FOI 191010
Document 1

**From:** s22 DPIPWE)
**To:** s22
**Subject:** RE: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]
**Date:** Monday, 26 November 2018 3:40:29 PM

---

Thanks s22

No worries!

Yes, happy to provide extra information where we can for CA updates Potentially much easier for species than communities).

Re 40-spot, I will send you s47F response to me FYI. She would be happy to be contacted further.

s22

Cheers

s22

---

**From:** s22 @environment.gov.au]
**Sent:** Monday, 26 November 2018 3:34 PM
**To:** s22 DPIPWE)
**Cc:** s22
**Subject:** RE: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]

Hi s22

Thanks so much for your response (I note that you sent this early on Sat morning!).

Where you have provided comments that the CA for a species needs reviewing, will it be possible for you (over time) to provide us with the new information for those species that we could incorporate into the CAs? That would be much appreciated. To give you a bit of context on the timing, there is less of an urgency to have the CAs themselves updated/finalised until the time of the Minister's final subsequent recovery plan decision – and we don't expect that to happen for at least six months. What I might do is make a note of these in our system, and perhaps check in with you again later for the info, if that's OK?

FYI, with the forty-spotted pardalote (noting that you advised 'yes' to a recovery plan), our scientific committee had requested additional consultation on this one as they considered it was borderline. Thanks for providing the contact details of s47F as we will contact her directly (once we are ready to go out for public consultation) to seek her views. Depending on all views being considered from the various consultation processes it is still possible that the committee could recommend that a recovery plan continue to be required.

s22

Kind regards,

s22
Terrestrial Threatened Species Section
Protected Species and Communities Branch
Department of the Environment and Energy
s22 @environment.gov.au

*We acknowledge and celebrate the First Australians on whose traditional lands we meet and work,* *and whose cultures are among the oldest continuing cultures in human history.*

**From** s22 (DPIPWE) s22 @dpipwe.tas.gov.au]
**Sent:** Saturday, 24 November 2018 7:16 AM
**To** s22
**Cc:** s22
**Subject:** RE: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]
Hi s22

My apologies for the late response - please find attached the Tas jurisdictional position on the need for recovery plans for the identified species. Please don't hesitate to contact me if further information or clarification is required.

Kind regards,

s22

---

**From** s22 environment.gov.au]
**Sent:** Friday, 23 November 2018 10:57 AM
**To:** s22 DPIPWE)
**Cc** s22
**Subject:** FW: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]

s22

Terrestrial Threatened Species Section
Protected Species and Communities Branch
Department of the Environment and Energy
s22 environment.gov.au

*We acknowledge and celebrate the First Australians on whose traditional lands we meet and work,*
*and whose cultures are among the oldest continuing cultures in human history.*

**From:** s22 DPIPWE) s22 @dpipwe.tas.gov.au]
**Sent:** Tuesday, 6 November 2018 2:27 PM
**To** s22 @environment.gov.au>
**Subject:** RE: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]

s22

Manager
Policy and Conservation Advice Branch
Natural and Cultural Heritage Division
Department of Primary Industries, Parks, Water and Environment

PO Box 44 Hobart 7001
s22

**From** s22 @environment.gov.au]
**Sent:** Tuesday, 6 November 2018 2:15 PM
**To** s22 DPIPWE)
**Subject:** RE: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]

Thanks for your prompt response s22 – your comments much appreciated.

s22

Kind regards,
s22
Terrestrial Threatened Species Section
Protected Species and Communities Branch
Department of the Environment and Energy
s22 @environment.gov.au

*We acknowledge and celebrate the First Australians on whose traditional lands we meet and work,*
*and whose cultures are among the oldest continuing cultures in human history.*

**From** s22 DPIPWE s22 @dpipwe.tas.gov.au]
**Sent:** Tuesday, 6 November 2018 1:36 PM
**To:** s22 @environment.gov.au>
**Subject:** FW: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]

Hi s22

Please find attached responses and amendments in tracked changes, as requested. Please don't hesitate to contact me if you have any questions.

Kind regards,
s22
Manager
Policy and Conservation Advice Branch
Natural and Cultural Heritage Division
Department of Primary Industries, Parks, Water and Environment
PO Box 44 Hobart 7001
s22

**From** s22 environment.gov.au>
**Sent:** Friday, 28 September 2018 4:00 PM
**To:** s22 DPIPWE s22 @dpipwe.tas.gov.au>
**Subject:** FW: Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]

Hi s22

I have just sent this email to s22 and noticed that he is away for a while longer. Thought I would send it through to you, as I wanted to give your team as much time as possible to consider and respond.

Happy to discuss if you have any queries.

Kind regards,
s22

s22
Terrestrial Threatened Species Section
Protected Species and Communities Branch
Department of the Environment and Energy
s22 @environment.gov.au

*We acknowledge and celebrate the First Australians on whose traditional lands we meet and work,*
*and whose cultures are among the oldest continuing cultures in human history.*

---

**From** s22
**Sent:** Friday, 28 September 2018 3:47 PM
**To:** s22 (DPIPWE)' s22 @dpipwe.tas.gov.au>
**Cc** s22 @environment.gov.au>; s22
s22 @environment.gov.au>; s22
s22 @environment.gov.au>
**Subject:** Review of recovery plan decisions under the EPBC Act [SEC=UNCLASSIFIED]

Hi s22

You may recall that we consulted with your agency about one year ago on a project to systematically review the need to continue having a recovery plan for EPBC-listed threatened species and ecological communities. s22

s22

This email is providing you with another 12 species and ecological communities that we would like to similarly seek your views on whether a recovery plan or conservation advice would provide the most appropriate guidance for conservation and recovery actions (noting that all listed species and ECs that no longer have a recovery plan will have an approved conservation advice put in place). The majority of the entities are in the position of being overdue to have a recovery plan in force under the EPBC Act, with one that will have its recovery plan due to sunset in 2022.

s22

We are keen to consult with you on the list of entities (attached table) to ensure we have considered all relevant matters in making this determination. In particular we are seeking:

- Your agency's views about having a conservation advice, rather than a recovery plan.
- If you consider a recovery plan is needed for any of the species on the list, please indicate this in the attached table and provide your reasons.
- If you agree that a recovery plan is no longer needed (and if relevant), we would welcome your feedback on any gaps or improvements for the current conservation advice. Please provide

any necessary information that you are aware of in your email response, including references/citations for the new information.

- Contact details of any recovery teams or groups you know of that are involved in coordination and/or implementation of a recovery plan for these species. We will ensure that these teams are consulted during the review process.

The attached table of the entities includes basic information and links to the conservation documents for these entities. We ask that you enter those details that are relevant in the columns and attach it to your response (together with your feedback on any of the conservation advices, if needed).

For your information, a flowchart is again attached that outlines the process for a subsequent recovery plan decision under s269AA(5) of the EPBC Act.

We would appreciate a response from your agency by **Friday 23 November 2018**, after which we will group these entities together with the ones we consulted you on last year, and proceed to brief the Minister for the Environment, the Hon. Melissa Price (the Minister) on the *proposed* subsequent recovery plan decision. Please provide your responses to me on the contact details below.

Please note that the attached list of entities has been provided to your agency for consultation only and should not be distributed more widely than necessary. At an appropriate stage in the process, the Minister's proposed decision, and list of species and ecological communities, will be made available for public comment on the Department's web site.

Further background information about the review of recovery plan decisions is provided below.

If you have any questions about this process, please do not hesitate to contact me (details below), my manager s22 [redacted] (tel: 02 6274 s22 [redacted] or director s22 [redacted] (tel: 02 6275 s22 [redacted]

s22 [redacted]

s22

Terrestrial Threatened Species Section
Protected Species and Communities Branch
Department of the Environment and Energy
s22 @environment.gov.au

*We acknowledge and celebrate the First Australians on whose traditional lands we meet and work,*
*and whose cultures are among the oldest continuing cultures in human history.*

---



---

CONFIDENTIALITY NOTICE AND DISCLAIMER
The information in this transmission may be confidential and/or protected by legal professional privilege, and is intended only for the person or persons to whom it is addressed. If you are not such a person, you are warned that any disclosure, copying or dissemination of the information is unauthorised. If you have received the transmission in error, please immediately contact this office by telephone, fax or email, to inform us of the error and to enable arrangements to be made for the destruction of the transmission, or its return at our cost. No liability is accepted for any unauthorised use of the information contained in this transmission.

---

CONFIDENTIALITY NOTICE AND DISCLAIMER
The information in this transmission may be confidential and/or protected by legal professional privilege, and is intended only for the person or

**Tas species proposed for subsequent recovery plan decision (to not have a plan) under s.269AA(5) of the *Environment Protection and Biodiversity Conservation Act 1999***

| Scientific Name - of listed threatened entity | Common Name | Jurisdiction(s) of Occurrence | Notes | Recovery plan needed Y/N (please provide reasons if 'yes') | Contact details of recovery team/group (if any) |
|---|---|---|---|---|---|

s22

[redacted]

| Scientific Name - of listed threatened entity | Common Name | Jurisdiction(s) of Occurrence | Notes | Recovery plan needed Y/N (please provide reasons if 'yes') | Contact details of recovery team/group (if any) |
|---|---|---|---|---|---|
| s22 | | | | | |
| *Pardalotus quadragintus* | Forty-spotted Pardalote | TAS, | Conservation advice approved 15/7/16. Recovery plan in force 10/11/06 - due to sunset under *Legislation Act 2003* on 1/4/22. TSSC recommended review of RP decision (Sept 2018), with additional targeted consultation. | Y | s47F |
| s22 | | | | | |

# s22

FOI 191010
Document 2

s22

**From:** s22 (DPIPWE)
**Sent:** Thursday, 11 April 2019 1:36 PM
**To:** s22
**Subject:** RE: s22 [SEC=OFFICIAL]

Hi s22

Great to see you the other day. Answers to questions below.

