Environment Protection and Biodiversity Conservation (National Recovery Plan for the Malleefowl (*Leipoa ocellata*)) Instrument 2024

I, Tanya Plibersek, the Minister for the Environment and Water, make the National Recovery Plan for the Malleefowl (*Leipoa ocellata*) in the following instrument, jointly with South Australia, Western Australia and Victoria.

Dated 27/08/2024

Tanya Plibersek
Minister for the Environment and Water

1 Name

This instrument is the *Environment Protection and Biodiversity Conservation (National Recovery Plan for the Malleefowl (Leipoa ocellata)) Instrument 2024*.

2 Commencement

This instrument commences on the day after it is registered.

3 Authority

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

4 Jointly made recovery plan

The National Recovery Plan for the Malleefowl (*Leipoa ocellata*) in this instrument is jointly made with South Australia, Western Australia and Victoria, as agreed by the following State Ministers:

(a) the Minister for Climate, Environment and Water (South Australia);

(b) the Minister for Energy; Environment; Climate Action (Western Australia);

(c) the Minister for Environment (Victoria).

Australian Government

Department of Climate Change, Energy, the Environment and Water

National Recovery Plan for the Malleefowl

(Leipoa ocellata)

Cataloguing data

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This publication is available at SPRAT EPBC Act Recovery Plans.

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Species Profile and Threats Database (SPRAT) pages for this species is available at Malleefowl (Leipoa ocellata).

Acknowledgement of Country

Acknowledgement of Country Our department recognises the First Peoples of this nation and their ongoing connection to culture and country. We acknowledge Aboriginal and Torres Strait Islander Peoples as the Traditional Owners, Custodians and Lore Keepers of the world's oldest living culture and pay respects to their Elders past, and present.

Images credits

Front Cover: A Malleefowl digging a sandy mound ©Sharon Gillam, DEW, SA.

Back Cover: Malleefowl tracks, Aṉangu Pitjantjatjara Yankunytjatjara (APY) Lands, SA ©Joe Benshemesh, NMRG.

Australian Government

Department of Climate Change, Energy, the Environment and Water

NATIONAL Malleefowl RECOVERY TEAM

NATIONAL MALLEEFOWL Recovery Group Inc.

GOVERNMENT OF WESTERN AUSTRALIA

Department of Biodiversity, Conservation and Attractions

Victorian Malleefowl Recovery Group inc.

Malleefowl Recovery Group

WA MALLEEFOWL RECOVERY GROUP

australian wildlife conservancy

Government of South Australia

Department for Environment and Water

VICTORIA State Government

Energy, Environment and Climate Action

Malleefowl/Nganamara tjukurpa (story) painting ©Natalie Robin, Walalkara Indigenous Protected Area, SA.

This Recovery Plan is dedicated to everyone who cares for and is working to conserve this amazing ancient megapode. Your collective appreciation, sharing of wisdom, and observant monitoring have shaped this plan for recovery. Together, we are making great progress towards ensuring this incredible bird survives for many generations to come.

Ngow
Nggow
Ngau
Naaua
Nganarmara
Ngguoo *Nhawarru* **Ngamurre** *Ngowa*
Anthelkarlwilenhe *Gabiny*
Yungadhu *Gnow*
Warntu Yuunggaay *Ngamerre*
Ngow'wa Ngaua
Lawani **Lawan** Nganamara
Ngaamarra
Yungkay ***Ngauoig***
Unematye
Lauan
Ngama

The number of Indigenous names for the Malleefowl highlights its importance for Indigenous people across Australia. The word mallee comes from the Woiwurrung language in Vic but is also found in other Indigenous languages of Vic, SA and southern NSW (ANU, 2017).

There are at least fifteen names (with a variety of spellings) for Malleefowl used across Australia, represented in this word cloud.

WARNING: Indigenous and Torres Strait Islander viewers are warned that this recovery plan contains images of deceased persons.

Contents

Acknowledgements

A special acknowledgment to Tjilpi Robin’s daughter for granting us permission to use his photo (undertaking tjanpi (spinifex) burns), keeping his legacy alive.
Further text to be included in this section once the plan is finalised after public consultation.

Acronyms

AMPE	Adaptive Management Predator Experiment
DCCEEW	Department of Climate Change, Energy, the Environment and Water
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
APY	Aṉangu Pitjantjatjara Yankunytjatjara
LiDAR	Light Detection and Ranging
NMRG	National Malleefowl Recovery Group inc.
NMRT	National Malleefowl Recovery Team
NRM	Natural Resource Management
NSW	New South Wales
NT	Northern Territory
SA	South Australia
VIC	Victoria
WA	Western Australia

1 Summary

This document constitutes the national recovery plan for the Malleefowl, *Leipoa ocellata*, made under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The plan aims to halt the decline and support recovery of the Malleefowl, and recommends the research and management actions necessary to maximise the Malleefowl's long-term survival in the wild. The objectives of this recovery plan are that by 2033:

- The Malleefowl population is stable or increasing across the species' range.
- The occupancy of habitat by the Malleefowl has been maintained or increased throughout the species' range.
- The genetic integrity of isolated populations is maintained.
- Indigenous organisations, communities and individuals have a greater role in Malleefowl conservation.

The plan outlines on-ground actions to enhance protection and improve or maintain quality, connectivity and extent of Malleefowl habitat, and to manage the impacts of herbivore grazing, fire and introduced predators. These actions are planned to occur within a monitoring framework that measures the impact of management and considers effects of climate change. The plan also includes actions which set out the research necessary to conserve the species and guide governance of the recovery process and engagement of communities in Malleefowl conservation.

Nganamara (Malleefowl, Leipoa ocellata) tracks, A̲nangu Pitjantjatjara Yankunytjatjara (APY) Lands, SA ©Joe Benshemesh, NMRG.

2 Introduction

The Malleefowl, *Leipoa ocellata*, is a large ground-dwelling bird with strong feet and a short bill. The species is the only living representative of the genus *Leipoa* and is one of only three species of mound-building birds, known as megapodes, found in Australia (Firth 1956). The original distribution of Malleefowl covered much of the southern half of the continent from the west coast to the Great Dividing Range in the east (Blakers et al. 1984). Within the past century this range has contracted, particularly in arid areas and at the periphery of its former range as the result of several threatening processes (Blakers et al. 1984; Priddel 1989).

This recovery plan considers the conservation requirements of the Malleefowl across its range. It identifies the actions to be taken to ensure the species' long-term viability in the wild, and the parties that will undertake those actions. This plan seeks to achieve a viable, self-sustaining wild population of Malleefowl capable of persisting through extended poor breeding seasons, and to put in place long-term management arrangements that ensure Malleefowl habitat is appropriately managed. To achieve this outcome, it is intended to resolve uncertainties in the effectiveness of management actions such as control of invasive predators through adaptive management.

The success or failure of management strategies and actions will ultimately be evaluated by their benefits to Malleefowl populations, which will be measured by monitoring programs that are already underway in many regions. These programs are run by stakeholders in each state, consisting largely of volunteers under the guidance of the National Malleefowl Recovery Team.

2.1 Conservation status

Malleefowl numbers have declined greatly over the past century (Benshemesh 2007b). Malleefowl are currently threatened by a range of factors. In many areas, there has been such loss and fragmentation of their habitat that remaining populations are small and isolated, and prospects for their long-term conservation are poor. It has proven difficult to assess the conservation trajectory of Malleefowl across their extensive range except in broad terms.

Nationally, the Malleefowl is listed as **Vulnerable** under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Malleefowl occurs in all mainland states except Queensland and is recognised as threatened wherever it occurs:

- In New South Wales (NSW), the Malleefowl is listed as **Endangered** under the *Biodiversity Conservation Act 2016*.
- In the Northern Territory (NT), the Malleefowl is listed as **Critically Endangered** under the *Territory Parks and Wildlife Conservation Act 1976* and may be extinct there (Kimber 1985, Barrett et al. 2003).
- In South Australia (SA), the Malleefowl is listed as **Vulnerable** under the *National Parks and Wildlife Act 1972 – Schedule 8*.
- In Victoria (Vic), the Malleefowl is listed as **Vulnerable** under the *Flora and Fauna Guarantee Act 1988* (Victorian Department of Energy, Environment and Climate Action).
- In Western Australia (WA), the Malleefowl is listed as **Vulnerable** under the *Biodiversity Conservation Act 2016*.

In addition to the national and state listings, the Malleefowl qualifies as **Vulnerable** under international criteria for threatened species (IUCN 2022 criteria: A2bce+3ce+4bce).

Volunteers training day, Goonoo National Park, NSW ©Melanie Bannerman, NPWS, NSW.

2.2 Role and interests of Indigenous people

The preservation of Malleefowl in central Australia is important both for the species' conservation and because Malleefowl feature in Indigenous mythology and are associated with certain 'Dreaming' sites and trails. Here are some stories which demonstrate the significance of Malleefowl. Others that haven't been included are equally important. A list of some the Indigenous names for Malleefowl is presented in Appendix I.

Why mallee bird lays her eggs in the sand

(From 'Legends of the Birds')

WAYAMBEH a descendant of the original Wayambeh, who was turned into a tortoise, married Kookaburra, a very unusual union. They argued about where their eggs should be laid. Kookaburra (male) argued that they should be in a nest where they can be kept warm, Wayambeh (female tortoise) argued that she couldn't fly and would break the eggs if she sat on them to keep them warm. The couple argued so much when it came time for the turtle to lay their eggs Kookaburra had left. Wayambeh had no choice but to lay her eggs in the sand. She had an interested spectator – Woggoon, the Mallee Fowl who said it was a silly place to lay her eggs. Wayambeh explained she lay them close to the surface where the sun keeps them warm and didn't have to sit on them to keep them warm "See how much trouble we are saved". Woggoon spoke to her husband and said she was going bury her eggs that year. The husband and wife argued all night but the next morning the male bird gave in and helped her to make a mound of leaves, sticks and sand and scraped a hole in which to bury her eggs. After waiting and checking the nest every day eventually *the female was convinced her eggs had died and so dug up the nest to find only eggshell. And then she saw little Malleefowl chicks whom she recognised at once as her own. Ever since then Woggoon has followed Wayambeh's example and has laid her eggs in leaf-mound so they will hatch in the warm earth (Legends of the Birds n.d.).*

A Malleefowl egg in an open mound with two Malleefowl ©Graeme Tonkin, NMRG.

Lyra, the Almanac, and Human Emotions

The story of the Lyra constellation for the Boorong Indigenous people around Lake Tyrell in northwestern Victoria makes for an insightful connection between the location of stars in the night sky and the ability to predict and find a valued food source. One of the stars in the Boorong night sky was called Neilloan. It is named after the Lowan or Loan (Malleefowl). The star is part of a constellation that contemporary astronomers call "Lyra". For the Boorong people, its collection of stars have the general shape of a bird with Malleefowl-like characteristics, including a star in a position that gives the appearance of a large foot or leg issuing from the body of the bird.
The almanac connections between the Malleefowl and the Lyra constellation: "Lyra appears in the southern hemisphere only between March and October, coinciding with the mound building period of the Malleefowl. The behaviours of the Malleefowl is also linked to an annual event in the Lyra constellation. The Lyrids is the name given to meteor showers in this constellation that can be seen in April, and "they remind us of the bits of sand, twigs and other matter flying through the air as the Malleefowl kicks material on or away from the mound". The constellation not only looks like the bird, it behaves like one. Also, as Neilloan fades in the southern sky in October, the loan's eggs will be ready to harvest.

The story of the Malleefowl in the night sky indicates an acute knowledge of the timing of events between cosmos and the bird. Human care and empathy intersect with the Malleefowl's phenology and fecundity, which must be respected, or else it would be lost to the ecosystem. For this reason, some people in the Boorong clan would have had the Malleefowl as their totem. The special empathy with the bird meant not only that they could not eat it, but also that a major role in their life would be to look after its habitat. Telling the story of the Malleefowl in the sky in an account of how to live and how to relate to other beings. There is an emotional astronomy that, once understood, gives to people an intimate empathy with fellow creatures that in turn given them sustenance (Albrecht, 2019).

On Indigenous land in both SA and WA, Malleefowl typically occur at low densities, and the challenges to their conservation are very different from those in the more arable areas of the species range. The recovery effort will depend on Indigenous-led land management due to the Traditional Knowledge, skill and land management practices of Indigenous people in these areas, and their connection to and knowledge of Country on which Malleefowl occur.

In particular, the plan aims to promote the role of Indigenous communities by:

- encouraging traditional land management, particularly in regard to fire;
- encouraging the recording of sightings;
- promoting Indigenous community leadership of science, survey and monitoring; and
- providing access to technical information on Malleefowl ecology, lessons from previous management actions and information and connection to conservation planning and governance.

As major partners in Malleefowl conservation, Indigenous landholders and Traditional Owners will be encouraged to participate in the Recovery Team to inform planning and governance. Nothing in the plan is intended to affect Native Title rights or interests. The relevant provisions of the *Native Title Act 1993* should be considered before undertaking any Future Acts that might affect Native Title Rights. Procedures under the *Native Title Act 1993* are additional to those required to comply with the *Indigenous Heritage Act 1998.*

2.3 Affected interests

Malleefowl have an extensive potential range and occur on a variety of land tenure types comprising Indigenous land, pastoral leases, private land and land managed by State and Federal Governments in the form of national parks, reserves and uncommitted/unallocated Crown Land.

All of these land managers will be involved in the implementation of this plan to some degree. Planned recovery actions include promoting the continuation of Traditional Knowledge and cultural/customary practices relating to Malleefowl and supporting Traditional Owner leadership, research, management and monitoring on Indigenous lands where Malleefowl may occur.

Numerous community groups have been formed throughout southern Australia to help conserve the Malleefowl. Total membership of these group's numbers over 1000 people, of which well over 100 are active in the field. Their role in survey, monitoring, predator control, forming landscape linkages and educating the public has been instrumental in the conservation of Malleefowl. The important contribution of these community groups is encouraged in this plan.

Organisations likely to be affected by the actions proposed in this plan include Indigenous groups, Australian and State Government agencies, particularly those with environmental, agricultural and land planning concerns, the agricultural sector, researchers, conservation groups, national resource managers and the mining sector. 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.

Some representatives from the Oak Valley community behind a Nganamara (Malleefowl, Leipoa ocellata) mound, A<u>n</u>angu Pitjantjatjara Yankunytjatjara (APY) Land, SA ©Samantha Doudle, Oak Valley Ranger Coordinator.

The Malleefowl's contemporary distribution encompasses lands traditionally owned by many Indigenous Australian groups. These include, but are not necessarily limited to:

Western Australia: Amangu, A<u>n</u>angu, Badimia, Ballardong, Kalaamaya, Kaniyang, Koreng, Kuwarra, Malgana, Malpa, Mandjinja, Martu, Minang, Mirning/Ngandatha, Naaguja, Nakako, Nanda/Nhanta, Natingero, Ngaanyatjarra, Ngaatjatjarra, Ngadju/Ngatjumay, Nhanhagardi, Noongar, Nyaki Nyaki, Nyangatjatjara, Pinjarup, Tjalkadtjara/Tjalkanti/Djalgandi, Tjupan, Wadjarri/Wajarri, Wagyl Kaip, Wangkatha, Wawula, Whadjuk, Wiilman, Wilunyu, Wudjari, Yamatji, Yinggarda, Yued/Yuat

South Australia: A<u>n</u>angu , Banggarla/Barngarla/Pangkala, Barkindji, Bindjali/Bodaruwitj, Buandig/Bungandidj, Danggali/Thangkaali, Jardwadjali, Kaurna, Kokatha, Luritja, Meru, Mirning/Ngandatha, Nakako, Nawu/Nauo, Ngadjuri, Ngalia, Ngargad, Ngarrindjeri, Nharangga, Nukunu, Nyangatjatjara, Peramangk, Pitjantjatjara, Wergaia/Maligundidj, Wilyakali/Wiljali, Wirangu, Yankunytjatjara

Victoria: Barapa Barapa, Bindjali/Bodaruwitj, Dja Dja Wurrung, Djab Wurrung, Jardwadjali, Latji Latji, Meru, Ngargad, Tatti Tatti/Dadi Dadi, Wadi Wadi, Wemba Wemba/Wamba Wamba, Wergaia/Maligundidj, Yorta Yorta

New South Wales: Barapa Barapa, Barindji/Parrintyi, Barkindji, Danggali/Thangkaali, Kamilaroi/Gamilaraay, Kureinji/Keramin, Mutti Mutti/Madi Madi, Nari Nari, Ngiyampaa, Tatti Tatti/Dadi Dadi, Wadi Wadi, Wangaaypuwan/Wongaibon, Weilwun, Wemba Wemba, Wiradjuri, Yita Yita, Yorta Yorta.

