data, remote sensing data and vegetation mapping):</p> <ul style="list-style-type: none"> • Investigate relationship between modelled bilby habitat and fire history (for example area of habitat to area burnt), and development and climate. 	<p>Sites to be selected by recovery team.</p>	<p>Recovery team Science subcommittee, Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, researchers, state and territory government conservation agencies, WWF, relevant NRM</p>

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Action	Description	Relevant site/s	Partners organisations.
5e	<p>Enlarge and reconnect small wild populations. Improve connectivity by managing habitat quality between bilby populations in south-west Qld:</p> <ul style="list-style-type: none"> • Improve habitat condition and reduce predators in the strip of land between Astrebla and Diamantina NPs by undertaking joint strategic introduced predator controls, implementing strategic or ecological burns, and reducing or improving management of water points and grazing regimes. • Provide information, advice, and support to land managers to ensure land condition remains suitable to enable bilbies to persist at existing and periodically occupied bilby sites. • Manage predators in buffer zones around bilby sites to enable bilby numbers to expand in good seasons and facilitate dispersal between bilby sites. 	Astrebla Downs NP (Qld) and Diamantina NP(Qld), Pullen Pullen Reserve (Qld) and adjacent lands.	DES, Bush Heritage Australia, Save the Bilby Fund, landholders of lands adjacent to Astrebla Downs and Diamantina NPs, and Pullen Pullen Reserve.
5f	<p>Maximise the retention of bilby habitat, and enhance retained habitat:</p> <ul style="list-style-type: none"> • Avoid habitat alteration, fragmentation, and loss, where possible. • Where habitat is unavoidably affected, implement predator, fire, and habitat management to increase the chances of long-term persistence at the site, and to expand the occurrence into an adjoining or nearby area. 	All sites	State and territory government conservation agencies, Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, and other land managers.
5g	<p>Develop guidelines on minimising impacts on bilbies from agriculture and other development. Include information to identify how to maintain and enhance sufficient extent and connectivity of habitat, maintenance or restriction of any associated subsurface and surface waters, undertake fire management, and manage predators to promote resilient bilby populations.</p>	<p>All relevant sites.</p> <p>Currently sites identified by partners include Karajarri (WA), Nyul Nyul (WA), survey and liaison areas in Western Queensland, Northern Territory, and Western Australia.</p>	State and territory government conservation agencies and land managers.
5h	<p>Identify sufficiently large areas to support populations of up to 10,000 individuals (target a lower limit of 3000):</p> <ul style="list-style-type: none"> • Determine bilby densities at low and high points in cycle in different habitats. Locations: south-western Qld, Kiwirrkurra IPA, Ngaanyatjarra IPA, Punmu area and western Tanami Desert. Determine size of areas required to support high bilby numbers. 	To be identified via metapopulation planning.	Recovery team science and metapopulation subcommittees.

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Action	Description	Relevant site/s	Partners
5i	<p>Define how bilbies/predators are affected by roads/rail/utility corridors in terms of dispersal, road kill, impact mitigation measures, and promote effective management, including:</p> <ul style="list-style-type: none"> Determine if disturbance around roads attract bilbies, for example regrowth or ease of burrowing. Determine if road kill is a significant cause of mortality for bilbies in different areas and, if so, investigate mitigation/management measures. Determine if rail/roads/utility corridors are barriers to bilby dispersal/gene flow. 	<p>All relevant sites.</p> <p>Currently sites identified by partners/recovery team include Nyul Nyul (WA), Yawuru (WA), Illeuwurru (NT), Gooniyandi (WA), Railway South TCK (SA), The Granites (NT).</p>	<p>Relevant Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, recovery team science subcommittee, state and territory government conservation agencies.</p>
5j	<p>Trial the treatment of weeds to determine the effects of weed reduction on the suitability of habitat for the bilby; including:</p> <ul style="list-style-type: none"> Buffel grass. Couch grass growing along drainage lines. 	<p>All relevant sites.</p> <p>Currently sites identified by partners/recovery team include Illeuwurru (NT), Newhaven (NT), STIPA Lander River (NT), Hanson River (NT), Munglawurru (NT), Gooniyandi (WA), Karlumpurla (NT), The Granites (NT), Nyul Nyul (WA), Yawuru (WA), NTIPA1 (NT), Mungarlu (WA), Katjarra (WA), Mankarr mulga place (WA).</p>	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, recovery team science subcommittee.</p>