Cheers

s22

---

**From:** s22 @environment.gov.au>
**Sent:** Thursday, 11 April 2019 12:42 PM
**To:** s22 (DPIPWE) s22 @dpipwe.tas.gov.au>
**Subject:** FW: s22 [SEC=OFFICIAL]

s22

s22

With the pardalote, we'd need to get s47F and the recovery team on board either way. In asking states/territories on their initial views on the proposed decisions, we know that that there are other affected interests that need to be consulted eg recovery teams, NGOs etc. In part we are relying on states for that advice (as is the case here) prior to any recommendation, but given the proposed decision changes will involve a public consultation period, we can also capture all those views than. How do you want to proceed with this one then? Is this something you can have a chat with s47F about? There is a 2016 CA in place – it could be updated to included objectives, etc as a plan should. And I can't remember if you said, but is a recovery team still active? I consulted with s47F and the RT before coming to the "yes" position on this one. However, the RT hasn't met for two years and I do not see a resourcing opportunity to produce a new one. In any case, our knowledge of the species is changing quite quickly (some populations discovered, some gone, new info on parasite issues etc). In that context a CA makes sense. The counterview is that development is placing huge pressure on many remaining colonies, so the regulatory role of a RP is attractive. s47F
s47F

| **Scientific name** | **Common name** | **Tas comments** |
|---|---|---|
| s22 | | |
| *Pardalotus quadragintus* | forty-spotted pardalote | **Tas** – RP needed. |

Cheers

s22

s22

s22 s47F

s22

s22

s47F

---

FOI 191010
Document 3

**From:** Jaana Dielenberg
**To:** s22
**Cc:** Research; Rachel Morgain (rachel.morgain@anu.edu.au); s22 ; TSR Publications
**Subject:** Product submission - Science for Saving Species Magazine #10
**Date:** Wednesday, 6 March 2019 3:30:59 PM
**Attachments:** image001.png
SfSS#10 whole V5.pdf
20190310 NESP Research Product Subm ssion Form SFSS Mag 10.pdf

---

Hi s22
Please find attached a product submission for the latest edition of Science for Saving Species Magazine – No 10, which has the climate change focused editorial and a picture of a fish on the cover
Kind regards,

**Jaana Dielenberg**
Science Communication Manager

Centre for Biodiversity and Conservation Science
Room 533, Goddard Building, The University of Queensland, St Lucia, Qld 4072
P: +61 7 3365 2450 | M: +61 413 585 709 | F: +61 7 3365 1655
E j dielenberg@uq edu au
The Threatened Species Recovery Hub is supported through funding from the Australian Government s National Environmental Science Programme
www nespthreatenedspecies edu au | @TSR_Hub

FOI 191010
Document 3a

Australian Government

National Environmental Science Programme

# Research Product Submission Form

The Department of the Environment will use the research product and information provided in this form to share the knowledge generated under the NESP, support its adoption and identify opportunities to promote NESP research.
Hold the cursor over each answer field for instructions on completing this form.

### Project Information

| | |
|---|---|
| Hub name | Threatened Species Recovery |
| Project number | N/A |
| Project title | Hub level |
| Product lead author/researcher | Jaana Dielenberg |
| Program funding (NESP/NERP/CERF/Combination) | NESP |

### Research Product Information

| | |
|---|---|
| Select the type of research product | Other |
| Other | Magazine |
| Title | Science for Saving Species Magazine: Edition 10, Summer 2019 |
| Journal or location name | TSR Hub website |
| DOI | TSR Hub website |
| Citation | NESP Threatened Species Recovery Hub, 2019, |
| Synopsis | Magazine with a range of stories on TSR Hub research |
| Media/other interest | nothing planned |
| Keywords | climate ch night parrot fish barriers forty-spotte hollow-nes |

### Research Product Accessibility

| | |
|---|---|
| Date of publication | 03/10/18 |
| Date of product availability | 03/10/18 |
| Location of product availability | TSR Hub website |
| Version of product attached | yes |

☑ I certify that I have attached the copy of the publication that can be provided to and used within the Department of the Environment in accordance with the specific publisher copyright restrictions that relate to this product.

Email Form

Functionality may be limited unless opened in Adobe. If the instructions do not appear or the above button does not work, visit www.environment.gov.au/nesp for instructions and email the form to your hub Communications or Administration Officer.

FOI 191010
Document 3b

# Science for saving species

Summer 2019
Issue 10

## Climate change and threatened species

## How did the fish cross the road?

Ghosts of digging mamm past

Night parrots on Paraku country

Conserving hollow-nesting birds

The forty-spotted pardalote

New TSX for Australian birds

Threatened Species Recovery Hub

National Environmental Science Programme

IMAGE: BY NICOLAS RAKOTOPARE

# Droughts, heatwaves, floods and fires

## Threatened species in a changing world

The world is changing. Some of this change is planned and desirable. But much else is an unwanted consequence of the expansion of the human species. Those unwanted impacts will affect our lives and those of our descendants. But they are also affecting – and will increasingly threaten – many of the world's endangered species, including many Australian plants, animals and ecosystems.

The Australian environment is now experiencing climate change. Of course, not all single abnormal climate events are a consequence of our pattern of greenhouse gas emissions. But the pattern is evident.

### Extremes becoming the new normal

In the last 12 months, fires without recent precedent occurred from the mountain rainforests of Queensland to the World Heritage alpine heathlands and rainforests of south-western Tasmania. Unusually long periods of extreme heat baked much of inland and eastern Australia. The long drought intensified across much of inland Australia. Exacerbated by unsustainable water management, hundreds of thousands of fish, including the Vulnerable Murray cod and the Critically Endangered silver perch, have died in the Menindee Lakes and the lower Darling River. Increasingly frequent and extensive bleaching events – driven by unusually warmed waters – damage our coral reef systems. In the Australian Alps, the intricate interconnections among species fray as the region warms and snow cover diminishes. The thread connecting these very different examples of loss is climate change.

Perhaps we imagined that the impacts of climate change will be felt mostly in far-flung polar regions with melting ice caps – but not here at home. However, the recent biodiversity losses across many parts of Australia demonstrate that the changes will also happen far closer to home. Much of Australia's nature, the essence of our country, is susceptible to climate change. Indeed, the loss in the last decade of Australia's Bramble Cay melomys may be one of the first cases in the world of extinction due to climate change.

IMAGE: VICKI NUNN, PUBLIC DOMAIN

The 2010 flood of the Calliope River in central Queensland.

### Catastrophic losses

A sobering and acute example is of the mass mortality over a few days of extreme heat for the now Endangered spectacled flying-fox. Reports indicate that up to one-third of the total Australian population of this species succumbed to the extremely hot temperatures over just two days in late 2018. Episodes of such extreme heat, and consequent mortality, are becoming more frequent. We cannot expect this to stay a single 'freak' event. Many other (less conspicuous) threatened species are also likely to have experienced acute population losses but without such public awareness.

Many other precariously imperilled species have the odds tipped further against them by climate change, and it is likely to exacerbate other threats. Recent fires have threatened the tiny remaining ranges (and tenuous populations) of three of Australia's most Critically Endangered species, the Gilbert's potoroo and western ground parrot in south-western Australia, and the central rock-rat in a few mountaintops in central Australia. At least for south-western Australia, the likelihood and menace of these fires is being magnified by an increasingly drier climate.

### Incremental impacts are also a danger

Large sudden catastrophic events like the Menindee Lakes fish deaths kills confront us, but in many cases, climate change impacts operate incrementally and insidiously. For decades rainfall in south-western Australia has been decreasing and with it the swamps of the Western Swamp Turtle dry for longer periods each year. In future there may not be enough wet months each year to allow the turtles to eat, grow and reproduce before the swamps dry up.

Humans suffer as a consequence of climate change. But, to an extent, we can respond, such as by using air-conditioning and more water. Most threatened plants, animals and ecosystems have less capacity to cope. It is largely our actions that have caused their declines; increasingly, it will be up to us to prevent their extinctions. We are now witnessing degradation of Australian biodiversity as a consequence of climate change. But this is just the beginning: it will get worse. The momentum, pervasiveness and complex manifestations of climate change will increase the need for our actions, but render the response increasingly challenging.

### Responding to the challenge

But the challenge must be faced, for otherwise we will lose our nature, and much else. There are many things we can and should do. Our governments have committed to greenhouse gas reductions, and instituted some mechanisms to achieve these targets. But this is a gradational response. The equations are straightforward: the more we rein in emissions, the less will be the environmental loss and the impacts to the lives of our children, and those of their descendants. We can and should be ambitious and strategic in reducing emissions and tackling this global problem.

### Helping nature to cope

We need to reverse the ongoing losses of habitat due to vegetation clearance. In a new world buffeted by climate change, many species may persist only if they can disperse to cooler, wetter or more equitable locations, or to unburnt areas after extensive fire.

IMAGE: ROB BLAKERS CC BY-SA 3.0 WIKIMEDIA COMMONS

The aftermath of the 2016 fire in the world heritage area on Tasmania's central plateau

We can give such climate refugee species more of a chance by restoring habitat connectivity; but even more so by halting land clearance.

We can and should identify, and then stringently protect and carefully manage, those special and critical parts of the landscape that give refuge to species at times of short- and longer-term climatic stress. Research in this Hub is doing much to recognise such refugial areas. For some species, we will need to actively intervene and translocate populations to such relatively secure areas or to areas more likely to support favourable climatic conditions in the future, as is now being trialled for the Critically Endangered western swamp turtle.

We can strengthen environmental laws and policies, such that they are not set aside or abused when humans face their own crises due to climate change. We can establish more precautionary buffers for use of natural resources such as water, to ensure that our resource use, particularly in periods of stress, does not lead to irreversible collapse of the environmental systems on which we depend.

As a concerned society, with a stake in the future, we should ensure that laws and processes governing developments appropriately factor in climate change considerations. The recent case of a ruling against a New South Wales Coal mine, which included climate change impacts as one of the deciding factors, is a heartening precedent.