2.4 Malleefowl Recovery Team

Recovery teams provide advice and assist in coordinating strategies described in recovery plans. They include 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. The National Malleefowl Recovery Team has the responsibility of providing advice and coordinating the implementation of the recovery strategies outlined in this recovery plan. The membership of this Recovery Team (which may change over time) includes, but is not limited to individuals with relevant expertise from Department of Biodiversity, Conservation and Attractions (WA), Department for Environment and Water (SA), Department of Energy, Environment and Climate Action (Vic), Department of Planning and Environment (NSW), Department of Climate Change, Energy, the Environment and Water (Cth), Bush Heritage Australia, Greening Australia, Australian Wildlife Conservancy, National Malleefowl Recovery Group Inc., Western Australian Malleefowl Recovery Group (WA), Victorian Malleefowl Recovery Group (Vic), NSW Malleefowl Recovery Group (NSW) and a community representative (SA).

The National Malleefowl Recovery Team is committed to maintaining existing relationships and cooperation with Indigenous stakeholders and continuing to develop participation of Indigenous people and organisations in the national governance for Malleefowl, with the aim of maximising recognition of the role and knowledge of Indigenous people in the conservation of the species.

2.5 National Malleefowl Recovery Group (NMRG Inc.)

The role of the National Malleefowl Recovery Group Inc. (NMRG) is to manage the volunteer-based national monitoring program and collected data. This role is supported by volunteers and state based Malleefowl Recovery Groups in Vic, WA, NSW, and community volunteers in SA regions, and the A<u>n</u>angu-Pitjantjara-Yankunytjatjara (APY) Lands. The monitoring program provides critical data for the conservation of the species and is important for conservation planning and decision-making. Since the species is widespread across southern Australia, a nationally-coordinated approach to monitoring is critical. This allows species-wide population trends to be determined, and for regional data to be considered within this context.

To ensure robust and reliable population estimates, the NMRG designed and instigated a standardised monitoring program which is coordinated in conjunction with project partners across Australia. The work of the NMRG includes:

- Developing and adapting scientifically rigorous monitoring methods
- Maintaining monitoring protocols and manuals for use by volunteers and project partners
- Delivering training events for monitoring and data management

- Liaising and collaborating with volunteer groups
- Providing ongoing technical support to monitors and volunteers
- Maintaining the smartphone app used for monitoring
- Error-checking and validating all monitoring data
- Maintaining the National Malleefowl Monitoring Database
- Establishing standardised protocols for adopted technologies (e.g. LiDAR, drones)
- Working with university researchers, industry and regional, state and federal government to ensure data are suitable for management and decision-making
- Creating educational materials
- Collating management and environmental data in order to understand Malleefowl population trends
- Trending and periodically undertaking analyses and reporting results
- Analysing regional and national data to determine population trends
- Reporting regional Malleefowl population trends to each partner NRM agency and to the state and federal governments each year

The data gathered at a regional level underpin the ability to supply local and national trends, for which reason the NMRG's aim is to work collaboratively with all NRM agencies, national parks managers, Indigenous ranger groups and conservation organisations that manage land within Malleefowl distribution.

2.6 Adaptive Management Predator Experiment (AMPE)

The Adaptive Management Predator Experiment (AMPE) draws on the data from a subset of sites monitored under the volunteer-based national monitoring program mentioned above, alongside supporting government and private organisations. The initial aim of the Malleefowl AMPE is to learn about the effect of fox and cat reduction on Malleefowl breeding activity by establishing a network of control and treatment sites (Hauser et al. 2019) to be monitored alongside existing long-term monitoring sites. Introduced predators are managed in and around treatment sites, while nearby control sites are left unmanaged. This arrangement will help tease apart the effect of fox and cat control from other environmental factors that might cause a change. Once resolved, the experiment can be modified to learn about the effectiveness of other actions as conservation strategies, such as fire or herbivore management (Southwell et al. 2018) or the complete exclusion of feral predators (e.g. Smith et al. 2020).

2.7 Monitoring

Monitoring in semi-arid areas:

Monitoring populations involves obtaining reliable and repeatable measures of Malleefowl numbers over time in order to measure changes in population size and distribution. Malleefowl are shy and elusive birds, making counting of the birds themselves very difficult. However, their mounds are conspicuous and monitoring breeding activity provides a reliable means of measuring the abundance of breeding birds in an area.

In order to establish the abundance of breeding birds in an area, a monitoring site is established by thoroughly searching a chosen area for all Malleefowl mounds, both active and inactive. Areas are either searched on ground, or from the air using LiDAR (Light Detection and Ranging) or photogrammetry. The advantage of LiDAR is that it shows vegetation as green dots and has great potential in mapping habitat structure. Details are provided in the National Malleefowl Monitoring Manual. The location of every mound that is found in an area is accurately recorded, thereby enabling monitors to return to the mounds for annual monitoring.

The monitoring of Malleefowl sites is the agreed method for determining Malleefowl breeding trends on a national scale. Historically, Malleefowl sites have been set up in areas where mounds have been known to exist, and/or where opportune sightings of birds have been recorded. Sites are blocks of habitat, normally covering an area of 2 to 4 km^2, a size large enough to provide an estimate of breeding density, yet still small enough to be effectively monitored. Sites monitored by air (e.g. helicopter) are generally much bigger and may be in the order of 10 km^2 to 20 km^2. The size of a monitoring site can be influenced by a number of factors including the density of mounds, access, tenure and interest.

As Malleefowl tend to renovate old mounds rather than construct new mounds afresh each year (Frith 1959, Benshemesh 2007c), each old mound is a potential site for breeding, and annually checking the known mounds each spring/summer provides a good estimate of the trends in breeding numbers at each site. Nonetheless, new mounds are occasionally built by the birds and a thorough re-search of monitoring sites at least every 5 to 10 years is needed to capture these and ensure accurate estimation of breeding numbers.

The primary aim of the Malleefowl monitoring program is to track changes in the number of breeding birds inhabiting specific areas. Observers (mostly volunteers) examine and categorise all the known mounds at each site as either active, i.e. currently used as an incubator, or not active. To enable vetting of records and the detection of errors in judging the activity of the mound, the size, shape and appearance of mounds is also described each time a mound is visited. These descriptors have been defined and are included in the National Malleefowl Monitoring Manual. The resulting protocols have been used in both Vic and SA from the early 1990s, in WA since 2004 and NSW since 2014.

Monitoring in arid areas:

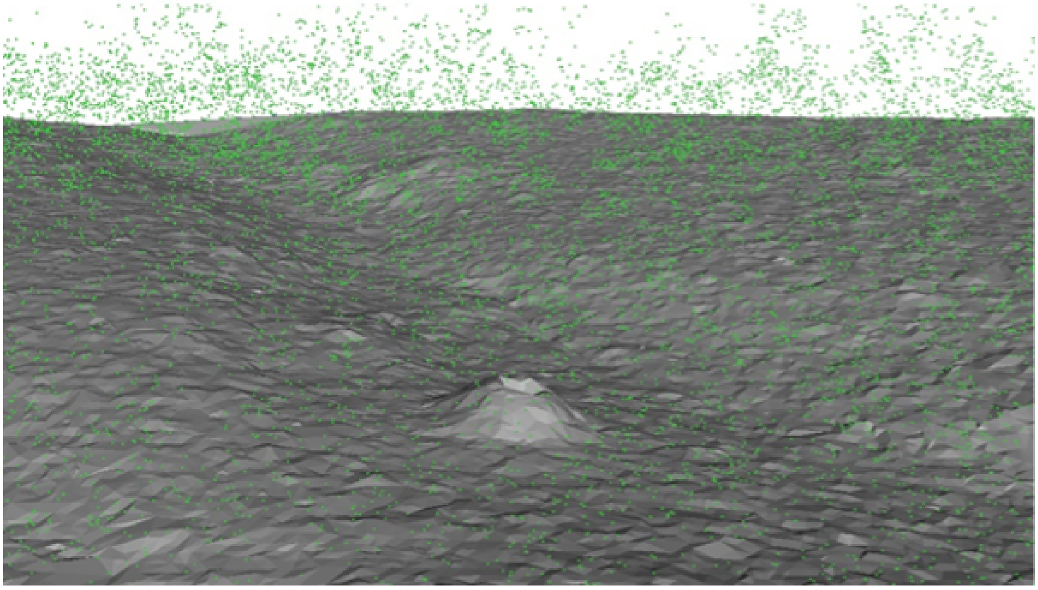
Monitoring Malleefowl in arid regions presents distinct challenges. These regions tend to be very remote, and the Malleefowl typically occur at very low densities making it onerous to thoroughly search areas large enough to encompass several active mounds. Consequently, mound-based forms of monitoring, as used in semi-arid regions, are not suitable in the arid zone. Rather than basing monitoring on the activity at mounds, a more efficient approach in the arid zone is to search areas for the distinctive footprints (or tracks) of Malleefowl. The sandy and open substrates typical of arid areas inhabited by Malleefowl provide excellent opportunities for tracking which are not available in semi-arid areas. Malleefowl footprints are distinctive and are a rich source of information on where Malleefowl have been (Benshemesh et al. 2014). Provided the weather is dry and not too windy, their tracks are likely to accumulate over several days. The abundance of prints in an area provides a useful and efficient indicator of the birds' activity in that area. Where birds are resident, their prints are likely to consistently occur through their home range (1–4 km^2). However, the prints of birds that have merely passed through an area are likely to be less prevalent in space and time.

Long Walk survey method:

A 'Long Walk' method is being utilised by Aṉangu, the Traditional Owners of the Maralinga Tjarutja Lands (MTL) in the eastern Great Victoria Desert, South Australia. Pairs of observers are dropped off by vehicle every 2 km along established tracks and roads. Each pair then walks the 2 km stretch to the next drop-off, searching for Malleefowl prints parallel to and about 50–150 m from the road. The number of pairs of observers varies with their availability, but the technique enables large distances to be covered quickly (e.g. five pairs of observers searched 10 km in one hour). Linear transect walks of 16–28 km length alongside existing tracks provide a useful means of broadscale survey (Benshemesh et al. 2014).

Slow Drive method:

Slow Drive method involves searching for Malleefowl prints from vehicles driving along disused vehicle tracks (e.g. 14 km stretch) by driving at about 10 km/hr while observers spot Malleefowl tracks from the windows (Benshemesh et al. 2014).
Whatever technique is considered, a critical component in its successful application will be how the technique is received by the local Indigenous communities.



A 3D computer image of a Malleefowl mound generated through Light Detection and Ranging (LiDAR) ©Anditi.

Measuring a Malleefowl mound, Ninghan, WA ©Todd Erickson, University of Western Australia.

Malleefowl tracks in red desert sand, APY Lands, SA ©Joe Benshemesh, NMRG.

3 Background

3.1 Species description

The Malleefowl is a large ground-dwelling bird with strong feet and a short bill. The head and neck are mostly grey, with a dark stripe extending down the foreneck from the throat to the upper breast. The underparts are mostly creamy-coloured, and the upperparts are more striking. The upperwings are a complex combination of mottles, barring and variegations of grey, cream, black and rufous. The bill is blackish and the legs and feet are pale greyish. The sexes are similar (Birdlife n.d.). Expert Aṉangu trackers are able to tell the sex of a Nganamara (Malleefowl) from its tjina (tracks) (APY Land Management, n.d).

3.2 Distribution

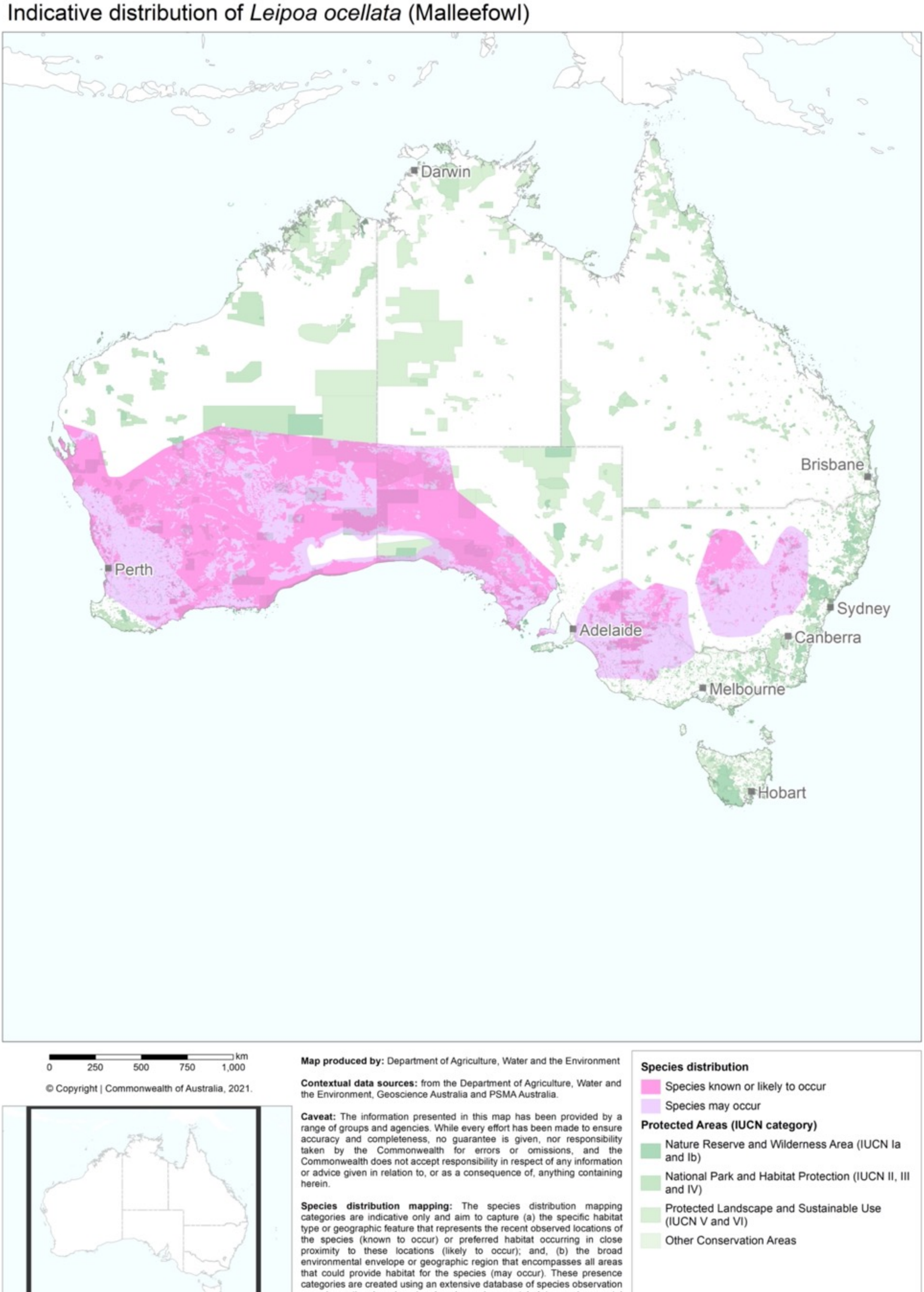
The original distribution of Malleefowl covered much of the southern half of the continent from the west coast to the Great Dividing Range in the east (Barrett et al. 2003; Garnett et al. 2011) and the species was widespread in every mainland state except Queensland (Figure 1). The species occurred in more than a quarter of the 80 biogeographic regions of Australia (as defined by Thackway & Cresswell 1995) and ranged as far north as the Tanami Desert in the Northern Territory (Kimber 1985), and to within 60 km of Melbourne in the south (Campbell 1884, Campbell 1901, Mattingley 1908). While there have been various searches of historical records for the original distribution of Malleefowl (Blakers et al. 1984, Kimber 1985, Gara 1989), little systematic effort has been made to understand the nature, ownership and sensitivity of Traditional Knowledge (but see Kimber 1985; Copley & Williams 1995; Richards & Short 1996; Copley et al. 2003). This Traditional Knowledge includes accounts of the bird's range, habits and habitat requirements, and is fast disappearing. A list of some Indigenous names for Malleefowl is presented in Appendix I, and it is hoped that this recovery plan may encourage further work in this field.