Table 7 Managing impacts of herbivore grazing

Action	Description	Relevant site/s	Partners
5k	<p>Continue to exclude cattle from currently ungrazed habitat at bilby sites and consider the management of other introduced herbivores that are having an effect on bilby sites.</p>	<p>All WA/NT sites where relevant, including: Lander River (NT), Hanson River (NT), Gooniyandi (WA), Karlumpurla (NT), Sangsters Bore (NT), STIPA Central (NT), STIPA Lander River (NT), Mungarlu (WA), Illeuwurru (NT), Karajarri (NT), Kurrara Kurrara (WA), Mina mina (NT), Matuwa (WA), Nyirripi (NT), NTIPA 1–4 (NT), Nyul Nyul (WA), Yawuru (WA), Katjarra (WA).</p>	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, and other land managers and conservation organisations.</p>
5l	<p>Trial the effectiveness of reducing the number of introduced herbivores on improving persistence or population size growth at known sites.</p>	<p>All relevant sites.</p> <p>Currently sites identified by partners include Illeuwurru (NT), Gooniyandi (WA), Newhaven (NT), Kiwirrkurra (WA), Yawuru (WA), Katjarra (WA), Kurrara Kurrara (WA), Marruwa (WA), Matuwa (WA), NTIPA 1 (NT), Nyul Nyul (WA), other sites identified by recovery team.</p>	<p>Indigenous land managers and organisations, including Indigenous rangers and Traditional Owners, and other land managers, conservation organisations.</p>
5m	<p>Reduce water point density in habitat at bilby sites and in adjacent habitat to 1970s level by 2025:</p> <ul style="list-style-type: none"> Investigate potential for stewardship payments to reduce water points or water availability to compensate for associated stocking reductions. 	<p>All relevant sites as identified by partners. Currently sites identified by partners include Tanami Downs (NT), Birdsville Block (Qld), Cluny Block (Qld), Coorbulka (Qld), Pullen Pullen (Qld), Palparra (WA).</p>	<p>State and territory government conservation agencies.</p>
5n	<p>Develop guidelines for stocking levels based on stocking levels at grazed sites</p>	<p>For sites proposed or under grazing. Currently sites identified by partners</p>	<p>State and territory government</p>

Action	Description	Relevant site/s	Partners
	where the bilby has persisted.	include Tanami Downs (NT), Yawinya (WA), Nyangumarta (WA).	conservation agencies.
5o	Trial reduction in stock grazing intensity in areas of potential habitat adjacent to bilby sites, to encourage bilby expansion. Include predator management in trials where appropriate.	Sites to be determined by land managers in consultation with recovery team science subcommittee.	State and territory government conservation agencies in collaboration with pastoral land managers.
5p	Liaise with and provide information and advice to pastoral companies and other land managers about opportunities to support management to increase bilby population size and resilience on pastoral and other privately managed lands.	Survey and liaison areas in Western Queensland, Northern Territory, and Western Australia.	State and territory government conservation agencies, relevant NRM organisations, pastoral land managers.
5q	Define and promote tolerable grazing levels of introduced herbivores, relative to suitable habitat, fire, predators and water points.	Where applicable.	Recovery team science subcommittee, state and territory government conservation agencies.
5r	Quantify the effect of grazing on bilby population size and persistence. Compare bilby abundance near and remote from grazing pressure under different grazing intensities (to determine thresholds of acceptable grazing).	Where applicable.	Recovery team science subcommittee.

6.3.6 On-ground Strategy: Metapopulation management

This strategy includes actions to manage the Greater Bilby metapopulation that maintains genetic diversity, maintains evolutionary potential, reintroduces the species to sites within its former range, and insures against extinction in the wild (Table 8). Significantly growing the size of the Greater Bilby population is likely to be required to effectively recover the Greater Bilby in the longer term. Accordingly, opportunities to grow the population size, whilst meeting other objectives should not be discounted on the basis of this plan.

The metapopulation will be managed at three levels with each playing a different role in achieving the metapopulation goals:

- Captive management: receives and intensively manages genetically valuable individuals and amplifies them for distribution to fenced-wild and wild sites; engage in education and advocacy.
- Fenced wild management: provides long-term of permanent sites supporting bilbies as part of the managed metapopulation; provides a source of individuals for dispersal to wild and to other fenced-wild sites.
- Wild management: provides long-term or permanent sites supporting bilbies as part of the managed metapopulation; acts as a source of wild founders for the managed metapopulation; sites receive bilbies generated through the managed metapopulation to support viability.

While not specifically identified as an action, it is important that existing traditional ecological knowledge be considered when implementing this strategy.