The world is changing.
We can help shape that change.

Professor John Woinarski
Deputy Director, TSR Hub
John.Woinarski@cdu.edu.au

*Further reading*

Garnett, S. and Franklin, D. (Eds) (2014). *Climate Change Adaptation Plan for Australian Birds.* CSIRO Publishing: Melbourne.

Mitchell, N., Hipsey, M., Arnall, S., McGrath, G., Tareque, H., Kuchling, G., Vogwill, R., Sivapalan, M., Porter, W., and Kearney, M. (2013). Linking eco-energetics and eco-hydrology to select sites for the assisted colonization of Australia's rarest reptile. *Biology* 2, 1–25.

Waller, N. L., Gynther, I. C., Freeman, A. B., Lavery, T. H., and Leung, L. K.-P. (2017). The Bramble Cay melomys *Melomys rubicola* (Rodentia: Muridae): a first mammalian extinction caused by human-induced climate change? *Wildlife Research* 44, 9–21.

Watson, J. (2016). Bring climate change back from the future. *Nature* 534, 437.

IMAGE: TONI FISH CC BY 2.0 FLICKR

## Inside the Summer 2019 issue of *Science for Saving Species*



Threatened Species Recovery Hub

National Environmental Science Programme

# The ghosts of **digging mammals past**

Native digging mammal species used to occur throughout Australian landscapes. Many are now missing. IMAGE: LEONIE VALENTINE

IMAGE: LEONIE VALENTINE

Once upon a time, not that long ago, Australia hosted an abundance of digging mammals like boodies, bilbies and potoroos. With the loss of these species from many parts of the landscape comes the loss of the work they did as ecosystem engineers. **Leonie Valentine, Bryony Palmer** and **Gabrielle Beca** unearth some important findings about the importance and role of native digging mammals in the Australian landscape and things to consider when returning lost diggers to their homelands.

From subterranean marsupial moles to hairy-nosed wombats, digging mammals once occurred right across the Australian mainland, and on many islands. However, over the past 200 years, most of Australia's unique digging mammals have undergone drastic population reductions and range declines due to habitat loss, predation by cats and foxes and altered fire regimes. Species like the boodie (or burrowing bettong, *Bettongia lesueur*) were previously widespread, but are now found only on offshore islands like Barrow Island or in fenced conservation reserves where they have been reintroduced. Other species, like the lesser bilby (*Macrotis leucura*) and pig-footed bandicoot (*Chaeropus ecaudatus*), were considered common by Indigenous Australians and early Europeans but are now gone forever.

The quenda (*Isoodon fusciventer*) is a digging bandicoot endemic to south-western Australia.

IMAGE: LEONIE VALENTINE

## Why are digging mammals important?

By creating burrows for shelter, ploughing through soil or digging foraging pits when searching for food, mammals (and other animals) move and rework soils, a process known as bioturbation. Although the digging activities of some mammals appear small at a local scale, their cumulative impact can be surprisingly important for broader-scale landscape processes. Consequently, many of Australia's digging mammals are considered ecosystem engineers. But many digging mammals are now absent from much of their former range. Without them, the ecosystem functions these animals once provided are no longer taking place. This may be compromising landscape health by reducing key processes such as soil turnover, water infiltration, nutrient cycling and plant recruitment.

## What about the rabbit?

The European rabbit, an introduced digging mammal, has spread throughout many Australian landscapes. This invasive species, with its ability to procreate rapidly and proclivity to overgraze, has caused enormous ecological damage and been the subject of many control programs. But could the rabbit be an ecological replacement for our lost native diggers? Unfortunately, it seems unlikely. Despite being considered an important ecosystem engineer in its native range, research on its impact in Australia

IMAGE: LEONIE VALENTINE

Quenda create many foraging pits while searching for underground invertebrates, tubers and fungi.

strongly suggests that they are not functionally equivalent to our native digging mammals.

## Quenda and woylie as diggers

To better understand the roles of Australian digging mammals, we have been examining what some of the persisting species can do.

A frequently spotted native digging mammal in Perth bushland reserves is the quenda (*Isoodon fusciventer*). Like other bandicoots, the quenda has suffered range contractions and population declines, but it persists in some urban bushlands and has been reintroduced to others, such as Craigie Bushland (managed by the City of Joondalup).

Quenda use their well-developed fore-limbs to dig for underground food, such as invertebrates, fungi and tubers, turning over substantial amounts of soil in the process. Through the creation of foraging pits, quenda break the crust of the soil surface, which changes the ability of soil to repel water. The combination of digging and discarding soil exposes subsurface soil and buries organic matter and litter under the spoil heap, potentially helping litter decomposition.

We've recorded higher levels of soil properties important for plant growth, such as potassium and electrical conductivity, in the spoil heaps created by quenda than in undug soil. These extra nutrients may assist seedling growth. In a trial, the seedlings of a local eucalypt, tuart (*Eucalyptus gomphocephala*), grew faster and bigger in soil from quenda spoil heaps than seedlings grown in undug soil.

Previously occurring across much of southern Australia, the woylie (or brush-tailed bettong, *Bettongia penicillata*), is now restricted to just 1% of the mainland and is listed as Critically Endangered. This delightful digging mammal still occurs in the proposed Dryandra Woodland National Park, an unfenced reserve approximately 170 km south-east of Perth. Woylies are also ecosystem engineers, turning over vast amounts of soil while digging for their dinner (mostly fungi, roots and seeds). They may also play an important role in the dispersal of some plant species, such as sandalwood (*Santalum spicatum*), through seed-caching behaviours. We are investigating their effect on both soil properties and seed dispersal.

## Returning lost diggers

Digging mammals are now absent from vast areas of the country. To improve the conservation status of these species, many conservation organisations, including Australian Wildlife Conservancy and Western Australia's Department of Biodiversity, Conservation and Attractions, are working to reintroduce them to selected areas – usually behind predator-proof fences or on predator-free islands.

Reintroducing digging mammals could help to restore or reinvigorate lost ecosystem functions but the landscapes these animals are being reintroduced into are very different to when they were last present. Many native species are missing or reduced in abundance, new species of plants and animals are present, vegetation communities have been restructured by altered fire regimes and grazing by sheep or cattle, and the functions that the boodie itself contributed to have been reduced.

In this new landscape, how would the cumulative effects of thousands of foraging pits and burrows of species like boodies alter soil properties and structure vegetation communities? To find out, we are measuring soil properties and quantifying plant abundance and species composition on and off boodie warrens to see how they differ from undisturbed areas. We'll then assess the same variables across large areas with and without boodies, and other digging mammals, to see what happens when the ghosts of diggers past are returned to Australian landscapes.

Reduced to 1% of its former range, the woylie is still found at proposed Dryandra Woodland National Park, in south-west Western Australia.

IMAGE: MIKE WYSONG

The boodie is a bettong that was previously widespread but is now listed as Vulnerable.

***Read more:***

Valentine, L. E., Ruthrof, K. X., Fisher, R., Hardy, G., Hobbs, R.J., and Fleming, P. A. (2018). Bioturbation by bandicoots facilitates seedling growth by altering soil properties. *Functional Ecology* 32, 2138–2148. https://besjournals.onlinelibrary.wiley.com/doi/abs/10.1111/1365-2435.13179

***For further information***

Leonie Valentine
leonie.valentine@uwa.edu.au

Boodies create extensive underground warrens, with multiple entrances. Bryony Palmer examines how soil manipulation by boodies alters soil and plant properties at Yookamurra Sanctuary (Australian Wildlife Conservancy) where they have been reintroduced.

IMAGE: DAN BOHORQUEZ FANDINO

# Talking night parrots on Paruku Country


IMAGE: STEVE MURPHY


IMAGE: JAANA DIELENBERG

Paruku Indigenous Rangers and elders recently hosted a workshop on night parrots for other Rangers and conservation groups from the southern Kimberley and northern Western Deserts. The TSR Hub's **Nick Leseberg** from The University of Queensland went along to learn from the rangers about the night parrot population on Walmajarri Country, the Paruku Rangers' work with the bird, and the Paruku Indigenous Protected Area (IPA) and to share findings from his research on the bird in western Queensland.

ABOVE: The workshop was attended by elders, rangers or their representatives from Paruku, Ngurrura, Ngururrpa, Ngurra Kayanta, Kija, Nyikina Mangala, Nyangumarta, Karajarri and Kiwirrkurra, as well as KLC staff, and scientists from the TSR Hub, WA DBCA, Environs Kimberley, the BBO and WWF.

The Paruku Rangers, supported by the Kimberley Land Council, have achieved something few people in Australia have. Since mid-2017, Ranger Coordinator Jamie Brown, and rangers Abraham Clayon, Lachlan Johns and Hanson Pye have confirmed (now multiple times) the presence of night parrots on Walmajarri Country in the Great Sandy Desert.

Finding the endangered nocturnal parrots the first time was a collaborative effort between Paruku Rangers, Paruku IPA, the Kimberley Land Council, WWF Australia and Environs Kimberley. Together they analysed very old records from the region, identified potential habitat and spoke to elders. Confirmation came during fauna surveys, when a camera trap image and then an audio recording were captured.

Discovering the bird on their country has opened up new opportunities for the Paruku Rangers, including receiving a grant from the Australian Government's Threatened Species Commissioner to manage threats to the bird, including fire and feral cats. Other Indigenous groups in the Kimberley and Central Deserts may also have the rare and elusive bird on their country and are interested to learn more about it.

The location of the workshop was the Handover Site, a patch of scattered woodland close to the shores of Lake Gregory, where Tjurabalan Native Title was handed down. The lake shimmering in the distance and covered in thousands of water birds provided a spectacular backdrop to the workshop. The heat of late October (45C in the shade) was no deterrent to the enthusiasm of Rangers and Traditional Owners from nine different Native Title groups who attended the workshop. They came to share information about the bird and the best ways to detect, monitor and care for it.