Within the past century, the range of Malleefowl has contracted, particularly in arid areas and at the periphery of its former range. For example, an assessment of records of the species up to 2005 (Benshemesh 2007b) found that, of the 194 one-degree grid cells across Australia in which the species has been recorded at some time in the past, only 70% had Malleefowl records after 1981, and 53% after 1992. Declines were particularly apparent in arid areas and the species may be extinct in the NT where it was last recorded in 1965. Further, from 1981 to 2005 the species' range appears to have contracted by 22% in eastern Australia (NSW and Vic), 26% in SA and 28% in WA (Benshemesh 2007b). In WA, Parsons et al. (2008) examined a larger dataset and provided similar estimates (30%) for the contraction of the species' range since 1981. Parsons et al. (2008) cautioned, however, that estimates of range contraction using presence-only data may be unreliable in remote areas as there is a high likelihood of the species being present but undetected. In the past decade there have been efforts in both SA and WA to collate records in the Great Victoria Desert (Benshemesh 2007a; Department of Parks and Wildlife 2016) and to undertake surveys on Indigenous lands (Bellchambers 2007; Benshemesh et al. 2014; Pennington et al. 2014; Benshemesh 2017). These efforts have greatly increased knowledge of the current distribution of Malleefowl in these areas.

Malleefowl crossing a sandy wheel track, ©Michael Gooch, NMRG

In the semi-arid zone, where Malleefowl densities are highest, the clearing of habitat has been the major cause of the marked decline in the distribution of the species. Apart from removing much of the habitat supporting high densities of the species, this clearing has fragmented the distribution of Malleefowl. Over much of its range the species now persists in small patches of habitat that are inadequate for its long-term conservation without careful planning and management.

Figure 1 – Indicative current distribution of Malleefowl (*Leipoa ocellat*a)



3.3 Population trends

The most comprehensive analysis of Malleefowl population trends across Australia was undertaken from monitoring data collected from 1989–2017 across 127 sites (Benshemesh et al. 2020). The average monitoring period of these sites was 14.4 years. Analysis of these data showed a decline in Malleefowl breeding numbers of 4.8% per year in SA and 2.1% per year in WA. Breeding numbers were stable in Vic and increased by 4.8% per year in NSW, although the NSW result was uncertain due to limited monitoring data and was considered not representative of Malleefowl in that state. This analysis found strong evidence for a positive effect of winter rainfall and time since fire on breeding numbers, and a positive interaction between time since fire and the proportion of a site burnt. While the index of fox abundance decreased as baiting effort increased, there was little evidence for this benefiting malleefowl. A more localised analysis of Malleefowl population trends at six sites on the Eyre Peninsula, SA, showed breeding activity was positively associated with increased cumulative rain in the previous 2 years, lower average maximum temperatures in the winter, higher-than-average Southern Oscillation Index (i.e. more rain) two years before breeding and greater winter vegetation cover, suggesting that moisture and vegetation cover are important for higher breeding activity in Malleefowl (Stenhouse and Moseby, 2022).

3.4 Biology and ecology

3.4.1 Longevity

In captivity, Malleefowl reach breeding age at three to four years (Bellchambers 1916; K Brumby pers. comm. cited in Benshemesh 2007b; M Johnson pers. comm. cited in Benshemesh 2007b). Once birds reach breeding age, they appear to be long-lived, although data are limited, anecdotal and of uncertain generality:

- Frith (1962a) noted that no banded birds disappeared during his eight-year study unless an area was cleared.
- In captivity a male bred at the Adelaide Zoo lived until at least 1998 when he was at least 19 years old (and perhaps much older) (M Johnson & M Craig pers. comm. cited in Benshemesh 2007b).
- An unbanded but recognisable pair of Malleefowl was known to breed for 25 years at the Little Desert in Vic (K Hately pers. comm. cited in Benshemesh 2007b).
- Also at the Little Desert, an unbanded but recognisable pair was reported to breed over 17 years, although they apparently found other mates and did not breed together towards the end of this period (W Reichelt pers. comm. cited in Benshemesh 2007b).
- At Yalgogrin in NSW, of 25 breeding Malleefowl that were banded in 1988, four were still alive 12 years later (Priddel & Wheeler 2003). Although the population declined markedly during the study, the average time that Malleefowl were known in the study was 7.5 years. The age of birds when they were first captured and marked as breeding adults was unknown.

These observations suggest an average breeding life in the field of about 15 years. However, much higher mortality than suggested above has been recorded amongst adults in a SA study (Booth 1987a). In that study, several adult deaths occurred over a short time and were attributed to predation by foxes. These birds were recaptured and handled every month and the resulting stress might have contributed to the high mortality. In captivity, the condition and behaviour of Malleefowl may be affected for several weeks after handling (C Sims pers. comm. cited in Benshemesh 2007b; K Brumby pers. comm. cited in Benshemesh 2007b). In the wild, the behaviour of radio-tagged birds is often atypical and erratic for a day or two after capture and handling (Benshemesh 2007b).

3.4.2 Diet

Malleefowl are generalist feeders. Various anecdotal reports and studies have described the diet of Malleefowl as consisting of the seeds, flowers and fruits of shrubs (especially legumes), herbs, invertebrates, tubers and fungi (Barker & Vestjens 1981; Booth 1986; Brickhill 1987a; Kentish & Westbrooke 1994; Harlen & Priddel 1996; Reichelt & May 1997; Harold & Dennings 1998). These studies, and the differences between them, indicate that Malleefowl diet is characteristically variable and that different foods are important at different times and locations. For example, Frith (1962a) observed the diet of adults throughout the year as mostly seeds and fruits of shrubs (73%), particularly of acacias, whereas in other studies seeds from introduced herbs and crops have been predominant in the summer (Booth 1986; Brickhill 1987a; Kentish & Westbrooke 1994; Waag 2004), and herbs and fungi predominate through the cooler months of the year (Benshemesh 1992; Reichelt & May 1997; Harold & Dennings 1998). In habitats bordering croplands, Malleefowl are often observed feeding on fallen grain at the edges of uncleared habitat and up to 100m or so into cropland, and these foods may be crucial to the persistence of the birds in small reserves (Brickhill 1987a; Storr 1991; Copley & Williams 1995). GPS tracking of three adult Malleefowl living within 300 m of cropland showed that these three Malleefowl were closely tied to patches of native vegetation (at least 97.5% of their time was spent in native vegetation), only moving up to 250m across cleared land and making very little use of cleared agricultural land, mainly before and during harvest (Stenhouse and Moseby, 2023).

In general, the diet of chicks is thought to be similar to that of adults, although observations have been mostly restricted to summer. During this time, free-ranging chicks have been observed eating insects and the seeds from both shrubs and herbs (Frith 1962b; Benshemesh 1992; Waag 2004). While a regular supply of food throughout the year is clearly important for the birds' persistence in an area, occasional super-abundance of foods probably benefits the survival of chicks and may be important for recruitment of young into the adult population. In one observational study, over half the diet in some months comprised fallen lerp, a food that had not previously (or subsequently to any degree) been recorded in Malleefowl diets (Benshemesh 1992). Lerp are the secreted shields of sap-sucking psyllid insects and are high in sugars and starch. While usually rare, lerp occasionally occurs in very high numbers (Beveridge 1884). The occasional availability of such super-abundant foods may greatly enhance chick survival as their mortality from stress and predation is likely dependent on food supply.

Food resources for Malleefowl are typically varied, transient and patchily distributed (Harlen & Priddel 1996) reflecting the highly irregular rainfall and inherent patchiness of the habitats they occur in. In particular, a diversity of food shrubs, rather than abundance of any one species, is probably critical to ensure continuity of food for the birds during lean times such as droughts (Harlen & Priddel 1996).

3.4.3 Movement patterns and habitat use

Malleefowl mostly move about their home-range by foot, and rarely fly except when they are disturbed or to roost in the canopy (Frith 1962b). Breeding birds tend to be sedentary, nesting in the same general area year after year (Frith 1959; Benshemesh 1992). Nonetheless, a pair sometimes moves several kilometres between nesting seasons, the reasons for which are not known (Frith 1959). Home-ranges do not appear to be defended, although in the vicinity of its nest the male is vigorously aggressive toward other Malleefowl except its mate (Frith 1959). Radio-tracking studies (Booth 1987b; Benshemesh 1992) have shown that over the course of a year the birds may range over one to several square kilometres and that home-ranges overlap considerably. During the breeding season, males spend most of their time in the vicinity of their mounds and consequently, male home-ranges are usually much smaller than those of their mates at these times and may rarely overlap with other males. The male and female of a pair spend most of their time together outside the breeding season and hence their ranging behaviour is similar at these times. Stenhouse and Moseby (2023) also found that breeding birds were more sedentary, i.e. moved less per day and hour, had smaller home ranges, did not undertake any long-range movements and remained closer to the mound than non-breeding birds. In contrast, non-breeding home ranges increased sixfold, daily displacement (directional movement) doubled and the average distance to mound increased tenfold. Non-breeding Malleefowl in large native vegetation patches recorded total range lengths of up to 2 km and daily movements of up to 10km. In comparison one bird stayed within a 100ha patch of isolated native vegetation and bred each year for 5 years.

Various anecdotal reports suggest Malleefowl use corridors of relatively thick vegetation when dispersing through open landscapes. These include sightings of single birds (D Martin pers. comm. cited in Benshemesh 2007b; S Dennings & K Vaux pers. comm. cited in Benshemesh 2007b) and pairs (K Willis pers. comm. cited in Benshemesh 2007b) walking along wooded strips of vegetation along roadsides several kilometres from the nearest remnant of native scrub. Similarly, birds have been reported to use strips of dense unburnt vegetation when dispersing through an otherwise burnt landscape (Benshemesh 1992). Malleefowl chicks are capable of dispersing widely almost immediately after emerging from their nests and do not seem confined to particular habitat types. Mean dispersal rates of over 600m per day have been measured for newly hatched chicks in a radio-tracking study, with some chicks averaging over two kilometres per day (Benshemesh 1992). In this study, dispersing chicks readily moved out of the unburnt habitats in which they were released and into recently burnt mallee and open woodlands with little cover. Some chicks settled in small (2–8ha) areas of burnt or unburnt mallee habitat where they found food and at least some unburnt trees for roosting.

While the movements of chicks and their apparent disregard for habitat boundaries may facilitate their dispersal and potential to recolonise patches of habitat, it is possible that recruitment in small reserves may be unsuccessful if chicks attempt to cross cleared land.

3.4.4 Breeding

Malleefowl show little sexual dimorphism and are generally monogamous, probably pairing for life (Frith 1959, Frith 1962b). However, a single case of polygyny has been recorded in which two females laid eggs in separate mounds tended by the same male (Weathers et al. 1990), and there is genetic evidence of extra-pair paternity and of egg-dumping (Cope et al. 2014). Malleefowl tend to breed annually except in drought years (Frith 1959, Booth & Seymour 1983). The mound comprises a large mass of sand, usually 3–5 metres in diameter and up to one metre high, in which up to a cubic metre of moist litter is buried. The construction of this incubator-mound involves several months of intermittent work (autumn to spring) by both members of a pair, but when the mound is completed (early spring) the sexes lead mostly separate lives (Frith 1959). The male then spends several hours most days maintaining the condition of the mound and regulating the incubation temperature, while the female spends most of her time feeding for egg production and may only visit the mound to lay. Early in the breeding season the heat for incubation of the eggs is produced by microbial decomposition of the litter, but late in the season heat from the sun is also utilised (Frith 1956). The main function of the litter incorporated into the mound appears to be to enable the birds an early start to egg laying. Successful mounds that have been built without leaf litter have been recorded (Frith 1959; P Burton pers. comm. cited in Benshemesh 2007b) but these appear to be rare and are built in early summer rather than spring.

Egg laying usually begins in September and an egg is laid every 5–9 days until mid to late summer (Frith 1959; Benshemesh 1992; Priddel & Wheeler 2005; Ryan-Colton et al. 2011; Hedger 2014, Blythman 2021). The incubation period of eggs varies with temperature but is about 60 days at typical nest temperatures (Frith 1959; Vleck et al. 1984; Booth 1987b). Seven detailed studies have been conducted on the breeding success of Malleefowl, all of which were in south-east Australia (Frith 1959; Booth 1987b; Brickhill 1987b; Benshemesh 1992; Benshemesh & Burton 1997; Priddel & Wheeler 2005; Ryan-Colton et al. 2011). Average clutch size varied between years and localities but was often 15–25 eggs of which about 60–80 % hatched unless a high proportion of mounds were disturbed by predators (Frith 1959; Benshemesh & Burton 1997), unseasonal weather conditions (Brickhill 1987b) or drought. Much of the variation in clutch size is due to the duration of the egg-laying season, which is thought to depend on food supply and the onset of very hot weather. Egg size varies considerably both between years and studies, and there is some evidence that egg size is related to the survivorship of chicks (Benshemesh 1992). The availability of food (Frith 1959; Booth 1987b; Priddel & Wheeler 2005; Hedger 2014) and water balance (Benshemesh 1992) are possible causes for this variation in mean egg sizes in populations, but the relationships are not clearly understood.

Chicks typically begin hatching and emerging from mounds in November, and although hatching may continue until March in some seasons, most chicks usually emerge from mounds before January (Frith 1959; Benshemesh & Burton 1997; Priddel & Wheeler 2005). Chicks hatch buried with up to a metre of sand above them, and their unaided struggle to the surface may take up to 15 hours (Frith 1959; Frith 1962b). The chicks receive no parental care after hatching, but like other megapodes can thermoregulate efficiently (Booth 1984; Booth 1987c), run and feed themselves almost immediately and fly within a day (Frith 1959; Frith 1962b). Mortality of chicks is very high over the first few weeks after hatching: radio-tracking studies have recorded mortality at about 80 % over the first ten days or so (Priddel 1989; Priddel 1990; Benshemesh 1992), with most chicks succumbing to predators or metabolic stresses such as starvation. Thereafter, mortality declines (Benshemesh 1992) but may nonetheless be high (see Predation section (4.2.6).

Malleefowl chick emerging from shell in mound ©Joe Benshemesh, NMRG.

3.4.5 Habitat

Malleefowl occur in a wide range of habitat types; common elements include a sandy substrate with trees 3–8m in height and a shrub layer providing horizontal cover. Habitat critical to the survival of the species is known only in broad terms (see section 3.4.6 below). Nonetheless, mappable habitat models have been developed for Malleefowl and other threatened species in the Murray Mallee of eastern Australia (Clarke 2005). These models used Malleefowl sightings and GIS data on landforms, habitat type and fire history to develop statistical and spatially explicit maps of the broad habitat preferences of the species. In the WA Wheatbelt, Parsons (2008b) has created statistical models of Malleefowl occurrence in remnants within the Wheatbelt, and these models have been applied to prioritise management initiatives (Short & Parsons 2008).

All populations and areas occupied by Malleefowl are considered of equal importance for the protection and recovery of the Malleefowl. This is despite any variability of Malleefowl density, population size, conservation challenges relevant to the area, or other factors that may be perceived as discounting the relative importance of an area or population.

Malleefowl still occur over most of their range, and although populations tend to be sparser in areas with low or highly variable winter rainfall, this is compensated by these areas being extensive. Conversely, Malleefowl densities are highest in remnants of habitat within the wheatbelts, but these areas are usually small and fragmented and will require intensive management in the long term to retain the species.

3.4.6 Habitat critical to survival

The Malleefowl's extensive distribution encompasses a variety of climatic conditions and geomorphological and biological features and systems. Malleefowl habitat consequently varies across the distribution, is incompletely known and has low certainty. Malleefowl habitat has been described for some locations within the distribution, but these present an incomplete understanding of the habitats likely to be critical to the survival of the Malleefowl.