Table 8 On-ground strategic actions to manage metapopulation

Action	Description	Relevant site/s	Partners
6a	Develop and implement a single overarching adaptive metapopulation management plan, acknowledging one national genetic management unit. The plan is to identify the number, quality and arrangement of bilbies that are necessary to be resilient to stochastic losses; provides insurance against loss, retain evolutionary potential, provide for supplementation and reintroduction and foster cultural and community involvement in bilby conservation.	Entire distribution of bilby particularly at reintroduction sites which include Scotia (NSW), Mallee Cliffs NP (NSW), Sturt NP (NSW), Currawinya NP (Qld), Arid Recovery (Woomera) (SA), Venus Bay CP (SA), Yookamurra (SA), Thistle Island (SA), Mt Gibson (WA), Peron Peninsula (WA), Pilliga SCA (NSW).	Recovery team, CPSG, ZAA and ZAA Bilby program zoos, state and territory government conservation agencies.
6b	Reintroduce the Greater Bilby to sites within its former range as required, including in introduced predator-free areas, and maintain and enhance such populations in accordance with the metapopulation management plan.	Entire distribution of bilby.	AWC, Save the Bilby Fund, Arid Recovery, Wild Deserts (UNSW), TCSA, state and territory government conservation agencies, ZAA and ZAA Bilby program zoos.
6c	Implement metapopulation management plan including: <ul style="list-style-type: none"> Maintain and enhance existing populations and consolidate or establish new holdings of bilbies as required. Further founder collection, as required. Movement of genetic resources between facilities and wild bilby sites. Amalgamate holdings of bilbies as required. Breeding for release, as required. Maintaining selective pressures and evolutionary potential. Providing for growth in the size of each population, where opportunities exist. 	Entire distribution of bilby particularly at reintroduction sites which include Scotia (NSW), Mallee Cliffs NP (NSW), Sturt NP (NSW), Newhaven (NT), Currawinya NP (Qld), Arid Recovery (Woomera) (SA), Venus Bay CP (SA), Yookamurra (SA), Thistle Island (SA), Mt Gibson (WA), Peron Peninsula (WA), Pilliga SCA (NSW).	AWC, BHA, state and territory government conservation agencies, Arid Recovery, Wild Deserts (UNSW), TCSA, ZAA and ZAA Bilby program zoos, Save the Bilby Fund.
6d	Develop and implement a Captive Management Plan for the captive population to implement the metapopulation and recovery plans.	Zoos and other institutions that have captive populations (see 3.7.1).	ZAA and ZAA Bilby program zoos, AWC, Arid Recovery, Save the Bilby Fund, Wild Deserts (UNSW), TCSA, state and territory government conservation agencies.
6e	When reintroducing bilbies test: <ul style="list-style-type: none"> responses to varying levels of disturbance including low levels of predators, stock grazing and other sources of disturbance. Habitat preferences and factors that limit population size. 	At sites identified by state and territory government conservation agencies, AWC, Save the Bilby Fund, Arid recovery, Wild Deserts (UNSW), including at Mallee Cliffs NP (NSW), Sturt NP (NSW), Newhaven (NT), Currawinya NP (Qld), Arid Recovery (Woomera) (SA), Yookamurra (SA), Pilliga SCA (NSW).	ZAA and ZAA Bilby program zoos, AWC, Arid Recovery, Wild Deserts (UNSW), Save the Bilby Fund, TCSA, state and territory government conservation agencies.

6.3.7 Supporting Strategy: Research strategy

The on-ground management actions listed in sections 6.3.4, 6.3.5, and 6.3.6 incorporate or identify related monitoring and research actions that inform and measure the impact of on-ground actions. Beyond these, there is much to learn about bilbies, their habitat, and the effects and inter-dependencies of factors that threaten the conservation of the Greater Bilby. Research questions not tied to management actions that may reveal information are general research actions that will support the overall recovery of the Greater Bilby and may inform future action (Table 9).

Research that is planned to be conducted on Indigenous-managed land or affect or involve Indigenous people should be consistent with the principles for ethical research outlined by the Australian Institute of Indigenous and Torres Strait Islander Studies (AIATSIS, 2012) and embrace an approach reflecting the reciprocity of two-way science (Box 1).

“It is essential that Indigenous people are full participants in research projects that concern them, share an understanding of the aims and methods of the research, and share the results of this work. At every stage, research with and about Indigenous peoples must be founded on a process of meaningful engagement and reciprocity between the researcher and Indigenous people. It should also be recognised that there is no sharp distinction between researchers and Indigenous people. Indigenous people are also researchers, and all participants must be regarded as equal partners in a research engagement.”

Extract from: *AIATSIS Guidelines for Ethical Research in Australian Indigenous Studies 2012*

The recovery team science sub-committee will identify research priorities and will consider the research priorities identified in Cramer et al. (2017).