Insights from Paruku elders showed that the bird has been heard in the region in past decades. Some of the old people recognised the sound of the call when it was played to them and could recall where they had heard it as children. Rangers from other groups attending were enthusiastic to take recordings of the calls back to play to their own old people. This may yield valuable information on former (and possibly still active) night parrot locations.

BELOW: Paruku Ranger Coordinator Jamie Brown (centre) leading fire management discussion at the workshop. L-R: Paruku Rangers Abraham Clayon and Lachlan Johns, Jamie Brown, Alexander Watson from WWF Australia and Malcolm Lindsay from Environs Kimberley.


IMAGE: JAANA DIELENBERG

The workshop was also an opportunity to exchange information with scientists from other regions who are also studying the rare and elusive bird. Nick Leseberg's research in western Queensland is improving understanding of the parrot's preferred habitat, what threats impact their populations, and how those threats can be managed. Nick was able to share his findings with the rangers and to provide some training on the use of acoustic monitoring and analysis. Other scientists from the Broome Bird Observatory and Western Australia's Department of Biodiversity, Conservation and Attractions also shared insights gained from other populations.

The information exchange allowed the Indigenous Rangers to understand the ecology of the bird based on research in other parts of the country, while helping scientists understand the landscape in which the birds are likely to occur in Western Australia. The discussions also covered the opportunities presented by collaborations.

According to Nick Leseberg, a general difficulty of night parrot research is the very remote locations in which the birds occur, and the amount of effort required to conduct systematic surveys.

"Local people armed with good knowledge about the bird are our best opportunity to find new populations in this very vast region," Nick said.

"Rangers are in the best position to detect new populations. They know their country. Once we shared information on where the birds are likely to be found and the habitat they use, you could see the Rangers immediately thinking about where on their country these sites might be. By the end of the workshop, some of the Rangers had already decided exactly where they were going to search for night parrots."


IMAGE: JAANA DIELENBERG

ABOVE: Hub researcher Nick Leseberg showing rangers how to use acoustic analysis software to check audio data collected by automated recording devices.

As a scientist studying the bird, Nick found a site visit to where Paruku Rangers had found the bird incredibly valuable.

"Before the Paruku Rangers found these birds there were only two sites in the world where we were certain the bird occurs. This meant there was a risk that any conclusions we make about the bird's ecology and habitat preferences were biased by that small sample size. Seeing where the birds occur on Paruku country was extremely valuable, because it corroborated the conceptual models we have been developing based on our research at the other two sites. We can now be more confident that our predictions about where the bird might be found are valid."

The TSR Hub is now working with Paruku Rangers and other workshop partners to develop more resources for ranger groups to raise awareness about the bird and on how to search for night parrots and manage potential habitat.

The workshop was also an opportunity for the TSR Hub to share information on other Hub research projects, such as the Arid Zone Monitoring project, which is working with groups across Australia's deserts to collate tracking surveys.

***For further information***

Nick Leseberg
n.leseberg@uq.edu.au

Zack Wundke
zack.wundke@klc.org.au

*"Late last year, our team of Paruku rangers, we captured a picture of the night parrot here in the Great Sandy Desert. It was really exciting for us. Now we want to share what we've learned with scientists and with the other Indigenous Ranger groups.*

*So in October we had the first on-country Kimberley night parrot workshop. We hosted it here in Mulan, at Lake Paruku. We all got together, sharing stories of the experiences with working on the night parrot and sharing ideas on how to manage and protect the bird and its habitat. Some guests came a really long way.*

*If you ever come across sightings or sounds and you're on an IPA, please respect our rules. If you do find it, just come let one of us Rangers know. That would be good so we could go and have a look there in that area where you may have seen it or heard it.*

*I'd also thank our elders for supporting us through this journey with the night parrot and managing and protecting the animal here on Paruku."*

*Jamie Brown*
*Head Paruku Ranger*


IMAGE: JAANA DIELENBERG

# Gimme shelter: Conserving hollow-nesting birds


RIGHT: Larger-bodied birds, such as this little corella, need larger tree cavities, a rare resource in many human-altered habitats.

What influences where birds choose to nest? About 15% of Australian birds, or 114 species, need tree hollows for breeding or shelter. The number of hollow-bearing trees is declining due to timber harvesting and development, and competition is stiff in the animal world for these increasingly rare tree hollows. Non-native species and increasing urban numbers of natives such as rainbow lorikeets are changing the community dynamics of hollow-nesting species. Critical to conserving the range of hollow-nesting native birds is understanding how these interactions operate when it comes to who gets to nest and where. This has been the topic of **Andrew Rogers' PhD research at The University of Queensland**. He explains how his research on the drivers of nesting competition can help us effective manage invasive hollow-nesting species and improve the outlook for threatened native ones.

## Hollows for habitat

Australian hollow-nesting birds are opportunistic users of tree hollows. Unlike woodpeckers found in much of the rest of the world, they don't excavate their own cavities in living tree wood. Instead, the hollows they use for shelter and nesting are created by termites or fungal decay. The downside to this is how slowly these natural tree hollows form. Everywhere in Australia, trees bearing habitable hollows tend to be large and old – mountain ash trees from the Victorian Central Highlands, for example, don't begin to develop cavities for approximately 120 years. Losing them to land-clearing for agriculture and urbanisation has meant a sometimes devastating loss of habitat for hollow-dependent species.


## Predation and competition

Added to this loss of habitat are the twin threats of predation on nesting birds and competition for hollows by invasive species. Understanding these interactions between invasive and native species has been the focus of my research. If we are to effectively manage invasive species for the benefit of native species, we need a better grasp of the where and how of native–invasive interactions than we currently have. It can be tricky to quantify direct and indirect interactions, however. It requires a lot of time in the field observing, and even then we can rarely capture the big picture of community-wide interactions. In addition, species that are widespread throw up particular challenges for data collection, as native–invasive interactions are likely to differ across habitats and across communities with varying compositions of native species.

LEFT: A common myna sits at the entrance to a tree hollow. While the common myna can nest in buildings and other artificial structures, they can also compete for natural tree hollows in and around large urban trees.



RIGHT: A rainbow lorikeet squeezes out of a tree hollow. Cavity entrance size is important for hollow-nesting birds as it limits access to the nest of other, competitor and predator, species.

In response to these challenges, my research combined data on animal behaviour collected in the field with models of competition to see if we can better predict where and when invasive hollow-dependent birds are likely to be having an impact on native bird species.

## Hollow nesting success: The ins and outs

I used this combination of field data and modelling to assess the impact of competition on the nesting dynamics of Brisbane's hollow-dependent birds. Of the 114 Australian bird species (approximately 15% of the total) that need tree hollows for breeding or shelter, 46 are listed as threatened. There are around 48 cavity-nesting birds found in south-east Queensland or the greater Brisbane area.

My research used a combination of artificial nest boxes and behavioural observations around natural tree hollows to investigate where certain species nest and what influences nesting success. While the nest site requirements are broadly known for many species, for many others we still don't have a good idea of where they nest and how competition influences their ability to nest in certain habitats. For example, while many hollow-nesting species of birds are declining in urban areas, rainbow lorikeets have increased in numbers and are now one of the most common urban birds in Brisbane. Despite this, we don't know where most of these birds breed, and how their increasing numbers have changed the community dynamics. Similarly, the addition of invasive species is also likely to have driven changes in the nesting dynamics of hollow-breeding communities, and the challenge is to predict how such introductions have or will change species interactions at the community level.

## Invasions and interactions

Across Australia there are seven invasive hollow-breeding bird species, and an additional 15 Australian hollow-breeders that have been moved outside their historic range – but most of these have not yet been studied in the field. This is the case in Tasmania, where I reviewed the potential impacts of introduced birds. I found that the seven non-native species, representing 27% of the total hollow-nesting bird community, are likely to be competing with 65% of the native hollow-nesting birds. This makes Tasmania one of the most invaded places in Australia.

Several endemic and common species are likely to be impacted by introduced birds, but the consequences for their long-term population trends needs further research. With limited funds for monitoring, most studies of invasive species impacts have been necessarily restricted to just a few interacting species.

However, we hope that our work on the drivers of competition means we can model the consequences of invasive species introductions for entire hollow-breeding communities, and so improve the lot of our native hollow-dependent birds.

***For further information***

Andrew Rogers
a.rogers@uq.edu.au

BELOW: Amelie Genay and Andrew Rogers monitoring nest boxes set up for cavity breeding birds around Brisbane. The boxes were used by six native species, including birds and mammals, as well as the invasive common myna.

### Case study: Common (or Indian) myna

The common myna is one of Australia's most widespread invasive birds and it is a hollow nester. It occurs along most of the east coast and has the potential to establish in Western Australia and Tasmania. Despite this large range, most studies on its impact have come from the Canberra, Sydney and Newcastle areas. By examining its preferences for nest sites, including tree hollows, and comparing those to native species we can help identify where it's likely to compete with native species, and explore the underlying drivers of competition between all hollow-nesting birds.

Our work has shown that the common myna and other introduced hollow-nesters have significantly increased competition for nesting sites. Approaches like this one that we have developed for the myna can be explored for native threatened and vulnerable species to identify where competition could be impacting reproductive success, and help prioritise future field work.


Jabin Watson beside the flume.
IMAGE: NICOLAS RAKOTOPARE

# How did the fish cross the road?

## A new innovation to get fish past culverts


IMAGE: NICOLAS RAKOTOPARE

Fish need to move to find food, escape predators and reach suitable habitat for reproduction. Too often, however, human activities get in the way. Dams, weirs and culverts (the tunnels and drains often found under roads) can create barriers that fragment habitats, isolating fish populations. An Australian innovation, however, promises to help dwindling fish populations in Australia and worldwide. Our solution, recently described in *Ecological Engineering*, tackles one of the greatest impediments to fish migration in Australia: culverts.