The Malleefowl is found principally in the semi-arid to arid zone in shrublands and low woodlands dominated by mallee (Frith 1962a, Frith 1962b) and associated habitats such as broombush (*Melaleuca uncinata* complex (Woinarski 1989b, Woinarski 1989a)) and Scrub Pine (*Callitris verrucosa*). Malleefowl also occur in red Ironbark (*Eucalyptus sideroxylon*) woodland at the eastern limit of their distribution (Korn 1989) and in brown stringybark (*E. baxteri/E. arenacea*) woodland in the south of Vic and SA. In WA they are also found in some shrublands dominated by Acacia and occasionally in woodlands dominated by eucalypts such as wandoo (*E. wandoo*), marri (*Corymbia calophylla*) and mallet (*E. astringens*) (Storr 1985b; Storr 1985a; Storr 1986; Storr 1987; Storr & Johnstone 1988; Benshemesh et al. 2008; Parsons 2008a; Parsons 2008b).

In central Australia, Malleefowl occurred through large areas of mulga (*Acacia aneura*) (Frith 1962a; Kimber 1985). Mulga has been split into numerous species, and of those in the Aṉangu - Pitjantjatjara-Yankunytjatjara Lands (APYL) the Malleefowl seem to prefer the smaller desert mulga (*A. minyura*) (G Wikilyiri pers. comm. cited in Benshemesh 2007b; R Kankanpakantja pers. comm. cited in Benshemesh 2007b; J Benshemesh pers obs.). Of the four sites at which the ranging of Malleefowl has been studied in desert mulga in the APYL in the north-eastern Great Victoria Desert, the birds foraged in adjacent sandplain areas (Benshemesh 1997) where foods were more common. Malleefowl also occur in denser mallee, red mallee (*E. socialis*), sharp-cap mallee (*E. oxymitra*), and blue mallee (*E. gamophylla*), although by southern standards these habitats are very open. Typically, these mallee areas have an understorey of hard spinifex (*Triodia* *basedowii*) or other *Triodia* species, and shrub thickets on the ridges where umbrella bush (*A. ligulata*) and other seed-bearing shrubs are often common.

The habitat requirements of Malleefowl anywhere in Australia are poorly understood and have as yet received limited study. A sandy substrate and abundance of leaf litter are clear requirements for the construction of the birds' incubator-nests (Frith 1959; Frith 1962a). Densities of the birds are generally greatest in areas of higher rainfall and on more fertile soils and where shrub diversity is greatest.

The floristic and structural requirements of the species are not well understood and have been examined in only two studies of limited scope. Frith (1962a) found that breeding densities in SW NSW were highest where there were numerous food plants (especially leguminous shrubs and herbs), a dense canopy and an open ground layer, and that Malleefowl abundance in livestock grazed areas was only about a tenth that of ungrazed areas. In Vic, Benshemesh (1992) examined Malleefowl breeding densities at 12 sites in relation to habitat structure and the density of food plants. Dense canopy cover was the most important feature associated with high breeding densities. The abundance of those shrubs that may provide an important food source, such as acacias, was poorly correlated with breeding density, suggesting that this resource was not limiting the populations examined. Fire history was also important: the birds preferred old growth (i.e. long unburnt 40+ years) mallee. In SA, GPS tracking data and ground-based vegetation surveys on the Eyre Peninsula show that fine-scale Malleefowl habitat selection is mainly driven by canopy height and to a lesser degree by a preference for certain plant species (Stenhouse 2022). This highlights the importance of micropatches of mature mallee, possibly as roosting sites or as refuges from heat and possibly predators.

Habitat suitability modelling has been applied to Malleefowl in reserve systems in the Murray mallee of NSW, SA and Vic (Clarke 2005). This study used sightings of Malleefowl and data on landforms, general habitat type and fire history to develop a statistical model of the broad habitat preferences of the species. In particular, habitats on sandy substrates that support *Triodia* were of greatest importance (e.g. Woorinen and Red swale mallee sands). Chenopod mallee, which typically forms on heavy soils, and heath-dominated habitat, which usually forms on nutrient-poor sand (e.g. Lowan sands), were among the least preferred mallee habitats for Malleefowl.

In WA, Parsons (2008b) examined the distribution of Malleefowl within the Western Australian Wheatbelt. Malleefowl distribution was associated with landscapes that had lower rainfall, greater amounts of mallee and shrubland that occur as large remnants, and lighter soil surface textures. At a finer scale, Malleefowl occurrence was associated with mallee/shrubland and thicket vegetation with woodland representing poor habitat for the species. Parsons also examined the occupancy of small remnants in the wheatbelt and found that remnants occupied by Malleefowl typically possessed a greater amount of litter, greater cover of tall shrubs, greater abundance of food shrubs and a greater soil gravel content than those that were not occupied.

The areas of habitat critical to the survival of the Malleefowl are unable to be spatially delineated.

Malleefowl habitat, Patchewollock, Vic ©Michael Gooch, NMRG.

3.4.7 Malleefowl habitat and fire

Mallee habitats are the stronghold for Malleefowl and are considered amongst the most susceptible to uncontrollable broad-scale fire of Malleefowl habitat types (Gardner 1957; Noble 1984). Despite active suppression efforts, mallee fires can cover extremely large areas. For example, well over one million hectares of mallee was burnt in NSW during the 1974/5 fire season (Noble et al. 1980; Noble 1984). Large fires of tens or even hundreds of thousands of hectares occur at approximately 20-year cycles in mallee in south-eastern Australia (Cheal et al. 1979; Leigh & Noble 1981; Day 1982), usually following widespread and effective rainfall which produces a high abundance of ephemeral fuels. Such fuel conditions may make even habitats with a low potential for carrying a fire highly flammable.

The effects of fire on Malleefowl populations are twofold. Firstly, large fires may be catastrophic for Malleefowl as the birds are poor fliers and do not appear to disperse widely as fires approach (Benshemesh 1990, 1992a). Thus, large fires probably kill most birds in their path. Fragmentation of the landscape further exacerbates the catastrophic effect of wildfire on Malleefowl populations. Fires that burn entire habitat patches may cause the local extinction of Malleefowl where surrounding areas no longer provide safe haven or a source of recolonisation.

Secondly, fire in the mallee typically kills and removes all parts of vegetation above the surface and thus fire has a major influence on the structure and floristic composition of habitats occupied by Malleefowl. The effects of fire on Malleefowl populations appear to be severe and long-lasting. After extensive fires, Malleefowl may not breed for up to 17 years (Tarr 1965; Cowley et al. 1969), possibly due to a shortage of litter material for nesting or greater exposure to predators (Priddel & Wheeler 1997). In general, malleefowl often take 15-20 years to breed again at sites completely burnt by fire but may persist if even small patches remain unburnt. Breeding in areas burnt within 10 years occasionally occurs but is rare unless unburnt patches occur nearby (Benshemesh pers. comm. 2023). There are several records of Malleefowl breeding within six years of habitat being burnt (National Malleefowl Monitoring Program), although this appears an exception rather than the norm (Benshemesh pers. obs.). Somewhat ironically, the accumulated litter that is used in nesting is also a major fuel-bed in most mallee habitats (Noble 1984), so that even in years of average rainfall some mallee habitats may be able to sustain large fires every 10–20 years (Leigh & Noble 1981).

Numerous authors have suggested that fire may benefit Malleefowl in the longer term as relatively short-lived shrubs, such as acacias, increase in abundance after fire and are food sources for the birds. However, this does not appear to be the case. Benshemesh (1990; 1992a) found breeding densities at four sites burnt 20–30 years previously to be only about one third that of neighbouring sites that had remained unburnt for at least 40 years, and this probably reflected the species' habitat requirements. Woinarski (1989a; 1989b) also observed fewer birds in habitat burnt within the past 40 years than in long-unburnt (60–80 years) habitat. As Woinarski's study involved counting birds rather than estimating breeding densities, his results further suggest that substantial non-breeding populations do not exist in younger age-classes of mallee. More recently, Clarke (2005) used habitat suitability modelling to examine fire history preferences of Malleefowl and other threatened mallee birds within reserve systems in the Murray mallee of NSW, SA and Vic. This study used recent sightings of Malleefowl and GIS data to develop a statistical model of the preferences of the species and also found that there was a strong preference by Malleefowl for older age classes (>20 years) and avoidance of younger classes. Connell et al. (2017) analysed the relationship between fire and Malleefowl occupancy in the Murray Mallee and found the strongest association at ~20–50 years since fire. Parsons and Gosper 2011 found that the WA wheatbelt Malleefowl habitats developed structural attributes of importance to Malleefowl between 25 and 45 years, and some habitat is likely to remain suitable for Malleefowl for long periods in the absence of fire. A general pattern is nonetheless evident: habitat older than 20 years is generally preferred, and in some cases might decline in suitability after 40 -60 years, although this may vary with habitat and circumstances across the range of the species (Benshemesh pers. comm. 2023).

The reasons for the slow recovery of Malleefowl populations after fire, despite increased abundance of seed-bearing shrubs and after substantial quantities of litter accumulate on the ground, are unclear.

While large-scale fires are deleterious to Malleefowl populations in the short and long-term, the effect of fire is mitigated if fires burn patchily. Birds in a radio-tracking study in Vic survived in relatively small unburnt patches by utilising the burnt habitats for foraging, and the unburnt habitats for roosting, nesting and daytime shelter (Benshemesh 1990; 1992a). Unburnt patches were only about a tenth the average home-range size of Malleefowl in that study. Breeding density was greatly reduced by the fire, but the breeding success within the unburnt patches was similar to before the fire. Twelve years after the fire, Malleefowl breeding densities had returned to within 80 % of their original density (Benshemesh 1997a) and continued to increase until 16 years after the fire when breeding density peaked at 60 % above those before the fire. The population then crashed following a severe drought and stayed low for several years (Benshemesh 2005). While this example lends some support to the notion that limited and patchy burns might actually improve habitat for Malleefowl (Brickhill 1987b), the effect was temporary and longer term habitat enhancement of mosaic burns is yet to be clearly demonstrated in mallee for any size or pattern of fire.

In central Australia, much less is known about the fire ecology of Malleefowl. Cultural burning practices by Traditional Owners (Kimber 1983) appear to have protected some habitats important for Malleefowl such as mulga, particularly desert-mulga, by regularly burning surrounding spinifex habitat and thus reducing the fuel loads surrounding the mulga patches (Benshemesh 1997b). Recent studies suggest Malleefowl in central Australia may also benefit directly from such burning of spinifex habitat near mulga thickets as fire regenerates herbs and shrubs that are important food sources (J. Benshemesh, unpublished data). However, while the spinifex habitats appear well adapted to frequent burning, the mulga communities are sensitive to fire (Hodgkinson & Griffin 1982) and probably take at least 50 years after being burnt to recover a habitat structure that is suitable for Malleefowl to breed in. During the regenerative phase and before soil seed reserves are replenished, a second fire or high grazing pressure may permanently remove mulga communities (Griffin & Friedel 1985).

Traditional burning practices in central Australia likely created a mosaic of different aged habitats which prevented the occurrence of very large fires, in most years of average rainfall, that would have been threatening to Malleefowl and Indigenous inhabitants. Whether such burning practices were also used in mallee habitats further south is uncertain. In central Australia, these burning practices were interrupted and discouraged by European pastoralists from the 20th century onwards, and this lack of traditional burning is implicated in the occurrence of numerous huge fires in the past century. An unfortunate sequence in the 1920s, of huge fires followed by drought and grazing by rabbits, may be responsible for the eradication of mulga woodlands over large areas in the Great Victoria Desert (Griffin & Friedel 1985). These areas include those around the Petermann, Musgrave and Mann Ranges where Malleefowl were once considered “plentiful” (Carruthers 1892 in Kimber 1985).

Fires with a high edge-to-area ratio, such as fire-breaks, are likely to do less harm to Malleefowl populations than fires of the same size but with less edge. Mosaics of habitat at various ages might also provide a balance between habitat requirements of Malleefowl and protection from fire, and the attributes of such beneficial mosaics should be investigated after the populations of the birds are mapped across the larger reserves (DSE, 2003).

Tjilpi Robin undertaking tjanpi (spinifex) burns, APY Lands ©Joe Benshemesh, NMRG.

4 Threats

Historical, known and potential threats to the Malleefowl are outlined below. Threat prevalence and severity vary regionally. Currently, there is no information to suggest that any particular population of Malleefowl can be confidently regarded as secure. While issues such as fire, predation and climate change threaten the species wherever it occurs, threats resulting from clearing, fragmentation and grazing tend to be more concentrated in the southern agricultural regions where Malleefowl typically occur at higher densities.

4.1 Historical causes of decline

Clearing of the mallee for wheat and sheep production has been the major factor in the decline of Malleefowl in southern Australia, and this was forewarned by some of the earliest writers on Malleefowl (Campbell 1884, Campbell 1901, Mattingley 1908, Bellchambers 1916, Bellchambers 1918, Barrett 1919, Chandler 1934). The best habitats for Malleefowl tended to be on the more fertile soils and received relatively high rainfall (Frith 1962a), but these have been almost entirely cleared. Overall, up to 80 % of the Wheatbelts in WA and the eastern states were cleared by the 1990s (Glanznig 1995). This clearing has not only removed Malleefowl habitat, but also threatens remaining habitat due to fragmentation and dryland salinity.

Habitat remnants, where they exist within the wheatbelts, are often very small and isolated (Brickhill 1985, Saunders 1989, Saunders and Curry 1990, Cutten 1997, Priddel and Wheeler 2003). The larger remnants occur typically in areas unsuitable for agriculture and are often of marginal quality for Malleefowl.

4.2 Current threatening processes

4.2.1 Clearing and habitat destruction

Clearing and habitat destruction continue to be a threat to Malleefowl populations outside reserves even though controls on the clearing of mallee on private land have been imposed in NSW (*Local Land services Act 2013* (framework for legal land clearing in NSW) and the *Biodiversity Conservation Act 2016* (investigative and penalty framework where illegal clearing may have occurred in NSW)), Victoria (*Planning and Environment Act 1987* – Clause 52.17 and Victoria's *Native Vegetation Framework 2002*), SA (*Native Vegetation Act 1991*), and in WA (*Environmental Protection Amendment Act 2003*).

While agriculture has been the greatest reason for clearing mallee habitat in the past, new threats are emerging that are targeting remaining areas of habitat. Numerous mining operations, particularly mineral sand mining, have been proposed in mallee areas of NSW, SA, Vic and WA covering many thousands of hectares, and there have also been proposals to clear habitat for industrial waste containment facilities. Some forms of mining involve the removal of all vegetation at a site over large areas and cause major disturbance to the substrate, which has long lasting effects despite efforts at revegetation. Such destructive mining may irrevocably damage existing Malleefowl populations.

Another form of habitat loss and modification is the harvesting of mallee eucalypts for charcoal or oil, and the harvesting of broombush for fencing materials, and in some cases these industries may compromise Malleefowl conservation. For example, Yalgogrin in central NSW is managed for eucalypt production, but is also a highly significant area for Malleefowl conservation and harbours a declining population of the species (Priddel and Wheeler 2003). The part played by eucalypt harvesting in the decline of the Malleefowl has not been studied but the gross changes to habitat structure and floristic composition are likely to be detrimental.

4.2.2 Fragmentation and isolation

Before European settlement, mallee habitats were extensive and nearly contiguous across Australia and surrounded by other habitat types that also harboured Malleefowl or at least enabled their dispersal. However, clearing for agriculture has resulted in fragmentation of the remnant population into a large number of small populations with little opportunity for dispersal between them. Small and isolated populations are especially vulnerable to local extinction by a range of processes that deplete the number of individuals or degrade the viability of each population. It is likely that populations in low quality habitats have always depended on immigration from surrounding areas and once isolated from higher quality habitats such populations may become unsustainable.