While not specifically identified as an action, it is important that existing traditional ecological knowledge be considered when implementing this strategy.

Table 9 Supporting strategies to aid research

Action	Description	Partners
7a	Collate and report on the findings of research and revise actions where necessary.	Recovery team science subcommittee, recovery team, state and territory government conservation agencies.
7b	Establish systems to promote the integration of monitoring and management activities, so that management impact can be measured.	Recovery team science subcommittee, state and territory government conservation agencies.
7c	Facilitate the integration of management and associated research so that research findings influence management practice.	Recovery team, state and territory government conservation agencies.
7d	Develop a research plan that identifies priority areas for additional research. Research topics include: <ul style="list-style-type: none"> • Bilby biology, ecology, population dynamics and genetic diversity. • Predator biology, ecology, interdependencies, control methods and effects on the bilby. • Habitat quality, extent, processes and threats, such as fire and 	Recovery team science subcommittee, state and territory government conservation agencies, research providers.

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Action	Description	Partners
	<p>grazing.</p> <ul style="list-style-type: none">• Factors that influence the spread of fire, and its effects on habitat and food availability.• The effects of, and opportunities associated with, a changing climate.• Interdependencies between predators, fire, water availability and introduced species.• For northern Western Australia, the following research priorities have been proposed (Cramer et al. 2017): refine survey methods; improve understanding of habitat use; improve understanding of the genetic structure of (meta)populations; improve understanding of the threat posed by introduced predators and herbivores; and improve understanding of how fire regimes affect bilby conservation.	



Photo: Tjiturr bilby dreaming site – The Ninu Festival opened with a visit to a bilby dreaming site on the Kiwirrkurra IPA, Tjiturr © Kiwirrkurra IPA.

7 Social and economic considerations

The key social impact of this plan is expected to be positive and arise from the acknowledgement of the role that supporting Indigenous land managers, including Traditional Owners and Indigenous rangers, and Indigenous organisations and communities play in the future conservation of the Greater Bilby across much of its current distribution. The plan acknowledges the value of traditional ecological knowledge, traditional management practices, maintenance of culture and connection to country, and the understanding local communities have of threats and local conditions.

Economic impact may occur to those who require approval to remove or modify bilby habitat and are prevented from doing so, or are required to modify their proposal by a consent authority as a result of this plan. Although this plan indicates the need to understand how agricultural practices (such as grazing) affect bilbies and to consider modifying practices in consultation with land managers if necessary, the economic costs of any such voluntary changes may be significant at the station level but are not expected to be significant at an industry level.

The investments of state and territory governments and conservation organisations such as the Australian Wildlife Conservancy, Bush Heritage Australia, World Wide Fund for Nature and the Save the Bilby Fund in on-ground actions identified in this plan are considered significant economic benefits.

Another social benefit of this plan is that it deals with community concerns about the loss or local extinction of charismatic fauna.



Photo: Demonstrating cat trapping at the Ninu Festival, June 2016 © Kiwirrkurra IPA.

8 Partners and affected persons

Persons likely to be affected by the actions proposed in this plan include Traditional Owners, Indigenous rangers, and Indigenous organisations; Australian Government, state and territory government conservation agencies; land owners and managers; researchers; tourism operators; conservation groups; and wildlife interest groups (Table 10). This list, however, should not be considered exhaustive, as there may be other interest groups that would like to be included in the future or need to be considered when specialised tasks are required in the recovery process.

In addition to the organisations, institutions, and groups identified in Table 10, the conservation of the bilby has relied on (and continues to rely upon) the dedication, skills, and insights of individual champions and researchers who each have worked on the bilby for more than a decade. These key individuals include: Rick Southgate (Envisage Environmental Services), Katherine Moseby (Ecological Horizons) and Rachel Paltridge (Desert Wildlife Services), and Peter McRae and Frank Manthey who founded the Save the Bilby Fund.

Table 10 Partners

Partner	Shortened form
Arid Recovery	AR
Australian Wildlife Conservancy	AWC
Bush Heritage Australia	BHA
Conservation Planning Specialist Group (International Union for the Conservation of Nature)	CPSG
Central Land Council	CLC
Department of Agriculture and Fisheries (Queensland)	DAF
Department of Biodiversity, Conservation and Attractions (Western Australia)	DBCA
Department of Climate Change, Energy, the Environment and Water (Australian Government)	DCCEEW
Department of Environment, Parks and Water Security (Northern Territory)	DEPWS
Department of Environment and Science (Queensland)	DES
Department for Environment and Water (South Australia)	DEW
Department of Planning and Environment (New South Wales)	DPE
Environs Kimberley	EK
Indigenous Desert Alliance	IDA
Kimberley Land Council	KLC
Mulan Aboriginal Corporation	
National Parks and Wildlife Service (New South Wales)	NPWS
Northern Land Council	NLC
Rangelands NRM	
Save the Bilby Fund	STBF
Southern Queensland Landscapes	
Taronga Conservation Society Australia	TCSA
Territory NRM	