### A culvert crisis in our waterways

Freshwater ecosystems are one of the most heavily impacted by human activities.

Many freshwater species, such as the iconic barramundi, start their life as larvae in estuaries, then as small juveniles they make mammoth upstream migrations to freshwater habitats. In fact, about half of the freshwater fish species in southeast Australia need to migrate as part of their life cycle.

When fish are unable to pass human-made barriers, the decline in populations can be huge. For example, in the Murray-Darling Basin where there are thousands of barriers and flows are highly regulated, native fish numbers are estimated to be at only 10% of pre-European numbers.

In New South Wales alone, there are more than 4,000 human-made barriers to fish passage. Over half of these are culverts. Culverts are most often installed to allow roads to cross waterways. They are designed to move water under the road, which they do quite efficiently, but often with no consideration of the requirements of the animals that live there.

When a stream enters a culvert, the flow can be concentrated so much that water flows incredibly fast. So fast, in fact, that small and juvenile fish are unable to swim against the flow and are prevented from reaching where they need to go to eat, reproduce or find safety.

### Many current design 'fixes' come with problems

The problem culverts pose for fish is now well acknowledged by fisheries managers, and as a result efforts to make culverts fish-friendly are now widespread.

Where space allows, these new fish passage solutions can resemble a natural stream, where rocks of various sizes are added to break up the flow. Alternatively, artificial baffles (barriers to break up and slow the flow) are also commonly attached to the walls of the tunnel.

These designs do have some drawbacks. They may suit some fish sizes and species, but not all. They can be expensive to install. They also tend to catch debris, which increases maintenance costs and the risk of flooding upstream during high flow events.

BELOW: Most native fish would be unable to move past this road culvert under most flow conditions.


IMAGE: MATTHEW GORDOS

### Using physics to find a new solution

We took a new approach that harnesses a property of fluid mechanics that scientists call the "boundary layer". When a fluid moves over a solid surface, friction causes the water to slow down next to the surface. This thin layer of slower-moving water is called the boundary layer.

Where two surfaces meet, such as in the corner of a square culvert, the boundary layers of the bed and wall merge. This creates a small area of slower-moving water – the "reduced velocity zone" – right in the corner. This is quite small, but little fish can still use it and are very good at finding it.

We wanted to expand this zone (to accommodate a wider range of fish sizes) and slow the water in it further.

So, we added a third surface, generating three boundary layers that then joined. This was done by adding a square beam running the length of the channel wall, close to the floor. The boundary layers of the floor, wall and bottom surface of the beam merged to create a reduced velocity channel along the side of the main flow. The reduced velocity zone is revealed by adding a fluorescent dye, which lingers in the slower flowing water under the square beam we added to the channel.

Testing our design in a 12-metre channel (or flume) found that water velocity in the zone below the beam was slowed by up to 30%. For small fish, this is a huge reduction.

In tests, we focused on small-bodied species, or juveniles of larger growing species, because these are considered the weakest swimming size class and most vulnerable to high water velocities created within culverts. Every species tested saw significant improvements in their ability to swim and traverse up the channel.

All of the species benefited, regardless of their body shape or swimming style.

### Creating a slower-flowing zone

Our novel fish passage design is highly effective, yet very simple. It's a square beam installed along the length of a culvert wall, so it's easy to incorporate into new structures and cheap to retrofit into existing culverts. It is also much less likely to trap debris than baffles or rocks embedded in the floor of a culvert.

This is a totally new approach that has the potential for widespread application, helping to restore the connectivity of freshwater fish populations here in Australia, and overseas.

More research lies ahead. We're hoping that by optimising the dimensions of the beam we can get even more fish through the channels, with even greater ease. We're also planning field testing to check our laboratory findings work in the real world.

Freshwater biodiversity is greatest in the tropics. Here, developing countries are having drastic impacts on their freshwater ecosystems. The simplicity of this design may make it an affordable approach to help maintain and restore habitat connectivity in developing regions.

*Matthew Gordos from NSW Fisheries contributed to this article.*

*This article first appeared in The Conversation and is kindly reprinted with their permission.*

BELOW: Jabin Watson inspects an Australian lungfish.


IMAGE: NICOLAS RAKOTOPARE

*Read more:*

Watson, J. R., Goodrich, H. R., Cramp, R. L., Gordos, M. A., & Franklin, C. E. (2018). Utilising the boundary layer to help restore the connectivity of fish habitats and populations. *Ecological Engineering*, 122, 286–294. http://doi.org/10.1016/j.ecoleng.2018.08.008

***For further information***

Jabin Watson
jabin.watson@uq.edu.au

IMAGE: JAANA DIELENBERG


ABOVE: A fish swimming in the low velocity area created where three boundary layers merge.

# Self-fumigating birds and manna from heaven: **The remarkable forty-spotted pardalote**

ABOVE: A forty-spotted pardalote.

The forty-spotted pardalote has suffered severe range contraction. Although once widespread in Tasmania, this endangered bird is now largely confined to two south-eastern Tasmanian islands, Bruny and Maria. To add to pardalote woes, the larvae of a fly parasite that feeds on the blood of nestlings has been compromising its breeding success. However, researcher **Fernanda Alves**, from the Australian National University, has some good news. She reports on experiments that encourage forty-spotted pardalotes to 'self-fumigate' their nests by incorporating chicken feathers treated with a bird-safe insecticide. Fernanda takes up the story.

The forty-spotted pardalote (*Pardalotus quadragintus*) is a small olive-green bird with a short bill, which is endemic to Tasmania. It is one of Australia's rarest birds, and by far the rarest pardalote. Its range is naturally restricted as it can only live in habitat where white gum (*Eucalyptus viminalis*) is the dominant or sub-dominant species. Forty-spotted pardalotes are foliage gleaners, which means that their feeding strategy consists of plucking invertebrates from foliage. They feed on arthropods, lerps (crystallised honeydew produced by the larvae of psyllids as a protective cover) and manna, a sugary exudate produced on the foliage of white gums.

## Manna from heaven – or from white gums

Manna is the most important food item in the diet of pardalote nestlings. Previous research conducted at the Australian National University (ANU) showed that pardalotes can 'farm' white gum manna – they are the first Australian bird that has been found to deliberately cause trees to produce manna. They do this using their bills to clip the stalks of leaves of the white gum. The tree proceeds to exude its nutritious gum over the next few days, which the birds then return to harvest. This ecosystem engineering of the forty-spotted pardalote not only feeds its young but may also play an important role for many other animals in these woodlands.

## Range contractions

Historically, the forty-spotted pardalote was widely distributed across Tasmania, but it is now believed to be extinct in most of its range. Its decline and range contraction has resulted in the current listing of the species as Endangered under Australian law. It is now mainly found on two small islands off Tasmania's southeast coast, Bruny and Maria.

The cause of this range contraction is likely a number of threats in combination. Among these are habitat loss and degradation, fire, and aggressive competitors, such as noisy miners. The loss of hollow-bearing trees has been critical, as the forty-spotted pardalotes nest in tree hollows, where they build a dome-shaped nest out of bark and grass, lined with feathers or fur.

ABOVE: The research is improving the survival of forty-spotted pardalote chicks by protecting them from a fly parasite.

## A gory business

In 2012, an ANU researcher discovered that a fly parasite could be a threat to the forty-spotted pardalote. The ectoparasitic fly *Passeromyia longicornis* parasitises nestlings of forty-spotted pardalotes, causing severe mortality. The fly lays its eggs in the nests of forty-spotted pardalotes and once the nestlings hatch, the larvae burrow under their skin and feed on their blood.

Forty-spotted pardalotes usually nest in tree hollows, but also use nest boxes. This has allowed the research team to monitor them in nest boxes set up on North Bruny Island and to trial solutions. They found that fumigating nest boxes with bird-safe insecticide (pyrethrum) greatly improved the survival of chicks.

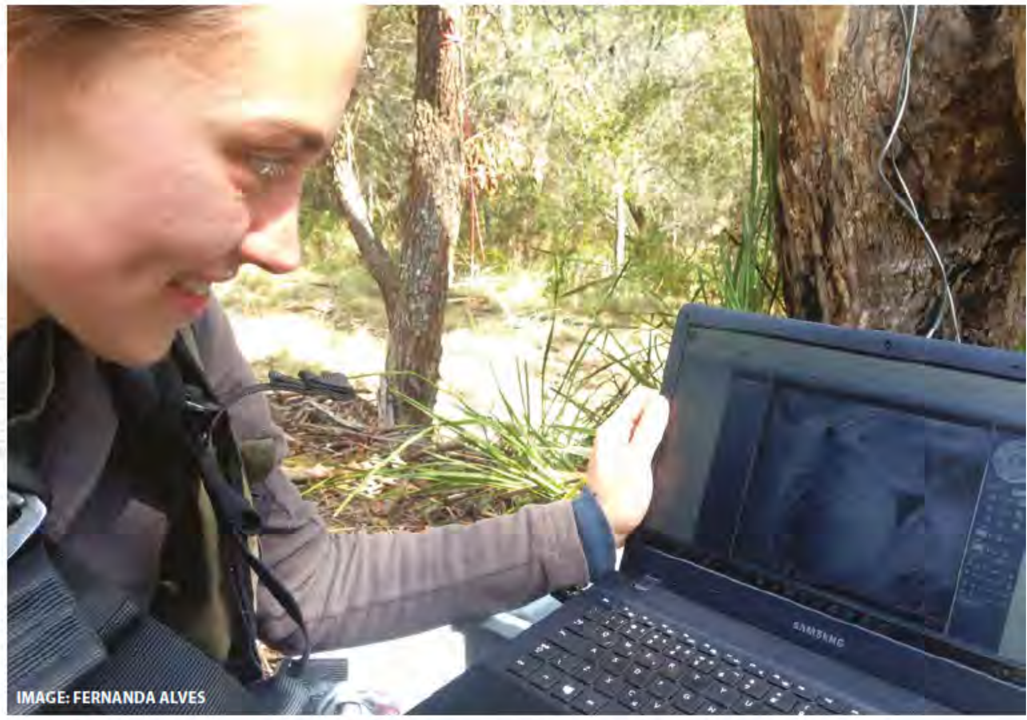
## The allure of a chicken feather

The natural tree hollows that forty-spotted pardalotes use for nesting are generally high in the canopy and very inaccessible to the average conservation manager. Manually fumigating large numbers of nests is simply not feasible. So how do you get the insecticide into the nests? You get the birds to do all the hard work by tempting them with soft feathers. As forty-spotted pardalotes love to line their nest with soft feathers, they will carry them back into their nests.