The clearing and fragmentation of Malleefowl habitats is also likely to exacerbate other threats. For example, foxes are probably more abundant near cleared land (Saunders et al. 1995), weeds are more likely to encroach, fragments of mallee may be completely consumed by fire leading to local extinction where sources for recolonisation no longer exist, and fragmentation may increase the exposure of Malleefowl to agrochemicals. Also, the combination of fragmentation of the landscape and climate change may seriously threaten the conservation of species such as the Malleefowl through increased risk of stochastic local extinction and insufficient recolonisation opportunities.

While there is no doubt that Malleefowl have disappeared from some small reserves (e.g. Brickhill 1987b) analysis of Malleefowl trends from mound monitoring data (Benshemesh et al. 2007, Benshemesh et al. 2020) suggested that Malleefowl conservation in small reserves and fragmented landscapes appear resilient in the short to medium term. Nonetheless, the authors considered that in the longer-term appropriate management will be necessary to avoid population and genetic bottlenecks in small and isolated populations.

4.2.3 Mortality on roads

Road mortality may be substantial and damaging to a small population. Malleefowl usually do not flee when approached by traffic. They are often killed on roads where they frequently feed on spilt grain.
Malleefowl use narrow roadside strips of native vegetation in preference to crossing open ground especially when dispersing. They have been seen walking along wooded strips of vegetation along roadsides several kilometres from the nearest remnant of native scrub.

Malleefowl road sign ©Elizabeth Kington, Western Australia Malleefowl Recovery Group.

4.2.4 Fire (wildfire and planned burning)

Climate change is influencing the extent, intensity and frequency of fire across the range of the Malleefowl, and these changes are expected to exacerbate the effect of fire as a threat to the conservation of the species. For example, extreme fire weather (Di Virgilio *et al.* 2019; Dowdy *et al.* 2019) is likely to increase in frequency and intensity in coming decades, as is drought (Evans *et al.* 2017), which affects Malleefowl food, leaf litter for nesting and vegetation cover needed to avoid predators (Benshemesh *et al.* 2021). Invasive species, particularly buffel grass (*Cenchrus ciliaris*) (see 4.2.7 below), are also altering the spatial extent, frequency and severity of fires in arid areas (Schlesinger et al. 2013).

Large fires are a major threat to the conservation of Malleefowl and many other threatened mallee birds (Woinarski 1999; Baker-Gabb 2004; Clarke 2005), especially species like Malleefowl that require old-growth mallee (Read et al. 2020). Populations of Malleefowl may suddenly be eliminated from vast areas that are burnt, and even if there are nearby sources for recolonisation, recovery in the burnt area to densities that occurred before the fire appears to be very slow, requiring 30 to 60 years (Woinarski 1989b, Benshemesh 1990, Benshemesh 1992, Clarke 2005, Benshemesh et al. 2007). Habitats much older than 30 years post-fire are rare in eastern Australia. Conservation reserves should ideally be large enough to allow for large-scale disturbance such as fire without the entire area being affected. However, the potential scale and frequency of fire in mallee habitats suggests that even the largest reserves may be entirely consumed by a single fire (Land Conservation Council 1987). The significance of fire as a threat has been recognised as a Key Threatening Process under the *EPBC Act 1999* Fire regimes that cause declines in biodiversity.

In some states that support Malleefowl, intentional broad-scale burning has been advocated as a pastoral management technique. Where such fire frequencies are employed, Malleefowl populations are likely to be greatly reduced or even extirpated (Benshemesh 1990).

Inspecting a Malleefowl mound after a wildfire, SA ©Graeme Tonkin, NMRG.

4.2.5 Herbivores and grazing

In areas grazed by sheep, Frith (1962a) argued that Malleefowl breeding densities were reduced by 80–90% compared to similar ungrazed habitats. Other herbivores may also compete with Malleefowl for herbaceous foods and damage shrubs that are important as seed sources for the birds. In particular, feral goats are abundant in some areas (Lewis and Hines 2014) and may be even more damaging to shrub populations than sheep. High numbers of kangaroos may also be a problem in areas where their numbers are artificially high due to access to water sources and agriculture and absence of predators. In central Australia, sheep and feral goats are rare but high numbers of other introduced herbivores such as domestic cattle, rabbits and feral camels occur in some areas and provide reasons for concern.

The effects of herbivores are twofold. Firstly, grazing and browsing denies Malleefowl food that may otherwise be available to them. Secondly, when maintained at high densities these herbivores may cause long-term change to the vegetation composition and structure due to supressed plant recruitment, compaction, changes in soil structure, and preferential browsing (Travers et al. 2019). This may make habitat structure less suitable for Malleefowl and, by making habitats more open, the birds may become more vulnerable to predators (Priddel et al. 2007). Heavy grazing may also reduce the soil-stored seed of many perennial and ephemeral species, and the diversity and abundance of invertebrates (another food source for Malleefowl), with potentially serious implications for the quality of Malleefowl habitats. These insidious effects of grazing are especially important after fire when vegetation is regenerating and has yet to reproduce, and where herbivore numbers are maintained at high levels by the provision of artificial water sources. By benefiting large grazing animals, such water sources may profoundly affect the distribution and abundance of native plants and animals for a radius of approximately 10km which includes most of the pastoral zone (Landsberg et al. 1997, Harrington 2002).

Feral goats and sheep are of particular concern for Malleefowl conservation in southern Australia as large tracts of mallee support goats or sheep. Some of the highest goat densities occur in reserves that support Malleefowl populations, particularly in large reserves and pastoral leases in NSW and eastern SA north of the Murray River. Sheep grazing for pastoral production continues on public land over large areas of Malleefowl habitat, particularly in WA and NSW. Feral deer appear to be an increasing problem in some Malleefowl habitats in more mesic areas, particularly in the Limestone Coast region in southeast SA where deer are common (T Rajic, pers. comm. 2020). The degree to which deer threaten Malleefowl is unclear but as selective feeders, deer can modify the composition and dynamics of plant communities even when not abundant (Cote et al. 2004). Additionally, deer have been recorded to destructively trample active Malleefowl mounds (V Natt pers. comm. 2020) and thus directly interfere with Malleefowl reproduction. There is little doubt that past and present grazing has damaged Malleefowl habitat and continued grazing by goats, sheep and perhaps in some cases kangaroos is keeping Malleefowl populations lower than would otherwise be the case. Much of the land most affected by grazing may be of relatively low quality for Malleefowl, but the large areas involved makes them of considerable value to Malleefowl conservation.

Feral goats in Malleefowl habitat (AMPE monitoring camera), Vic.

4.2.6 Predation

Predation is a cause of mortality of Malleefowl. Foxes, in particular, prey on Malleefowl at all stages of the bird's life cycle. Foxes have been known to take over a third of eggs at some sites (Frith 1962a, Benshemesh and Burton 1999), but fox predation on eggs has usually been found to be negligible in large studies (Booth 1987b, Brickhill 1987, Benshemesh 1992, Priddel and Wheeler 2005, Ryan-Colton et al. 2011). The two detailed cases where foxes were shown to have taken a substantial proportion of eggs followed widespread rabbit reduction by introduced viruses (myxomatosis in the 1950s, and rabbit haemorrhagic disease in 1996). The subsequent loss of rabbits as food for foxes may have caused foxes to switch prey to Malleefowl eggs (Benshemesh and Burton 1999).

A recent comprehensive analysis of long-term mound monitoring data found little evidence that reducing fox abundance influenced Malleefowl breeding activity (Benshemesh and Southwell et al. 2020), which align with previous studies (Benshemesh et al. 2007, Walsh et al. 2012). Other factors, such as rainfall and time since fire, were more important predictors of Malleefowl breeding activity. The lack of response of Malleefowl to fox reduction programs in these large-scale statistical studies is in accord with observations at local scales. For example, fox control failed to increase breeding densities after more than a decade of baiting at Bakara in SA (Gates 2004), Dryandra in WA (A Friend pers. comm. cited in Benshemesh 2007b) and Yathong in NSW (Wheeler and Priddel 2009). The Dryandra example is interesting in this regard as several species of medium-sized native mammals increased greatly after fox baiting, but Malleefowl numbers appear to have stayed the same or declined. In short, there is little evidence that Malleefowl populations increase following fox control operations, even though fox control is widely practised in areas where Malleefowl conservation is a concern. There is evidence that foxes and feral cats have compounding and complementary effects on native fauna (Stobo-Wilson *et al.* 2021a; Stobo-Wilson *et al.* 2021b) and that fox control can lead to increased cat numbers (Marlow *et al.* 2015), therefore the control of predation from both species may benefit Malleefowl. For example, six out of nine adult birds fitted with GPS trackers on the Eyre Peninsula died from cat and fox predation (three each; five within a year and one after 450 days of tracking) (Stenhouse and Moseby, 2023). For a long-lived bird this is a very high rate of mortality and suggests that reducing the rate of predation by cats and foxes increases population size.

Despite these studies being of sufficient duration to detect adult recruitment, the lack of evidence of a positive effect of fox control on Malleefowl breeding densities may be due to a number of factors: the control programs may have not sufficiently reduced foxes to benefit Malleefowl; foxes may have been effectively reduced but this may have resulted in other predators (such as feral cats) or competitors (such as mammalian herbivores) to increase and counter any net benefit to Malleefowl; or the detrimental effects of foxes on Malleefowl populations may be over-rated or be dependent on secondary factors such as an increase in resources that support high fox numbers. Further evaluation of the effectiveness of predator control on Malleefowl recovery is warranted and is of high priority to ensure that resources for Malleefowl recovery are targeted in an effective and efficient manner.

Predation on Malleefowl chicks is severe but difficult to measure in wild populations. Chicks released in mid-summer within a day of hatching have been shown to experience heavy mortality due to predation by foxes/cats, predation by raptors, and metabolic stress, in approximately equal proportions (Benshemesh 1992). Mortality was found to be greatest during the first few days and 80% of chicks were dead within ten days. Similarly, captive-reared chicks that were of various ages up to five months old and released into a small habitat remnant in autumn and winter experienced heavy (55–68%) mortality from introduced predators (predominantly foxes but also occasionally by cats) and 26–39% by raptors (Priddel and Wheeler 1994). In areas where fox abundance has been greatly reduced, juvenile Malleefowl have nonetheless suffered high mortality from raptors (Harlen and Priddel 1992). Older captive-reared Malleefowl appear less susceptible to raptors but are still highly susceptible to fox (and possibly cat) predation. At least 50% of juveniles (3–5 months old) released in autumn were thought to be killed by foxes, and a further 13% by either foxes or cats, whereas only 4% were known to have been taken by raptors (Priddel and Wheeler 1996). Predation probably accounted for an even greater proportion of juveniles than these percentages suggest as all juveniles were known to be dead within 104 days, although the cause of death could not be ascertained in nearly a quarter of cases. Sub-adult birds (14–28 months old) survived better than the younger juveniles released in the same areas, although fox predation still accounted for about 70% of birds that were released. Studies have also demonstrated that intensive fox baiting increases the survival of captive-reared birds released in the wild (Copley and Williams 1995, Priddel and Wheeler 1997), and a population of Malleefowl has been successfully re-introduced to Peron Peninsula following intensive predator and exotic herbivore control (C Sims pers. comm. cited in Benshemesh 2007b).

A common element in all these studies is that chick cohorts of any age encounter massive mortality rates during the first few days after they are released. Thereafter, mortality rates decline as birds spend more time in a habitat, and this possibly reflects the development of experience by the birds in finding reliable food sources and in evading predators. This pattern is most pronounced for chicks and captive-reared juveniles, but also applies to captive-reared sub-adults. It is also worth noting that all releases of radio-tagged Malleefowl less than a month old have occurred late in the breeding season, whereas it is characteristic for avian breeding success and offspring survival to be highest early in the breeding season and decline thereafter (Perrins 1970, Rohwer 1992).

Fox control improves the survival of captive-reared birds, but the degree to which fox predation is responsible for the decline of existing Malleefowl populations is less clear. Foxes are most common in mallee near agricultural land where high densities may be maintained by the ready availability of their principal foods such as rabbits, mice and sheep carrion (Saunders et al. 1995). However, many of the highest Malleefowl breeding densities occur in such areas and have appeared stable in the absence of habitat disturbance or drought (Frith 1962a, Benshemesh 1992, Copley and Williams 1995).

The relationship between fox predation and Malleefowl declines is still unclear but is being investigated by the national Adaptive Management Predator Experiment (AMPE) (Hauser et al. 2019, Benshemesh et al. 2018). While monitoring data over the past three decades, and several decade-long studies do not suggest that Malleefowl benefit from baiting programs that reduce foxes, it may nonetheless be warranted to reduce fox (and cat) numbers where Malleefowl populations show clear signs of decline. Reducing predator populations is especially important when rabbit numbers are suddenly reduced, such as following the spread of rabbit haemorrhagic disease, as this may lead to 'prey-switching' by foxes (Pech and Hood 1998), as similarly recorded for cats (McGregor et al. 2020).

Fox inspecting a Malleefowl mound, ©Graeme Tonkin, NMRG.

4.2.7 Weeds

Weeds in general (with the exception of buffel grass) are not a specific threat to Malleefowl but compete with native plants, therefore reduction in weeds leads to an improvement in habitat condition. It is especially important to prevent new and emerging weeds from spreading into Malleefowl habitat.

Buffel grass

Buffel grass has been identified as among the greatest threats to Australian arid and semi-arid flora and fauna communities (Read et al. 2020). It is a highly interactive and rapidly emerging threat that is considerably more costly to manage or eradicate than other threats (e.g. introduced predators, grazing, changed fire regimes) (Read et al. 2020). Buffel grass may affect Malleefowl via loss of dietary resources, changes in vegetation structure, and increased occurrence and intensity of fire (Grice et al. 2013; Read et al. 2020).

Buffel grass competes with and displaces native plant species and promotes more frequent and intense fires in communities that are adapted to infrequent and/or less intense fires. It can have measurable impacts on aspects of community dynamics even at low levels of cover (≤ 20%) (Smyth et al. 2009).

Foraging behaviour and dietary resources may be affected by buffel grass invasion. Bird species of all foraging guilds have been reported to spend less time on the ground and less time at individual sites as buffel grass cover increases (Young & Schlesinger 2014). Zebra finches (*Taeniopygia guttata*) prefer native seed over buffel grass seed (Young & Schlesinger 2018) and Malleefowl may exhibit similar preferences. Buffel grass has also been shown to influence invertebrate fauna in arid landscapes. For example, Bonney et al. (2017) found that ant abundance and richness were 50% lower in survey plots dominated by buffel grass. This may have profound impacts on the ecosystem service of seed dispersal, which may lead to long-term changes in plant community composition, structure and diversity, and consequent impacts on Malleefowl food resource availability.

Floristic species richness has been found to decrease substantially with the presence of buffel grass at multiple spatial scales (Franks 2002; Jackson 2005; Fensham et al. 2015). The greatest effects have been reported for native perennial grasses (Fensham et al. 2015; Young & Schlesinger 2018; Wright et al. 2021) and herbaceous species (Jackson 2005; Wright et al. 2021). Ground cover species richness has been shown to increase after the removal of buffel grass (Melzer et al. 2014; Wright et al. 2021), but perennial grasses may not recover in the short-term (≤ 12 years) (Wright et al. 2021). Native vegetation cover has also been observed to decrease with increasing presence of buffel grass (McDonald & McPherson 2011).

Buffel grass may reduce the seed viability and germination rates of some key perennial shrub species in arid and semi-arid communities (Edwards et al. 2019). This may reduce the accumulation of viable seeds in the seedbank, which is likely to reduce the efficiency of the plant community's response to sporadic rainfall events. Reductions in germination are also likely to lead to long-term declines in perennial shrub populations, leading to a substantially altered habitat composition and structure. Increased fire frequency and intensity linked to buffel grass invasion are likely to exacerbate these changes (Miller et al. 2010). Delaying the eradication of buffel grass increases the likelihood that the native seedbank will deteriorate, which may compromise restoration efforts (Wright et al. 2021).

The interaction between buffel grass and fire is of substantial concern for the preservation of Malleefowl habitat. Numerous studies have identified a positive feedback loop between buffel grass and fire, wherein buffel grass increases post-fire and promotes more frequent fire (Butler & Fairfax 2003; Miller et al. 2010; McDonald & McPherson 2013).