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Partner	Shortened form
World Wide Fund for Nature (Kimberley)	WWF
Wild Deserts Partnership (University of New South Wales Centre for Ecosystem Science, Ecological Horizons)	Wild Deserts (UNSW)
Zoo and Aquarium Association	ZAA
ZAA Bilby program zoos: Charleville Bilby Experience, Taronga Western Plains Zoo, Dreamworld, Kanyana Wildlife Rehabilitation Centre, Billabong Sanctuary, Alice Springs Desert Park, Australian Walkabout Wildlife Park, Monarto Zoo, Taronga Zoo, Caversham Wildlife Park, Darling Downs Zoo, Adelaide Zoo, Currumbin Wildlife Sanctuary, Perth Zoo, WILD LIFE Sydney Zoo, Halls Gap Zoo, Ipswich Nature Centre, Featherdale Wildlife Park, David Fleay's Wildlife Park, Cleland Wildlife Park, Tasmania Zoo, Kurunda Koala Gardens, Gorge Wildlife Park, Healesville Sanctuary.	ZAA Bilby program zoos

8.1 Indigenous rangers and groups

At the time of drafting the partners listed in Table 11 were known to be involved in conservation of the Greater Bilby. It should be noted this list is considered an incomplete list of partners that could be involved in the future.

Table 11 Indigenous rangers and groups

Ranger team	IPA/Ranger Group Organisation
Anangu Luritjiku Rangers	Central Land Council
Anmatyerr Rangers	Central Land Council
Bardi Jawi Rangers	Bardi Jawi IPA Bardi and Jawi Niimidiman
Birriliburu Rangers – Birriliburu IPA	Birriliburu IPA, Mungarlu Ngurrarankatja Rirraunkaja Aboriginal Corporation, Bush Heritage Australia
Gooniyandi Rangers	Kimberley Land Council
Jigalong Rangers	Kanyirrinpa Jukurrpa (KJ)
Karajarri Rangers	Karajarri IPA, Karajarri Traditional Lands Association, Kimberley Land Council
Kiwirrkurra Rangers	Kiwirrkurra IPA, Tjamui Tjamu, Desert Support Services
Kunawarrtji Rangers	Kanyirrinpa Jukurrpa (KJ)
Marditja Banjima Rangers	Banjima Native Title Aboriginal Corporation
Murnkurrumurnkurru Gurindji Rangers	Central Land Council
Muru-Warinyi Ankkul Rangers	Central Land Council
Ngaanyatjarra Rangers	Ngaanyatjarra IPA, Ngaanyatjarra Council
Ngurrara Rangers	Ngurrara IPA, Yanunijarra Aboriginal Corporation
Ngururrpa Rangers	Parna Ngururrpa Aboriginal Corporation, Desert Support Services
North Tanami Rangers	Northern Tanami IPA, Central Land Council
Nyangumarta Rangers	Nyangumarta IPA, Nyangumarta Warrarn Aboriginal Corporation
Nyikina Mangala Rangers	Walalakoo Aboriginal Corporation, Kimberley Land Council
Nyul Nyul Rangers	Kimberley Land Council
Paruku Rangers	Parurku IPA, Tjurabalan Aboriginal Corporation, Kimberley Land Council
Parnngurr men	Kanyirrinpa Jukurrpa (KJ)
Parnngurr women	Kanyirrinpa Jukurrpa (KJ)

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Ranger team	IPA/Ranger Group Organisation
Punmu men	Kanyirrinpa Jukurrpa (KJ)
Punmu women	Kanyirrinpa Jukurrpa (KJ)
Warlpiri Rangers	Southern Tanami IPA, Central Land Council
Walungurru Rangers	Central Land Council
Warburton Men Rangers	Ngaanyatjarra IPA
Warburton Women Rangers	Ngaanyatjarra IPA
Warnpurru Rangers	Warnpurru Aboriginal Corporation
Wiluna Martu Rangers	Mantjiljarra Yulparirra, Matuwa Kurarra Kurarra IPA, Tarlka Matuwa Piarku Aboriginal Corporations, Desert Support Services
Yawuru Country Managers	Yawuru Native Title Holders Aboriginal Corporation



Photo: Ninu Festival Group Photo, June 2016 © Kiwirrkurra IPA.

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