The researchers have left out piles of sterilised chicken feathers that are treated with the bird-safe insecticide, and the birds collect them and take them back to line their nests. The results from this 'self-fumigation' technique so far are giving cause for hope. The sight of a tiny pardalote, about the size of a matchbox, flying through the forest with a white feather, which is sometimes bigger than it is, is also quite entertaining.

## Next up: Back to the Tasmanian mainland?

A next stage in the conservation of forty-spotted pardalotes will be a full investigation of the prospect of reintroducing them to the main island of Tasmania. I am investigating a range of factors in order to develop a feasibility plan for reintroducing individuals to parts of their historical range.



ABOVE: Researcher Fernanda Alves watches the action inside a nest box caught by a remote camera.

This will include identifying the areas where forty-spotted pardalotes could be translocated to create insurance populations and increase the likelihood of the species' persistence.

Identifying locations will involve mapping the remaining white gum habitat on mainland Tasmania using remote sensing techniques and species distribution models. We will follow this mapping with on-ground surveys to identify the best available habitat on Tasmania – and possible suitable sites for translocation trials. I'm also looking at how changes in habitat quality can affect the distribution and abundance of the species and will then test tools to improve habitat quality.

This Endangered woodland bird may not yet be out of the proverbial woods, but our research is giving us good reason to hope for its future prospects.


***For further information***

Fernanda Alves

fernanda.alves@anu.edu.au


ABOVE: Sterilised chicken feathers treated with a bird-safe insecticide hang in a dispenser in the forest. Forty-spotted pardalotes are collecting the feathers and flying them back to their nests. In following this natural instinct, they have no idea that they are protecting their chicks from parasites.




# Trending now: The new Threatened Species Index for Australian birds

We are familiar with indices like GDP and the ASX indicating trends in the state of the Australian economy. But what about trends in the state of our environment? An exciting new tool called the Threatened Species Index offers a window into how threatened species are faring and if our collective conservation efforts are stacking up for imperilled wildlife. The index has been made possible through unprecedented collaboration and data-sharing by over 40 research partners led by The University of Queensland, working closely with BirdLife Australia. Project co-leader **Dr Elisa Bayraktarov** outlines the significance of the index and some of the powerful ways it can be used.

Australia has over 1800 threatened species. But although monitoring data is available for many of these species individually, until now there has been no way to bring it all together. With many partners, the Threatened Species Recovery Hub has risen to this challenge by creating Australia's first Threatened Species Index (known as the TSX).

The index is unique in that it compiles all available monitoring data to tell us how our threatened species are doing overall, and also which groups (e.g., shorebirds) or regions need more attention.

Locating and assembling the data is a huge undertaking, and has involved extensive collaboration with all state and territory governments and many other conservation and research organisations. In addition, there are more than 200 Friends of the Index who are supporters, potential end-users, or simply people who care about threatened species and want to know more about the index.

Ultimately the index is capable of compiling data for all threatened species in Australia, from orchids to tree-kangaroos.

As a start, we have collected and compiled all available bird data to create Australia's first threatened bird index. Planning is underway for mammal and plants indices.

## Creating the index

The statistical approach is modelled on the Living Planet Index, which was designed by the World Wildlife Fund and the Zoological Society of London. That index tracks changes in global vertebrate populations over time, and is used to report against international targets. It compiles data from published scientific literature to track the relative population abundance of thousands of mammals, birds, fish, reptiles and amphibians around the world.

The Living Planet Index has published results every two years since it was initiated in 1998. It was most recently published in October 2018 and showed that on average global vertebrate populations have decreased by 60% between 1970 and 2014. However, for all its value as an international reporting tool, very few Australian threatened species are included in the Living Planet Index – only 24 mammals and seven birds. That is because most data on threatened species in Australia are never published. Rather, they exist as raw data on people's computers, in the reports of recovery teams and in state or territory government repositories. That is why collaborating directly with the groups who undertake monitoring in Australia was so important to our project. It enabled us to assemble data from over 500,000 individual surveys and 35 monitoring programs just for the birds.


ABOVE: Launch of the Threatened Species Index for Australian birds on 27 November 2018 at the Ecological Society of Australia conferencing Brisbane. From left to right: Elisa Bayraktarov (UQ), Glenn Ehmke (BirdLife Australia), Hugh Possingham (The Nature Conservancy), Darren Grover (WWF), Sally Box (Department of the Environment and Energy), Brendan Wintle (University of Melbourne), Ayesha Tulloch (Sydney University), James O'Connor (BirdLife Australia).

Turning this data, which came in many formats, into a dynamic index was a huge undertaking. The Zoological Society of London helped us to adapt the method of the Living Planet Index.

The Terrestrial Ecosystem Research Network, together with the Research Computing Centre of The University of Queensland and a web-app development company called Planticle helped us to develop an automated scientific workflow to streamline data processing. And BirdLife Australia are hosting the raw data and the Threatened Bird Index component of the overall index.

## Tracking trends

The index works not by showing population numbers themselves, but by showing the average change in populations compared to a base year. It currently includes data for 43 species and subspecies of bird, which represents about 30% of all nationally listed threatened birds.

The base year for the index has been set at 1985, which gets a score of one. A score of 1.2 would indicate a 20% increase on average in numbers of threatened birds, while a score of 0.8 would indicate a 20% decrease on average since 1985.

The index shows us that between 1985 and 2015 the numbers of the 43 threatened species and subspecies decreased by 52% on average – see Figure 1. There is some variation among individual species within this multi-species index. The grey cloud indicates the variability between the trends for individual birds that build the composite.

One of the most exciting and powerful features of the Threatened Species Index is the ability to look at results for groups of birds, for example, shorebirds, or for regions, like Queensland – or both, for example, Queensland shorebirds.

Figure 2 shows the results when we select shorebirds. The index shows that their numbers have decreased by 72% on average over the past 30 years. The diagnostic tools tell us that this index is based on six species and subspecies, with good coverage for most of Australia's coastline except for the Northern Territory.

But the Threatened Species Index is not all bad news! For example, if we drill down to produce an index for Victoria's threatened birds, we obtain an index on 18 species and subspecies whose numbers decrease between 1985 and 2000 but then stabilise (Figure 3). This is where recovery actions may have kicked in and led to some successes.

## Over to you

You can explore and use the index at **tsx.org.au.** It is a dynamic tool to which more data will be added as they become available and are verified. And the more data, species and regions that are added, the more powerful, meaningful and representative the index will become.

We are always on the lookout for good additional data. If you have data spanning multiple years on threatened or near-threatened Australian bird species and subspecies, we'd be delighted to hear from you.

*Australia's Threatened Species Commissioner Dr Sally Box launched the Threatened Species Index on 27 November 2018 at the Ecological Society of Australia conference in Brisbane.*

***For further information***

Elisa Bayraktarov
e.bayraktarov@uq.edu.au

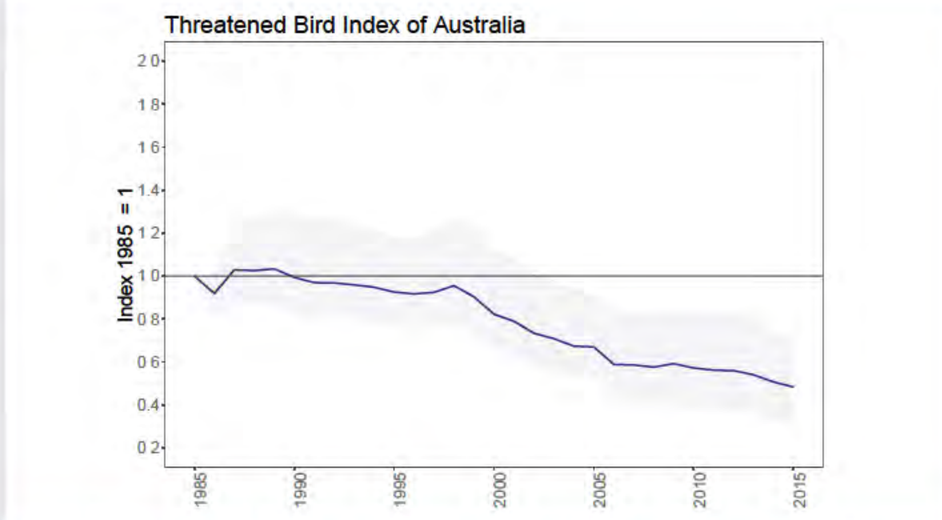



Figure 1: Between 1985 and 2015, the 43 threatened species and subspecies decreased by 52% on average.

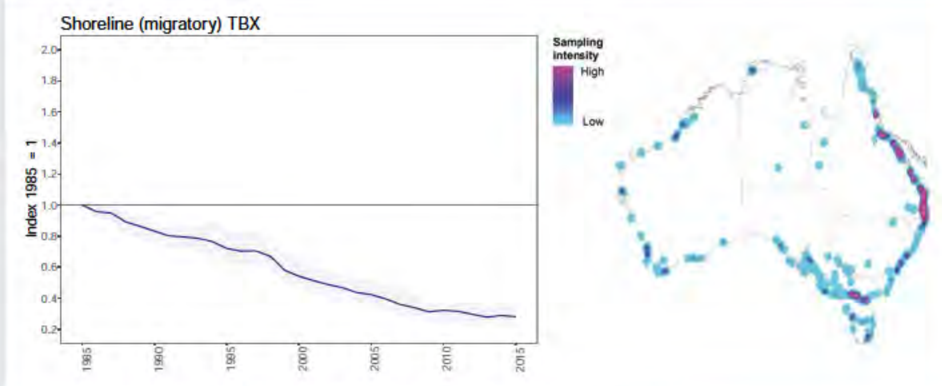



Figure 2: There has been a 72% decrease in shorebirds over the past 30 years.