Buffel grass increases the intensity of fire on higher nutrient soils (Miller et al. 2010; McDonald & McPherson 2011, 2013), leading to less patchy fire, a greater proportion of burnt ground, a higher rate of canopy dieback, death of mature trees, and the acceleration of negative competitive effects and habitat degradation (Butler & Fairfax 2003; Miller et al. 2010; Schlesinger et al. 2013). It also increases the frequency of fire by carrying fire through vegetation communities that are otherwise not fire-prone (Marshall et al. 2012; McDonald & McPherson 2013). The inter-annual variation in buffel grass biomass is much lower than that of native plant species, and so it presents a more consistent fire risk (McDonald & McPherson 2013). Furthermore, even after treatment with herbicide, buffel grass stands may require several years of decomposition before they no longer support fire spread (McDonald & McPherson 2013).

Climate change is likely to increase the threat posed by buffel grass and enable it to expand its potential range (Read et al. 2020). With climate change, buffel grass may pose an increasing threat in southern Australia, while conditions in northern Australia are projected to become less suitable (Martin et al. 2015). The risk of buffel grass invasion within Australia's national reserve system is likely to increase with climate change (Martin et al. 2015).

Buffel grass invasion is also exacerbated by other threatening processes in arid and semi-arid environments, including cattle grazing (Fensham et al. 2013) and land clearing (Fensham et al. 2015).

4.2.8 Genetic management of small populations (inbreeding)

In addition to appearing to have been through population contraction and expansion in an ancient context, Malleefowl populations have an isolation-by-distance structure where individuals that are geographically closer end up being genetically more similar, as neighbouring populations are more likely to interbreed, potentially resulting in inbreeding depression (Cope et al. 2014). Inbreeding depression may result in infertility, decreased fertility and other effects deleterious to subpopulation persistence.

On the Eyre Peninsula SA, habitat fragmentation from clearing and subsequent isolation has led to reduced gene flow and the differentiation of the isolated population (Stenhouse & Moseby 2023). The differentiation was relatively small, suggesting its relatively recent development. This study also provides preliminary genetic evidence of female-biased dispersal in Malleefowl in fragmented landscapes. A genetic management plan needs to inform any translocation for the genetic rescue of populations to ensure genetic material is appropriate and adequate records are maintained.

4.2.9 Climate change

Australia is currently experiencing the impacts of climate change. The southwest and southeast of Australia have experienced drier conditions, with more frequent years of below average rainfall, especially for the cool season months of April to October (Commonwealth of Australia 2020). There has been an increase in extreme fire weather and in the length of the fire season across large parts of Australia since the 1950s, especially in southern Australia (Commonwealth of Australia 2020). Australia is projected to continue to get hotter into the future, with more extremely hot days and fewer extremely cool days (Commonwealth of Australia 2020).

Current predictions of the impacts of climate change on Australian biota provide considerable cause for concern. Projected changes in rainfall, temperature or fire regimes are likely to threaten Malleefowl over their entire range (Morton et al. 2009, Head et al. 2014). Modelling projections of the suitable habitat for Malleefowl under future climate change scenarios indicate that the species range is likely to contract in some regions, and in mallee habitats in general, particularly under high emissions scenarios (Bennett et al. 1991, Parsons 2008b). If these projected declines in the suitability of habitat are realised, substantial declines in Malleefowl populations are likely (Parsons 2008b).

Malleefowl populations may be influenced directly by changes in climate (Boyle and Hone 2012). Analysis of monitoring data indicates a significant, positive effect of winter rainfall on Malleefowl breeding behaviour to the extent that it can be considered a surrogate for population trend (Benshemesh et al. 2007; Benshemesh and Southwell et al. 2020). Thus, declines in winter rainfall, as predicted under climate change in regions occupied by Malleefowl (Hughes 2003) are considered likely to have negative ramifications on Malleefowl populations.

Malleefowl movement can be expected to be directly affected by changes to the climate (Stenhouse and Moseby, 2023). Models using GPS tracking data from Malleefowl indicated a decrease in movement with increasing temperatures, with the strongest effect observed in the breeding season: daily distances travelled fell from approximately 1.3 km a day at 25°C to 0.9 km at 45°C. In non-breeding Malleefowl, the relationship was non-linear with the strongest declines observed over 30°C (1.2 km at 35 and 0.9 km at 45°C). The presence of rain improved daily distances travelled by about 100 m but only in the non-breeding season. It may be possible to identify areas that may act as refugia for Malleefowl under a changing climate. However, the uncertainty associated with such models, the need to maintain Malleefowl occupancy and the reliance on local conservation partners to implement conservation actions indicate that a number of factors must be considered when determining the location of conservation actions. Such modelling may be relevant when considering options for habitat restoration or improving habitat connectivity.

4.2.10 Disease

There is no information on disease in wild Malleefowl populations, although the species is susceptible to a range of common diseases in captive situations and may also be susceptible to exotic diseases, especially those found in other Galliformes (R Woods pers. comm. cited in Benshemesh 2007b). The risk of spreading disease should thus be considered in programs where Malleefowl are released following a period in captivity, especially in a zoo situation, and also where domestic fowl and pheasant farms are located near areas occupied by Malleefowl. No blood parasites could be detected in a preliminary investigation of blood smears of seven trapped Malleefowl on the Eyre Peninsula (Stenhouse P., unpublished data).

4.2.11 Chemical exposure

There is no evidence that agrochemicals are currently a threat to Malleefowl (see Ryan-Colton et al. 2011), although the increased exposure of Malleefowl to such chemicals in fragmented landscapes warrants further investigation.

5 Objectives and Performance Criteria

Under the EPBC Act, this recovery plan is required to maximise the long-term survival of the Malleefowl in the wild. The species' chances of long-term survival in the wild are affected by the extent, quality and connectivity of habitat as well as the species' levels of mortality at different life stages, longevity and breeding success. These parameters are influenced by threatening processes and impact the ability of the species to be resilient in the face of stochastic events and the operation of threatening processes.

The recovery plan intends to guide recovery actions for the Malleefowl across its entire range and is designed to operate over a ten-year period, with a mid-term review after the initial five years. The objectives of this recovery plan are that by 2032:

Objective 1: The Malleefowl population is stable or increasing.

Performance Criterion 1: Mound activity is stable or increasing between 2022–2032.

Objective 1 relates to the total number of Malleefowl as an indicator of extinction risk. Population size or trend is difficult to measure directly. Mound activity trend is assumed to be indicative of population trend. Mound activity is measured annually.

Objective 2: Malleefowl occupancy has been maintained or increased throughout the species range.

Performance Criterion 2: The area occupied by Malleefowl in 2033 has been maintained or increased compared to 2023.

Objective 2 relates to the distribution, and therefore resilience, of Malleefowl. Area of occupancy (AOO) is to be calculated using IUCN AOO methods based on presence-only data, taking climate variability into account. Measured AOO should be maintained or increased at all locations at which Malleefowl occur.

Objective 3: The genetic integrity of isolated populations is maintained.

Performance Criterion 3: By 2032, isolated Malleefowl display evidence of genetic exchange.

Objective 3 addresses populations in isolated patches of habitat that are at risk of loss due to inbreeding depression. Genetic integrity is assumed to be maintained if a population receives genetic input from at least one unrelated Malleefowl each generation. The priority isolated populations are to be identified by each NRM region, led by the NMRT. The evidence required for prioritised sites and measured improvements is to be determined by independent genetic expertise.

Objective 4: First Nations organisations, communities and individuals have a greater role in Malleefowl conservation.

Performance Criterion 4: By 2032, both the number of First Nations people actively engaged in Malleefowl recovery and the number of locations at which First Nations people are engaged in Malleefowl recovery has increased from 2023 levels, and Malleefowl recovery actions are incorporated into local-area management plans (e.g. Healthy Country plans) developed by First Nations land managers.

Objective 4 acknowledges the critical role of First Nations peoples and Country in the conservation of Malleefowl at many locations.

6 Strategies

This recovery plan identifies eight strategies which set out the management actions and research necessary to support the recovery of the Malleefowl. Each strategy describes how a threat, or set of related threats, will be mitigated in order to meet the objectives of this recovery plan. The four 'on ground strategies' directly address biological threats to the Malleefowl, while the four 'supporting strategies' establish the systems needed to ensure effective on-ground action. These strategies are:

On-ground Strategies

1. Enhance protection and improve or maintain quality, connectivity and extent of habitat for Malleefowl
2. Manage fire
3. Manage impacts of herbivore grazing and habitat destruction by feral animals
4. Manage and monitor impacts of introduced predators on Malleefowl

Supporting Strategies

5. Govern the Malleefowl recovery process
6. Engage the community
7. Conduct research to determine distribution, habitat requirements and population dynamics
8. Monitor the impacts of management interventions across sites, and use the information to adapt management

Where possible, the effectiveness of management strategies will be evaluated in an adaptive management framework so that learning may be obtained while management continues. This is especially important where there is uncertainty about the benefits of a management strategy to Malleefowl populations and where the costs of the management are high or may have unintended consequences (e.g., fox control may benefit cats). In practice, for sites outside the adaptive management experiment, this means that management actions should be recorded and reported wherever Malleefowl monitoring occurs, so that the outcomes of management can be evaluated, and that Malleefowl populations should be monitored where the outcomes of management are uncertain.

Malleefowl occur, or may occur, on lands traditionally owned by many Indigenous groups (see Section 2.2). Interests and opportunities for Indigenous peoples must be addressed when implementing actions outlined in this recovery plan (Thompson et al. 2020), including consultation and engagement protocols that are relevant to each organisation. There are significant opportunities for Indigenous peoples to lead recovery actions outlined in this plan.

Actions identified for the recovery of the Malleefowl are outlined below. The recovery actions describe what will be done and by whom.

7 Priority setting and costs

A prioritised table of actions has been established under this Recovery Plan, which provides for targeted actions aligned to regional priorities, and is subject to periodic review by the National Malleefowl Recovery Team. The risk presented by each threat varies across the distribution of the Malleefowl and between locations where Malleefowl 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 may reduce plan effectiveness.

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.

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 action or a modification of an existing action 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.

8 Recovery Actions

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
	ON-GROUND STRATEGY **1. Enhance protection and improve or maintain quality, connectivity and extent of habitat**		
1.1	***Habitat clearance and degradation***		
1.1.1	Identify Malleefowl habitat areas.	Identify known and predicted habitat for Malleefowl in addition to those areas already known to be Malleefowl habitat. Implement actions under supporting strategies 2 and 3 for lands identified as suitable Malleefowl habitat.	NRM organisations, State Recovery Groups, Indigenous ranger groups and Prescribed Bodies Corporate
1.1.2	Retain Malleefowl habitat.	As identified above.	Land managers, Commonwealth and State governments, Indigenous ranger groups and Prescribed Bodies Corporates
1.1.3	Increase area of Malleefowl habitat and quality of existing Malleefowl habitat.	Revegetate formerly cleared habitat. Carry out supplementary planting and control weeds, fire and grazing in degraded existing habitat.	NRM organisations, Greening Australia, Indigenous ranger groups and Prescribed Body Corporates
1.1.4	Fence Malleefowl habitat on public and private land to exclude stock.	Land manager to determine approach, method and timing to suit circumstances at location.	Parks, wildlife agencies and Land managers.
1.1.5	Control buffel grass in and adjacent to Malleefowl habitat.	Land manager/s/Custodian/s to determine approach, method and timing to suit circumstances at location.	Land managers (including private, public and Indigenous), parks and wildlife agencies, NRM organisations, Indigenous ranger groups and Prescribed Body Corporates

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
1.1.6	Control other weeds (especially newly emerging or highly invasive weeds) in and adjacent to Malleefowl habitat to retain habitat quality.	Land manager/s/Custodian/s to determine approach, method and timing to suit circumstances at location.	Land managers (including private, public and Indigenous), parks and wildlife agencies, NRM organisations, Indigenous ranger groups and Prescribed Body Corporates
1.1.7	Identify viable Malleefowl habitat on private land to target for conservation covenants.	Strategically pursue conservation covenants for priority locations.	NRM organisations, State governments, State Recovery Groups, Indigenous ranger groups and Prescribed Body Corporates
1.1.8	Provide information and opportunities for private landholders of Malleefowl habitat to enter into permanent conservation covenants that are registered on title of the property.	Assessment of the viability of these remnants to sustain viable habitat to support successful breeding populations is critical before investing in these remnants. Use conservation covenants that are permanent legal agreements placed on landholder's Certificate of Title to ensure long-term conservation and protection of the habitat which is binding on future landowners.	NRM organisations, State governments, State Recovery Groups
1.2	***Habitat and population fragmentation*** (See also: ***'Investigate infertility in isolated reserves'*** below)		
1.2.1	Identify small and isolated populations at risk of loss.	1. Each NRM region to identify the occupied habitats/patches at the extremities of the species' range (Extent of Occurrence (EOO)) within their NRM region and report on any losses each year. 2. Each NRM region to identify its most isolated and its smallest known occupied patches of Malleefowl habitat to gain some understanding of levels of risk from (a) intense bushfires that take out entire habitat blocks (with all Malleefowl too) and (b) local isolated populations becoming functionally extinct (extinct due to inbreeding and eventual infertility). 3. Identify those isolated Malleefowl populations estimated to have less than 25 breeding pairs (using IUCN criteria C and D; <50 mature individuals per sub-population), or less than 125 breeding pairs (<250 mature individuals per sub-population) to identify either existing, or potential, inbred isolated populations. Estimate isolation using a minimum distance from	NRM and Landcare organisations, State Recovery Groups Birdlife, Community Groups

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
		nearest occupied habitat. (see also relevant actions under '*Investigate infertility in isolated reserves',* below).	
1.2.2	Identify strategic locations to establish or augment habitat corridors and patches.	Patches to act as stepping-stones or habitat in its own right. Take into account the objective of the specific corridor/patch (i.e. should the birds be encouraged to linger or simply transit through). Use a strategic landscape approach so that Malleefowl end up in viable habitat. Consider the value of modelling future habitat suitability in response to climate change.	NRM organisations, Greening Australia, State governments
1.2.3	Collect and store appropriate seeds to be used for revegetation.	Give consideration to climate change when selecting suitable seed. Follow appropriate seed collection and storage protocols. (refer to eds Martyn Yenson et al. 2021).	Indigenous groups (opportunity for Indigenous enterprise), Greening Australia, NRM organisations and State governments
1.2.4	Plant suitable vegetation in strategic corridors and patches as identified in action above.	Consider food, cover and litter, depending on the objective of the specific corridor/patch (i.e. should the birds be encouraged to linger or simply transit through). Ensure biodiverse plantings to account for use of annual and perennial species and invertebrate food sources at different times of the year and in different years e.g. drought years.	Indigenous groups, Greening Australia, NRM and Landcare organisations, State governments
1.3	***Mortality on roads***		
1.3.3	Identify locations where signs are required to reduce the risk of vehicles colliding with Malleefowl.	Prioritise areas such as: • where there is likely to be spilt grain from grain transport vehicles • high traffic or high-speed mining roads	Mining companies, councils, State governments National Malleefowl Recovery Team and National Malleefowl Recovery Group.