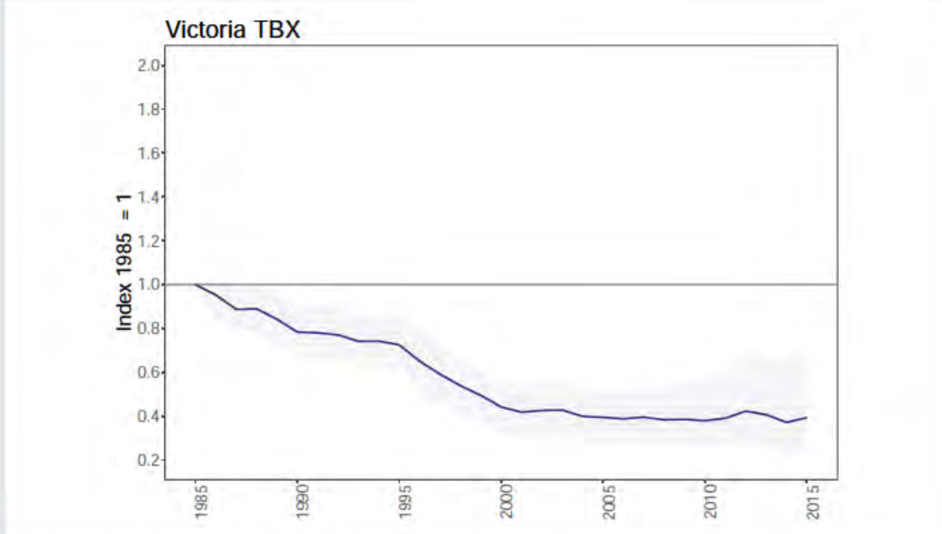



Figure 3: Recovery actions may be behind the stabilisation since 2000 of numbers of threatened birds in Victoria.

TSR Hub
Researcher Profile

IMAGE: GEORGIA GARRARD

IMAGE: GEORGIA GARRARD

# Georgia Garrard
# Connecting people with biodiversity

LEFT: The elusive spiny rice-flower.

After undergraduate majors in Geography, Environmental Science and Botany, I did my PhD on native grasslands. I was struck by how these Critically Endangered ecosystems existing right on the edge of my city were being lost without most people even knowing about them – or understanding what amazing, superdiverse ecosystems they are. They are not the brown, dead, snake-infested paddocks of popular imagination but rather home to an abundance of incredible plants and animals (e.g., striped legless lizard, earless dragon, plains wanderer).

My PhD looked at how much effort was needed to achieve confidence that threatened grassland species present at a site would be detected in surveys. I showed that the effort typically put into environmental impact assessments at proposed development sites was nowhere near enough. Because the proponents of new developments do not necessarily want to find any threatened species on their land, it makes sense for policy to specify minimum survey effort requirements. As a consequence of my work, these requirements now inform the Significant Impact Guidelines for the spiny rice-flower (*Pimelea spinescens* subsp. *spinescens*) under the EPBC Act.

## Humans and biodiversity

My research has increasingly focused on the human elements of conservation. Because cities are first and foremost human environments, it's impossible to ignore people in urban conservation decisions.

But cities are also really important for conservation, and home to many of Australia's most threatened species and ecosystems. My work on Biodiversity Sensitive Urban Design (BSUD) sought to reconcile the needs of residents, planners and developers with the requirements of native species and ecosystems to create a model for cities as places for both people and biodiversity.

There's a lot to be said for having more diverse native vegetation around our homes. I live in Castlemaine in regional Victoria and, for me, the striking difference between Melbourne and Castlemaine is the diversity of native vegetation. People's yards are bigger and include native grasses, shrubs and trees. The birdlife is amazing – eastern spinebills, mistletoebirds, brown thornbills, silvereyes and scrub wrens are all regular visitors to our yard. More nature in cities can deliver a huge range of benefits, from cooling and reduction in the urban heat island effect to health and wellbeing benefits like reduced risk of heart disease, lower stress levels, increased social cohesion, better sleep. Emerging research has shown that many of these benefits are improved when that nature is biodiverse.

## Fostering engagement

My work with the hub focuses on understanding why people may not be engaging with threatened species and biodiversity conservation and how best to (re)engage them. There's many reasons for disengagement. For some, the sense of loss and hopelessness can be overwhelming and disempowering. For others, the links between biodiversity and our own lives (and therefore the things that we can do to improve biodiversity) are not clear. Many people are time-poor, and this is where the everyday, incidental contact with nature that we aim to achieve with BSUD becomes so important.

The Threatened Species Recovery Hub is supported through funding from the Australian Government's National Environmental Science Program.

*Science for saving species*
A quarterly publication of the Threatened Species Recovery Hub

Editor: Jaana Dielenberg
j.dielenberg@uq.edu.au

Science Communication Officer: Kate Donnelly

Graphic Design: Mary Cryan

www.nespthreatenedspecies.edu.au

COVER IMAGE: JABIN WATSON INSPECTS AN AUSTRALIAN LUNGFISH (SEE PAGE 10 FOR THE FULL STORY). IMAGE: NICOLAS RAKOTOPARE

FOI 191010
Document 4

**From:** TSR Publications
**To:** Research; s22
**Cc:** Jaana Dielenberg; Rachel Morgain; TSR Publications
**Subject:** Product Submission form and 40 Spotted Pardalote Publication
**Date:** Friday, 12 April 2019 3:38:32 PM
**Attachments:** Webb 40 spotted pardalote esearch Product Submission Form[1].pdf
Figures 40spot ms.pptx
pardalote MS text version AEC 18 116 OA R1 (1)[1].docx

---

Hi s22 and Team,

I think you might already have this one, but just in case see attached almost finalised proof version and product submission form related to Project's 2.2 & 4.2 & 3.1:

Webb, M., Alves, F., Tulloch, A., Shaw, J., Bryant, S., Stojanovic, D., Crates, R., Heinsohn, R. (2019). All the eggs in one basket: Are island refuges securing an endangered passerine? *Austral Ecology*

Thank you!

Heather

**Heather Christensen** | Project Coordinator | Hub Coordination & Support Team | NESP Threatened Species Recovery Hub
Room 534 Goddard Building The University of Queensland St Lucia QLD 4072 | P +61 7 334 67541 | M +61 s47F | E heather.christensen@uq.edu.au | http //www.nespthreatenedspecies.edu.au/ | @TSR_Hub
*The Threatened Species Recovery Hub is supported through funding from the Australian Government's National Environmental Science Programme.*

FOI 191010
Document 4a

Australian Government

National Environmental Science Programme

# Research Product Submission Form

The Australian Government will use the research product and information provided in this form to share the knowledge generated under the NESP, support its adoption and identify opportunities to promote NESP research.

Hold the cursor over each answer field for instructions on completing this form.

## Project Information

| | |
|---|---|
| Hub name | Threatened Species Recovery |
| Project number | 2.2 & 4.2 & 3.1 |
| Project title | Tackling threats to endangered hollow-nesting birds |
| Product lead author/researcher | Matthew Webb |
| Program funding (NESP/NERP/CERF/Combination) | NESP |

## Research Product Information

| | |
|---|---|
| Select the type of research product | Journal Article |
| Other | |
| Title | All the eggs in one basket: are island refuges securing an endangered passerine? |
| Journal or location name | Austral Ecology |
| DOI | tba |
| Citation | |
| Synopsis | Refuges for threatened species are important to prevent species extinction. They provide protection from a range of environmental and biotic stressors, and ideally provide protection against all threatening processes. However, for some species it may not be clear why some areas are refuges and others are not. |
| Media/other interest | Authors may do a press release |
| Keywords | conservat refuge threatening Forty spott |

## Research Product Accessibility

| | |
|---|---|
| Date of publication | 01/01/19 |
| Date of product availability | 01/01/19 |
| Location of product availability | |
| Version of product attached | yes |

☑ I certify that I have attached the copy of the publication that can be provided to and used within the Australian Government in accordance with the specific publisher copyright restrictions that relate to this product.

**Email Form**

Functionality may be limited unless opened in Adobe. If the instructions do not appear or the above button does not work, visit www.environment.gov.au/nesp for instructions and email the form to your Hub Communications or Administration Officer.

# All the eggs in one basket: are island refuges securing an endangered passerine?

Matthew Webb[1], Fernanda Alves[2], Ayesha Tulloch[1], Justine Shaw[3], Sally Bryant[4], Dejan Stojanovic[1], Ross Crates[1] and Robert Heinsohn[1]

1. Fenner School of Environment and Society, Australian National University, Acton, ACT, Australia
2. Research School of Biology, Australian National University, Acton, ACT, Australia
3. Centre for Biodiversity and Conservation Science, School of Biological Science, The University of Queensland, St Lucia, Qld, Australia
4. Tasmanian Land Conservancy, Sandy Bay, Tas, Australia
5. Corresponding author: matthew.webb@anu.edu.au, +61400104088

**Acknowledgements**

Funding was received via crowdfunding (The parrot, the possum and the pardalote) and from the Australian Government's National Environmental Science Program through the Threatened Species Recovery Hub. Thanks to Weetapoona Aboriginal Corporation for land access. Surveys were conducted with ANU animal ethics approval A2014/26 and under a Tasmanian Government Scientific Permit (TFA14232).