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
		• areas with narrow roadside strips of native vegetation surrounded by open ground • roads that pass through known malleefowl habitat which have high speed limits	
1.3.4	Erect signs to warn drivers where Malleefowl may be on the road ahead.	Put signs where there are Malleefowl frequently sighted on roads. Signs should communicate the need to slow down. Reduce speed limits at high collision zones. Erect signs to encourage motorists to report Malleefowl collisions to wildlife carer organisations. Provide wildlife carers with information on storage and notification when they receive Malleefowl carcases. Wildlife carers should contact their state museum so that appropriate genetic material can be lodged. Museums to make genetic material available for genetic studies. Educational signs at grain silos and weighbridges in areas where Malleefowl occur may also be effective in alerting transporters of the issue.	Mining companies, councils, Road Traffic Authority, State governments
1.3.5	Assist and advise landholders to plan harvest processes that are Malleefowl-friendly to equip them with knowledge and skills when dealing with the transport of grain.	Foster an increased understanding from both land managers and the wider community around how to minimise Malleefowl road deaths from grain cart spillage.	NRM organisations

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
	ON-GROUND STRATEGY **2. Manage fire**		
2.1	***Inappropriate fire regimes***		
2.1.1	Update or establish fire management plans at local and landscape scales. Where appropriate, incorporate traditional patch burning around Malleefowl habitat (for fuel-reduction burning and to promote patchiness), wildfire control (to prevent large scale or frequent fire) and no-burn areas. Consider limiting the establishment of fuel breaks and access tracks, as they promote the movement of exotic animals.	In general, Malleefowl habitat should not be intentionally burnt, however it may be appropriate to control-burn a small proportion of habitat to protect the remaining habitat from wildfire. In central Australia, patch burning should be applied around Malleefowl habitat to protect it, rather than burning the habitat patches themselves. Habitat structure is very important for Malleefowl because they require overhead cover and trees to roost in. In mallee, fire tends to go straight to the crown, so fire management should focus on retaining the habitat structure. Where control and patch burning takes places, investigate the impacts of limited and patchy burns on Malleefowl habitat.	Land managers and Custodians (including private, public and Indigenous), State governments, parks and wildlife agencies, Indigenous groups and rangers, State Recovery Groups, NRM organisations, rural fire services
2.1.2	Identify Malleefowl habitat areas requiring special fire management.	Such as fire management to reduce fire frequency in mallee patches within desert heath habitat which burns frequently.	Land managers and Custodians (including private, public and Indigenous), State governments, parks and wildlife agencies, Indigenous groups and rangers, State Recovery Groups, NRM organisations
2.1.3	Identify, map and prioritise Malleefowl habitat patches for: Fire exclusion Fire suppression Prescribed burns	Map Malleefowl habitat age class (time-since-fire). Establish annual fire history map layers for all Malleefowl habitats within all regions. Map rainfall of Malleefowl habitat to assist determining climate change impacts and Malleefowl responses.	Land managers and Custodians (including private, public and Indigenous), State governments, parks and wildlife agencies, Indigenous groups and rangers, State Recovery Groups, NRM organisations
2.1.4	Implement fire management plans.	Land manager/s/Custodian/s to determine approach, method, and timing to suit circumstances at location.	Land managers and Custodians (including private, public and Indigenous), State governments, parks and wildlife agencies, Indigenous groups and rangers, NRM organisations, rural fire services

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
2.1.5	On Indigenous lands, promote and support Traditional Owners to incorporate Malleefowl needs into their fire management plans and to implement those plans	Provide resource materials and technical support to assist planning and implementation.	Traditional Owners, NRM and Landcare organisations, environmental Non-Government Organisations
2.1.6	Control buffel grass in areas where it may distort the usual fire regime or where fire may encourage its spread into Malleefowl habitat.	Buffel grass is a rapid coloniser of disturbed ground, responds positively to fire and assists fire in its intensity and duration, creating a feedback loop that encourages buffel grass to dominate native vegetation. Buffel grass invasion will destroy Malleefowl habitat.	Land managers and Custodians (including private, public and Indigenous), councils, parks and wildlife agencies, Indigenous groups and rangers, NRM organisations, mining companies
	ON-GROUND STRATEGY **3. Manage impacts of herbivore grazing and habitat destruction from feral animals**		
3.1	***Herbivore grazing and habitat destruction from feral animals***		
3.1.1	Control feral animals and other herbivores (especially goats, deer, rabbits/hares, camels, pigs and, in some situations, kangaroos) where there is evidence that they negatively affect Malleefowl habitat.	Consider appropriate buffers for control of each feral animal species, taking into account access to water and condition of surrounding area. For example, in more productive/fertile areas, feral animals will have a smaller range compared to less productive/harsher environments. Also consider thresholds required to facilitate and enhance natural regeneration of Malleefowl habitat (e.g. <1 rabbit per ha in Mallee Catchment Management Authority (Victoria). Fumigate rabbit warrens in culturally sensitive areas; otherwise, ripping is preferred due to the high success rate. Effective goat and camel control involves culling and may be facilitated by using a GPS collar on a 'Judas' animal. This enables goat and camel congregation events to be noticed and culling to be undertaken, resulting in highly efficient and cost-effective management.	Land managers and Custodians (including private, public and Indigenous), parks and wildlife agencies, Indigenous groups and rangers, NRM organisations and mining companies

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
3.1.2	Identify and decommission (remove/fill in) or fence artificial water source that support herbivore populations (feral stock, feral herbivores, or kangaroos) posing a threat to Malleefowl habitat.	This involves filling in/flattening dams and revegetation.	NRM and Landcare organisations
3.1.3	Erect adequate fencing to exclude stock, kangaroos and feral herbivores from Malleefowl habitat without impacting movement of malleefowl.	Applies to habitat on either public or private land.	Land managers
3.1.4	Where their browsing pressures are negatively affecting Malleefowl habitat, adaptively manage native herbivore populations (e.g. kangaroos).	Overabundant kangaroos impact Malleefowl in SA as they are thinning out understorey at the landscape scale, taking away cover and food of Malleefowl.	Land managers and Custodians (including private, public and Indigenous), parks and wildlife agencies, Indigenous groups and rangers, NRM organisations, mining companies
	ON-GROUND STRATEGY **4. Manage and monitor introduced predators**		
4.1	***Predator control***		
4.1.1	Undertake predator management consistent with the Adaptive Management Predator Experiment project, including treatment and control sites.	This includes monitoring changes in predator abundance/activity using the same approach as the Adaptive Management Predator Experiment (AMPE) which uses 8 to 10 camera traps in an array (Hauser et al. 2019; van Hespen et al. 2019). New sites that have not had historical baiting should be monitored under the Adaptive Management Predator Experiment.	Land managers and Custodians (including private, public and Indigenous), parks and wildlife agencies, Indigenous groups and rangers, NRM organisations, mining companies
4.1.2	Undertake control of introduced predators (particularly foxes and cats) where Malleefowl populations show decline and predation is a likely explanation of decline.	Draw on information from relevant Government advisory agencies, Adaptive Management Predator Experiment and other studies to inform implementation of this action. In particular, revise methods to those shown to be effective as a result of the AMPE.	Land managers and Custodians (including private, public and Indigenous), parks and wildlife agencies, Indigenous groups and rangers, NRM organisations, mining companies

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
4.1.3	Record all information relating to predator control in Malleefowl habitat areas and make the information easily available to the National Malleefowl Recovery Team.	Information required includes bait type, density, scale, deployment protocols, and frequency and timing. FeralScan or PestSmart could be used as tools.	Land managers and Custodians (including private, public and Indigenous), parks and wildlife agencies, Indigenous groups and rangers, NRM organisations, mining companies
4.1.4	Analyse data available on the relationship between predation rates from foxes and cats and habitat.	Identify if Malleefowl are more susceptible to predation in degraded habitat by herbivores.	Research partners*, National Malleefowl Recovery Team
	SUPPORTING STRATEGY **5. Govern the recovery process**		
5.1	***Managing the recovery process***		
5.1.1	Convene Recovery Team meetings.	At least twice per year.	National Malleefowl Recovery Team
5.1.2	Recovery Team is to maintain an open invitation to Indigenous Peoples to attend Recovery Team meetings.	To maximise the opportunity for cultural interests and knowledge are appropriately considered and managed.	National Malleefowl Recovery Team
5.1.3	Monitor and evaluate progress against the recovery plan.	Provide report to relevant government agencies and other relevant parties.	National Malleefowl Recovery Team
5.1.4	Communicate outcomes of Recovery Team meetings.	In accordance with communication plan.	National Malleefowl Recovery Team

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
	SUPPORTING STRATEGY **6. Engage the community**		
6.1	***Engaging the community***		
6.1.1	Support Indigenous people to maintain cultural practices and knowledge related to Malleefowl.	Consider incorporating actions to support the maintenance of Malleefowl-related cultural practices, law and conservation action in Healthy Country Plans or other Indigenous-led land management plans.	NRM and Landcare organisations, Indigenous land managers, Indigenous groups and rangers, Prescribed Body Corporates, Representative Native Title Bodies
6.1.2	Support Indigenous people to plan and implement Malleefowl conservation actions for their country where desired.	Consider incorporating actions to support the maintenance of Malleefowl-related cultural practices, law and conservation action in Healthy Country Plans or other Indigenous-led land management plans.	NRM and Landcare organisations, Indigenous land managers, Indigenous groups and rangers, Prescribed Body Corporates, Representative Native Title Bodies
6.1.3	Conduct community volunteer training.	Provide sessions in each State for mound monitoring and photo sorting as required.	National Malleefowl Recovery Group Inc., State Malleefowl Recovery Groups, NRM organisations
6.1.4	Provide training for Indigenous Rangers and Ranger Cadets (school children) to utilise data collection technology to record and analyse data.	Identify needs in consultation with community. Consider: collect field data, set up and service cameras, review camera images and identify and manage threats to Malleefowl.	NRM organisations
6.1.5	Encourage use of two-way science about Malleefowl in schools.	*Two-way Science* is an approach that connects the traditional ecological knowledge of Indigenous people, that is the scientific and cultural understanding of people, animals and the environment, with western science inquiry and links that to the Australian curriculum in a learning program. The *Two-way Science* approach should promote Indigenous leadership in education and foster partnerships between schools, communities, Indigenous ranger programs and scientists.	Schools, communities, Indigenous ranger programs, scientists, Prescribed Body Corporates, Representative Native Title Bodies

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
6.1.6	Invite mining companies with operations in Malleefowl habitat to participate in Malleefowl forums.	Prioritise mining companies with ventures in known Malleefowl habitat. Provide mining companies opportunities to showcase their Malleefowl conservation actions.	National Malleefowl Recovery Team, State Malleefowl Recovery Groups, State and Australian Government environmental regulators
6.1.7	Invite mining companies with operations in Malleefowl habitat to undertake monitoring.	Train staff to ensure monitoring contributes to the National Malleefowl Monitoring Program (mound monitoring) and the national Adaptive Management Predator Experiment (AMPE).	National Malleefowl Recovery Team, State Malleefowl Recovery Groups, State and Australian Government environmental regulators
6.1.8	Convene National Malleefowl Forum.	Forum should be undertaken every four years. Invite participation of all relevant land managers.	National Malleefowl Recovery Team
6.1.9	Maintain the National Malleefowl Recovery Team website.	Update website within 2 months of each National Malleefowl Recovery Team meeting with details of the meeting.	National Malleefowl Recovery Team
6.1.10	Develop and implement a Communications Plan to engage and inform the community about Malleefowl conservation.	Community is all target audiences as identified in the communications plan.	National Malleefowl Recovery Team
6.1.11	Install and maintain information boards in Malleefowl habitat.	Convey educational information relevant to the conservation of the Malleefowl at that location.	NRM agencies, Parks and Wildlife agencies, councils
6.1.12	Prepare and distribute information package to agricultural support agencies on Malleefowl conservation needs in cropland areas.	Prepare targeted packages of information relevant to the locality, e.g. select the changed behaviour sought - retention of habitat, feral animal control, revegetation to reduce fragmentation etc.	NRM organisations, National Malleefowl Recovery Team
	SUPPORTING STRATEGY **7. Survey, monitoring and research – determine distribution, habitat requirements and population dynamics**		
7.1	***Determine the current distribution and abundance of Malleefowl***		

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
7.1.1	Train and support Indigenous Rangers and Traditional Owners in Malleefowl survey and monitoring techniques and protocols that best suit their individual circumstances. Advise on the different survey and monitoring techniques available, the type of information they generate and the purpose they might serve.	Supporting Indigenous Rangers and Traditional Owners to upload data into the National Malleefowl Monitoring Database. Techniques include the Long Walk and Slow Drive methods for detecting Malleefowl in arid landscapes; line searches for detecting mounds; the National Mound Survey method for monitoring changes in breeding numbers; and air borne remote sensing methods such as Light Detection and Ranging (LiDAR)* and photogrammetry. * Consult with Traditional Owners whether LiDAR is appropriate as this technology method has the potential to put the security of culturally sensitive information at risk.	National Malleefowl Recovery Group Inc., State Malleefowl Recovery Groups, NRM Landcare organisations, Indigenous land managers, Indigenous groups and rangers, Prescribed Body Corporates, Representative Native Title Bodies
7.1.2	Undertake targeted surveys to detect Malleefowl, where distribution and abundance are poorly known.	Surveys in areas with exclusive and joint Native Title determinations are to be developed and managed, or co-developed and co-managed, by the relevant Native Title holders.	NRM and Landcare organisations, Indigenous land managers, Indigenous rangers, Prescribed Body Corporates, Representative Native Title Bodies, mining companies, researchers
7.1.3	Assess population trend of Malleefowl across all regions.	Report trends to government agencies and other interested parties.	National Malleefowl Recovery Group Inc.
7.1.4	Investigate the potential value of a model to show how climate change could affect the species distribution and location of refuges.	Once the value of a model is established, develop a climate change model.	National Malleefowl Recovery Team, Research partners*
7.1.5	Determine habitat requirements that predict breeding densities and population trends, including time since fire.	Report results to government agencies and other interested parties. GPS tracking of adult birds in different areas to identify important roost, nesting and foraging habitat.	Research partners*, National Malleefowl Recovery Team
7.1.6	Undertake a systematic study of a range of sites to identify habitat features that can be manipulated by management and used as targets for habitat restoration.	Report results to government agencies and other interested parties.	Research partners*, National Malleefowl Recovery Team

	Action required	Extra information about the action	**Potential Implementation partners** *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
7.1.7	Monitor the extent to which fire is affecting Malleefowl.	Establish annual fire history map layers for all Malleefowl habitats as the basis for National, State, and regional reporting on: • Reporting on annual fire impacts (% of Malleefowl habitat burnt) • Reporting on % of different post-fire age classes (TBD) within Malleefowl habitat • Providing a rolling 20-year figure for “% habitat burnt versus unburnt in previous 20 years”	State governments, Australian Government
7.1.8	Map annual rainfall patterns across Malleefowl habitat to understand or predict likely breeding responses.	Purpose is to collect real-time data on rainfall to analyse in conjunction with mound monitoring data.	State governments, Australian Government, research institutions
7.2	***Investigate infertility in isolated reserves***		
7.2.1	Review camera-trap photos from selected sites to detect young birds and temporal patterns over time.	It is assumed that presence of chicks in isolated reserves at similar rates to those elsewhere indicates that infertility is not resulting from inbreeding depressions associated with isolation.	Citizen scientists/volunteers, National Malleefowl Recovery Group Inc.
7.2.2	Identify isolated reserves with Malleefowl populations that may benefit from supplementation or genetic exchange or gene harvesting.	Prioritise these reserves by state and by NRM region.	State governments, National Malleefowl Recovery Team, Australian Government
7.2.3	Collect dropped Malleefowl feathers.	Provide feathers to state museum to store to utilise for genetic analysis	State Malleefowl Recovery Groups, citizen scientists/volunteers
7.2.4	Develop and implement a genetic management plan and translocation decision framework.	Objective of plan is to maintain the viability of small and isolated populations.	National Malleefowl Recovery Team, State governments, conservation agencies
7.2.5	Investigate infertility and low mound productivity in isolated reserves.	To inform decisions whether translocation is required.	Research partners*, museum partners, State governments

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
7.2.6	Investigate options to increase gene flow into isolated reserves where required under the genetic management plan.	E.g. corridors, reintroductions, translocations including egg transfers.	National Malleefowl Recovery Team
7.3	***Examine recruitment of young birds***		
7.3.1	Review camera-trap photos to detect young birds and analyse age classes to quantify recruitment.	Given the high reproductive output of Malleefowl, few Malleefowl chicks are expected to survive. Understanding the conditions under which they do survive may lead to important insights and improved management.	Citizen scientists/volunteers, National Malleefowl Recovery Group Inc., NRM and Landcare organisations, Indigenous land managers, Indigenous rangers, Prescribed Body Corporates, Representative Native Title Bodies, state recovery groups and Parks & wildlife agencies.
7.3.2	Collect and collate data on observations of young birds.	Analyse temporal patterns in detection of young birds in relation to potential drivers of breeding and fledgling success, and young survival.	National Malleefowl Recovery Group Inc.
	SUPPORTING STRATEGY **8.** Monitor the impacts of management interventions across sites, and use the information to adapt management		
8.1	***Annually monitor mound activity at sites***		
8.1.1	Undertake monitoring (annually where possible) at sites registered in the National Malleefowl Monitoring Program. Monitoring to include: • Mound monitoring in line with national guidelines • Recording of predator control and other management (e.g. herbivore control, fire) • Providing monitoring and other data to the National Malleefowl Monitoring Database annually	Monitoring in areas with exclusive and joint Native Title determinations are to be developed and managed, or co-developed and co-managed, by the relevant Native Title holders.	Indigenous land managers, Rangers and organisations and Custodians, National Malleefowl Recovery Group Inc., State Malleefowl Recovery Groups, citizen scientists/volunteers, land managers, State governments, conservation agencies, and species experts.

	Action required	Extra information about the action	Potential Implementation partners *Research partners include universities and other tertiary education institutions and land management organisations involved in research.
8.1.2	Analyse mound activity trend data for each NRM region annually.	Report trends to government agencies and other interested parties.	National Malleefowl Recovery Group Inc.
8.2	***Adaptively manage Malleefowl populations***		
8.2.1	Manage the Adaptive Management Predator Experiment (AMPE).	Coordinate the implementation of the AMPE across sites.	National Malleefowl Recovery Group and research partners*
8.2.2	Implement the Adaptive Management Predator Experiment.	• Annually where feasible • Over 5 years at a minimum of 30 sites nationally (15 treatment + 15 control) • Communicate results to key groups	Land managers in partnership with various Traditional Owners, Indigenous land managers and organisations, NGOs, NRM organisations, National Malleefowl Recovery Team, National Malleefowl Recovery Group Inc.
8.2.3	Commence an Adaptive Management Habitat Management Experiment.	Design experiment to determine impacts of herbivores on Malleefowl population trends.	National Malleefowl Recovery Group Inc. and research partners*
8.2.4	Undertake trend analysis of all AMPE monitoring sites every five years.	Report trends to government agencies and other interested parties.	National Malleefowl Recovery Group Inc. and research partners*
8.2.5	Convene annual AMPE meeting.	Present results, facilitate communication between Adaptive Management Predator Experiment partners and review results at meetings.	National Malleefowl Recovery Group Inc.
8.2.6	Share the results of the AMPE.	Prepare reports to NRM agencies, Adaptive Management Predator Experiment partners, citizen scientists/volunteers and National Malleefowl Recovery Team by June each year.	National Malleefowl Recovery Group Inc.

9 Effects on other native species and biodiversity benefits

Malleefowl share their habitat with numerous threatened species of mammals, birds, reptiles and plants that would also benefit from management actions that secure habitat, reduce grazing pressure, fox abundance, and the extent of fires, and increase the connectivity of habitat fragments. In particular, Malleefowl are one of a suite of threatened mallee birds that are listed under the EPBC Act including the Black-eared Miner (*Manorina melanotis*), Red-lored Whistler (*Pachycephala rufogularis*), Mallee Emu-wren (*Stipiturus mallee*), Regent Parrot (eastern) (*Polytelis anthopeplus monarchoides*), Western Whipbird (*Psophodes nigrogularis oberon* and *P. n. leucogaster*) and Mallee Bird Community of the Darling Depression Bioregion. Recovery plans have been prepared for some of these species and management recommendations in these are in accord with those for Malleefowl. Malleefowl also share their habitat with a number of near threatened and state-listed birds including the Striated Grasswren (*Amytornis striatus striatus*) (listed as Vulnerable in NSW and Vic and Rare in SA), Chestnut Quail-thrush (eastern) (*Cinclosoma castanotus castanotus*) (Endangered in NSW and Vic and Vulnerable in SA), Bush Stone-curlew (*Burhinus grallarius*) (Endangered in NSW and Vic and Vulnerable in SA) and Crested Bellbird (southern) (*Oreoica gutturalis gutturalis*) (Near Threatened in Vic). Some of these species might also benefit from increased community participation. The infrastructure used to monitor Malleefowl may also be useful to monitor the abundance of other species.

10 Social and economic considerations

This plan aims to contribute positively to communities within the range of Malleefowl. Conserving Malleefowl, and implementation of the actions in this plan in particular, is likely to have positive social and economic outcomes for several communities across Australia. The species is well known internationally for its unusual nesting habits and has achieved iconic status within Australia in many agricultural and conservation areas where it features in tourist information. As such, the species adds to the attractions of many areas. Malleefowl are also popular with local communities and feature in the emblems of several shires and councils across Australia. At Ongerup in the WA wheatbelt, the local community has developed the Yongergnow Australian Malleefowl Centre, which is intended to stimulate tourism as well as benefit the species.

Malleefowl are also important culturally to Traditional Owners. Traditional Owner Ranger groups and their Prescribed Body Corporates present an opportunity for engagement and partnership to undertake Malleefowl survey and monitoring work.

There are likely to be few adverse social or economic impacts of this recovery plan and no specific geographic areas have been identified where recommended actions would disadvantage any social or economic interest. Legislation for native vegetation retention and threatened species protection already exist in all states, and no additional social and economic impacts are likely to occur from the implementation of this plan. For example, mineral sands mining is restricted by existing legislation in areas occupied by Malleefowl, particularly where there is a clear net loss for Malleefowl conservation.

Some negative economic impacts may occur where stock are excluded from areas that harbour Malleefowl, although these impacts are likely to be minor as habitats favoured by Malleefowl are generally of poor quality for stock. We believe the benefits gained from such exclusions in the conservation of a range of threatened species outweigh these losses in the long term.

Some negative economic impacts may also occur if tighter restrictions are placed on the eucalyptus and broombush harvesting industries in an effort to manage these areas in a way that is more sympathetic to the conservation of Malleefowl and other species. These areas tend to be relatively small, but the benefit of improved management to the regional conservation of Malleefowl in some cases would be substantial and would outweigh short-term economic losses.

Unforeseen adverse effects will be avoided through consultation with interested parties.

11 Organisations/persons involved in evaluating the performance of the plan

This plan should be reviewed no later than five years from when it was endorsed and made publicly available. The review will determine the performance of the plan and assess:

- whether the plan continues unchanged, is varied to remove completed actions or varied to include new conservation priorities, or
- whether a recovery plan is no longer necessary for the species as conservation advice will suffice or the species is recommended for removal from the threatened species list.

The review should be coordinated in association with relevant Australian and state government agencies and key stakeholder groups such as non-governmental organisations, local community groups and scientific research organisations.

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13 Personal Communications

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Ms Tania Rajic (2020), Limestone Coast Landscape Board NRM, Mt Gambier, SA

Mr Whimpey Reichelt, Little Desert Lodge, Nhill, VIC (cited in Benshemesh 2007b)

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Dr Rupert Woods, Western Plains Zoo, Dubbo, NSW (cited in Benshemesh 2007b)

Appendix I Indigenous names for Malleefowl

The following table lists Indigenous languages (following Horton 1994) that overlapped the range of Malleefowl. Each of these languages is likely to have specific names for Malleefowl, although few have been recorded. Similarly, little has been recorded of the traditional knowledge of Malleefowl habits and distribution.

DESERT		
Language	**Nearby Town**	**Indigenous name for Malleefowl (with numbered sources below table)**
Kokatha	Tarcoola, SA	
Yankuntjatjara	Fregon	Nganamara (3)
Pitjantjatjara	Pipalyatjara, SA	Nganamara (3)
Luritja	Papunya, NT	
Arrernte	Alice Springs, NT	Ngamarre (3,4) Ngamerre (5), Unematye (5), Anthelkarlwilenhe (5)
Alyawarre		
Anmatyerre	Coniston, NSW	
Warlpiri	Tanami	Warntu (6,7), Nguumarra/Ngaamarra (7), Ngama (female), (6)
Ngarti		
Pintupi		
Ngatatjara		
Nakako		
Ngalea		
Ngaanyatjarra	Warburton	Nganarmara (10)
Mandjindja		
Nyanganyatjara	Rawlinna, WA	
Wawula		
Nana		
Tjalkanti	Laverton, WA	
Wangkathaa	Kalgoorlie, WA	
Kuwarra	Leinster, WA	
Tjupany	Wiluna, WA	

SPENCER		
Language	**Nearby Town**	**Indigenous name for Malleefowl (with numbered sources below table)**
Peramangk		
Kaurna		
Narangga	**York Peninsula, SA**	
Nukunu	**Port Pirie, SA**	

SPENCER		
Banggarla	**Whyalla, SA**	
Nawu	**Port Lincoln, SA**	
Wirangu	**Ceduna, SA**	**Gabiny (1), Nganamara (1)**

SOUTHEAST		
Language	**Nearby Town**	**Indigenous name for Malleefowl (with numbered sources below table)**
Wathaurong	Ballarat, VIC	
Djadjawurung	Bendigo, VIC	
Jardwadjali	Horsham, VIC	
Wergaia	Nhill/Ouyen, VIC	Lauan (1)
Bindjali	Bordertown, SA	
Ngargad	Pinnaroo, SA	
Ngarrindjeri	Kingston SE, SA	
Baraba Baraba	Echuca, VIC	
Wemba Wemba	Swan Hill, VIC	Lawan (1)
Wadi Wadi		
Dadi Dadi		
Nari Nari		
Madi Madi	Balranald, NSW	Lawani (1)
Latje Latje	Red Cliffs, VIC	
Meru	Berri, SA	
Kureinji	Mildura, VIC	
Danngali		
Wiljali	Broken Hill, NSW	
Barkindji	Menindee, NSW	Nhawarru (1)
Barindji	Ivanhoe	
Yitha Yitha		
Ngyampaa Wongaibon	Cobar, NSW Cobar, NSW	Yungadhu (12) Yungkay (9)
Wiradjuri	Corowa/Dubbo, NSW	Yuunggaay (2), Yungkay (9)
Wailwon	Coonambie	Yungkay (9)

SOUTHWEST		
Language	**Nearby Town**	**Indigenous name for Malleefowl (with numbered sources below table)**
Whanta	Northampton, WA	Ngow (11)

SOUTHWEST		
Yuat	Dandaragan, WA	Ngow (11)
Yuat	Berkshire Valley, WA	Ngow (11)
Wajuk	Perth, WA	Ngow (11), Ngowa (11)
Wiilman	Williams	Ngow (11)
Kaniyang	Bridgetown, WA	Ngow (11)
Kaniyang/Goreng	Katanning, WA	Ngow (11)
Minang	Kendenup, WA	Ngow (11)
Wardandi	Vasse, WA	Ngow (11), Ngau (11)
Wardandi	Wonnerup, WA	Ngow (11)
Wardandi	Korrlup	Ngow (11)
Wudjari	Esperance, WA	Ngow (11)
Amangu	Dongara, WA	Ngow (11)
Minang	Albany, WA	Ngow (11), Ngaua (11), Ngaow (11)
Yuat	Mogumber, WA	Ngowa (11)
Balardung/Wajuk	York, WA	Ngowa (11)
Balardung/Wajuk	Merkering	Ngowa (11)
Pinjarup	Pinjarra, WA	Ngowa (11)
Yuat	Gingin, WA	Ngowo (11)
Minang	Denmark, WA	Ngow'wa (11), Ngaua (11)
Minang	Plantagenet, WA	Ngau (11)
Goreng	Jerramungup, WA	Ngau (11)
Wiilman	Wagin, WA	Gnow (11)
Mirning	Eucla, WA	Ngauoo (8), Ngauoig (8)
Ngatjumay	Balladonia, WA	
Malpa	Norseman, WA	
Wudjari	Ravensthorpe, WA	
Nyaki-nyaki	Newdegate, WA	
Kalaamaya	Southern Cross	
Goreng	Gnowangerup, WA	Gnow
Bibbulman	Manjimup, WA	
Wardandi	Busselton, WA	
Kaniyang	Bunbury, WA	
Pinjarup	Pinjarra, WA	
Balardung	Goomalling, WA	
Yuat	Moora, WA	
Amangu	Geraldton, WA	

NORTHWEST		
Language	**Nearby Town**	**Indigenous name for Malleefowl (with numbered sources below table)**
Badimaya	Mount Magnet, WA	
Nhanta	Northampton, WA	
Watjarri	Wilga Mia	
Malkana	Denham, WA	
Yinggarda	Carnarvon, WA	
Maya	Carnarvon, WA	
Payungu		
Thalanyji	Exmouth, WA	

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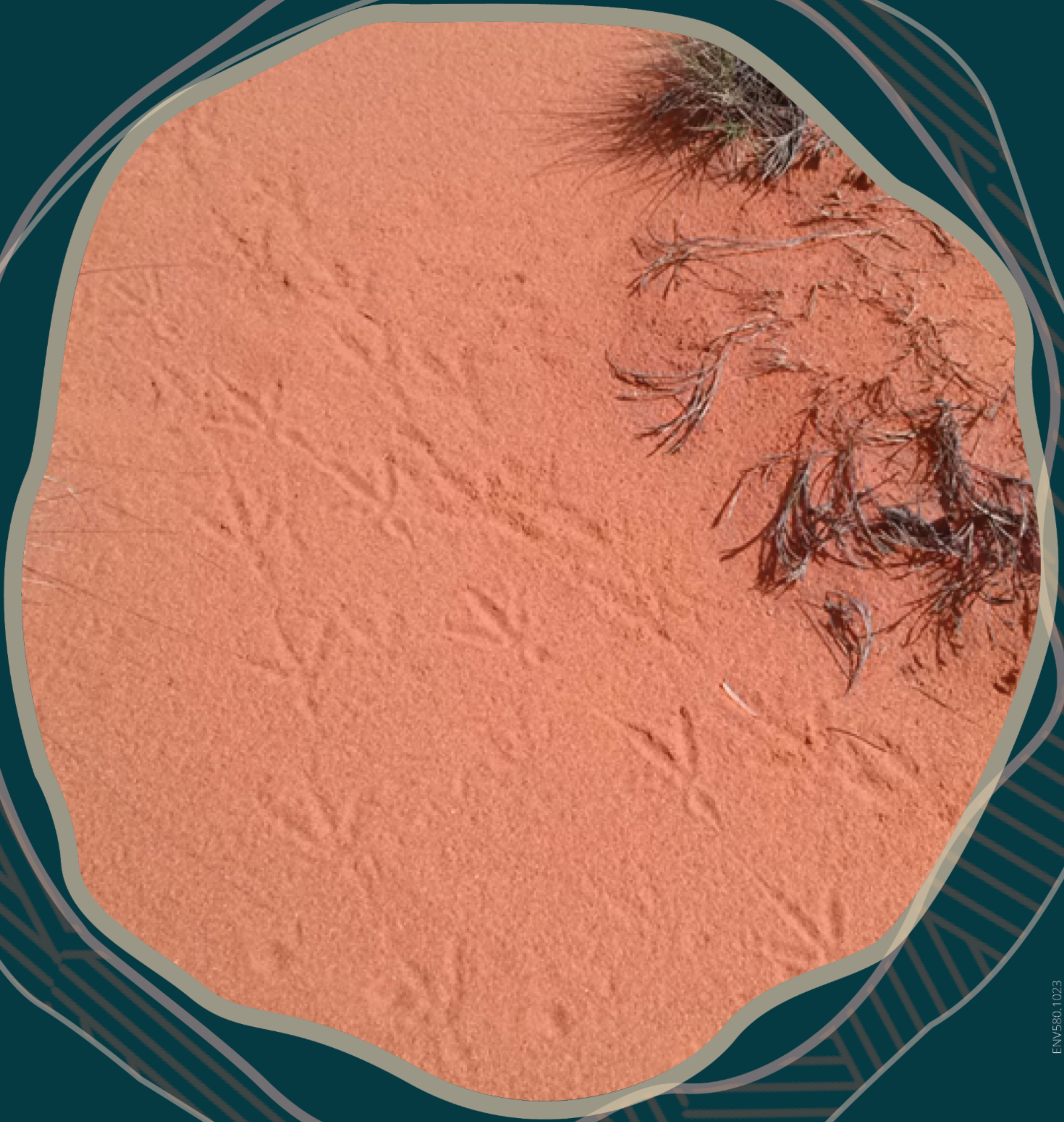

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