**Abstract**

Refuges for threatened species are important to prevent species extinction. They provide protection from a range of environmental and biotic stressors, and ideally provide protection against all threatening processes. However, for some species it may not be clear why some areas are refuges and others are not. The forty-spotted pardalote (*Pardalotus quadragintus*) is an endangered, sedentary, cryptic and specialized bird endemic to the island of Tasmania, Australia. Having undergone an extreme range contraction over the past century the species is now mostly confined to a few small offshore island refuges. Key threatening processes to the species include habitat loss, wildfire, competition and predation. The ways in which these processes have molded the species' contemporary range have not been clearly evaluated. Furthermore, the security of the remnant population within refuges is uncertain. To overcome this uncertainty we assessed key threats and established the population status in known refuges by developing a robust survey protocol within an occupancy modelling framework. We discuss our results in the context of planning trial reintroductions of this endangered species in suitable habitat across its former range. We found very high occupancy rates (0.75-0.96) at two refuges and in suitable conditions, the species was highly detectable (*p*, 0.43-0.77). At a third location our surveys indicated a local extinction, likely due to recent wildfire. We demonstrate that all refuges are at high risk of one or more threatening processes and the current distribution across island refuges is unlikely to secure the species from extinction. We identified large areas of potential habitat across the species' former mainland range, but these are likely too distant from source populations for natural recolonization. We propose that establishing new populations of forty-spotted pardalotes via reintroduction is essential to secure the species and that this is best achieved while robust source populations still exist.

**Key words**

Forty-spotted pardalote *Pardalotus quadragintus*, refuges, conservation biology, threatening processes

## Introduction

The identification of refuges for at risk species is increasingly important to conservation biology (Keppel and Wardell-Johnson Grant 2012). In the Australian context, refuges can generally be defined as locations or habitat within a landscape that facilitate survival of species after disturbance events (e.g. fire, drought) or protection against introduced predators (Pavey *et al.* 2017). Refuges can originate through geographic isolation (e.g. islands), topographic position and vegetation types less prone to fire, or anthropogenic activities such as predator control, fencing and fuel reduction burning (Taylor *et al.* 2005). There are numerous cases where a species' survival hinges on its persistence within refuges (Atkinson 2002; Morris 2000; Webb *et al.* 2016). Understanding the processes that form refuges is critical to conservation management. Moreover, understanding the spatial and temporal nature of these processes is important to evaluate if the protection provided by a refuge is short-term (e.g. fire refuges, invasive species), or potentially long-term security (e.g. islands) (Woinarski *et al.* 2011). This will ultimately determine what actions can be undertaken to increase their effectiveness (e.g. fire management, reservation, biosecurity) (Caughley 1994).

For small or rapidly declining populations, failure to act can quickly lead to extinction (Martin *et al.* 2012; Woinarski 2016). When a species has reached this critical stage, its distribution has often contracted to refuges (Lomolino and Channell 1995) and by default, these areas often become foci for conservation planning (Webb *et al.* 2016; Stojanovic *et al.*

2017). In such cases, conservation actions usually focus on the reservation of occupied habitat, increasing habitat area (Smith 2008) and evaluating how best to expand or protect refuges depending on spatial and temporal factors related to extinction risk (McCarthy *et al.* 2005; Schultz Courtney *et al.* 2013).

Typical approaches for threatened species in conservation are increasing population size (McCarthy *et al.* 2005); managing specific threats (Wilson *et al.* 2007), and ex situ conservation or translocations (Seddon 2015). If populations are viable but local habitat is at carrying capacity, creating 'new' populations (or restoring locally extinct populations) in suitable but unoccupied habitat may provide greatest cost-benefits rather than attempting to enlarge existing populations (McCarthy *et al.* 2005).

Despite islands being disproportionally represented in species extinctions (Blackburn *et al.* 2004; Tershy *et al.* 2015), conversely they can also provide critical refuges if threatening processes are absent (Heinsohn *et al.* 2015; Lentini *et al.* 2018; Taylor *et al.* 2005). Here we examine the benefits of focusing management actions on the protection of refuges compared to actions that target threats, both historic, current and future. We use the case study of an endangered bird that now only occurs in refuges, primarily on islands (Threatened Species Section 2006). The forty-spotted pardalote (*Pardalotus quadragintus*) is a small, cavity nesting, leaf gleaning passerine dependent on white gums (*Eucalyptus viminalis*) for food, and primarily nests in tree cavities of eucalyptus species (Woinarski and Bulman 1985). Historically the species was widely distributed across Tasmania (Fig 1) and it is now presumed extinct across most of its former range (Brown 1986; Rounsevell and Woinarski 1983). This range contraction has been occurring at least since the early last century and has continued over recent decades (Bryant 2010; Rounsevell and Woinarski 1983; Threatened Species Section 2006). Three decades ago the species' area of occupancy was estimated to be <50 $km^2$, mostly on Bruny, Maria and Flinders Islands off the Tasmanian coast and a mainland location, Tinderbox Peninsula. Tinderbox Peninsula is < 1.5 km from Bruny Island (Fig. 1; Figs. S1 & S2), and based on genetic evidence is likely supported by birds dispersing from Bruny Island (Edworthy 2017) . These locations are foci for the species' conservation, and 77% of refuge habitat has some level of statutory protection ( Bryant 2010). Importantly, an implicit assumption of this approach is that the species can be secured from extinction at these locations.

The probable causes of the species' range contraction are diverse (Table 1). Likewise, it is not known whether forty-spotted pardalotes are now restricted to island refuges, or if they are capable of recolonizing parts of their historical range on mainland Tasmania either naturally or through translocation (Threatened Species Section 2006). Here, we aim to: (1) quantify current threats to refuges and their security, and (2) provide baseline population data. We use our results to examine management options to prevent further range contraction and evaluate potential for range expansion through reintroductions.

## Methods

*Aim 1: quantifying the historical and future impact of threats and updating conservation assessments of refuge habitat*

We focus on widespread threatening processes with strong evidence of direct impacts: (i) deforestation, (ii) wildfire, (iii) noisy miner *Manorina melanocephala* competition, and climate change (see Table 1), but also consider threats where impacts are more uncertain such as a newly discovered parasitic fly that can cause high nestling mortality (Edworthy 2018). For each threat, we evaluated the potential risk of it impacting refuges.

To assess the impact of recent deforestation, we quantified the area of core forty-spotted pardalote refuge habitat using two data sources: (i) a 30-year-old spatial layer of core refuge habitat (Brown 1986; habitat (Natural Values Atlas www.naturalvaluesatlas.tas.gov.au, accessed 1 September 2015) and (ii) a recent map of vegetation types TASVEG 3.0 (Department of Primary Industries, Parks Water and Environment 2013) to identify key forest habitats. We assessed contemporary habitat loss/disturbance using a spatial layer of forest loss derived from Landsat imagery at 30 x 30 m resolution (Hansen *et al.* 2013). Hansen *et al.* (2013) classifies 'forest loss' as the result of land clearing, timber harvesting and wildfire. Here, we defined the cumulative area of impact of these processes as deforestation area. Using ArcMap 10.2, we estimated the total area of potential habitat of the forty-spotted pardalote and the total area of habitat affected by recent deforestation.

The forty-spotted pardalote's current and historical distribution is highly fire-prone (Fig S3 and S4). To assess the potential historical impacts of fire on refuges, we used a spatial layer of fires in Tasmania (1969 – 2016) (Tasmanian Fire Service 2017) to estimate the area of forty-spotted pardalote habitat affected by wildfire during this period. We also assessed the future risk of fires occurring in refuges using the Tasmanian Bushfire Risk Assessment Model (Parks and Wildlife Service, unpublished) by quantifying the area of each refuge and its respective 'fire ignition potential'. Ignition potential in this model is based on the number of historical fires, lightning probability and Bureau of Meteorology observations.

Noisy miners do not currently occur in forty-spotted pardalote refuges. However, they are widespread on the Tasmanian mainland, having expanded with land clearance (MacDonald and Kirkpatrick 2003). To examine possible historical impacts of noisy miners on pardalote populations and assess the future risk of noisy miner colonization of refuge habitat, we compared noisy miner environmental suitability of forty-spotted pardalote refuges and their historical range. We modeled environmental suitability for noisy miners across Tasmania using MaxEnt (Phillips *et al.* 2006). We used verified occurrence data with a location accuracy < 500 m downloaded from the Atlas of Living Australia (ALA, http://www.ala.org.au, downloaded 4/9/2016). We also included unpublished data collected by the authors, resulting in a total of 1550 noisy miner records for modeling. Predictor variables were total rainfall during the driest quarter, mean temperature of the warmest quarter, minimum temperature of the coldest period, temperature seasonality, vegetation cover (cleared or not), and ecosystem type (11 categories, reclassified from the Major Vegetation subgroups from the National Vegetation Information System v4.1, Australian Government 2012); these variables are known to relate to noisy miner prevalence and abundance (Maron *et al.* 2013; Thomson *et al.* 2015). Based on model outputs, we assessed the environmental suitability of forty-spotted pardalote refuges for noisy miners. We reclassified the Maxent logistic output into predictions of noisy miner presence or absence using equal sensitivity and specificity threshold values for each year (Liu *et al.* 2013). This resulted in a map of predicted suitable or unsuitable environments. This map aimed to represent current suitability and did not account for potential expansion of the species resulting from future disturbance or a changing climate. The potential impacts of climate change were considered in the context of the species' highly restricted distribution and likely exacerbation of other known threats (e.g. fire).

Using the information outlined above and the combined expert knowledge of the authors we used a standard threat risk assessment process (Hart *et al.* 2005) to identify the relative future risk posed by each threat to each refuge (and habitat in the historical range) over a 30-year period. Each threat was assessed for the consequence to the species and the likelihood of that consequence happening (Supplementary Material). Consequence was defined by the expected magnitude of the impact of a threat and the overall threat footprint. For example, habitat clearance in reserved refuges would be major but only small areas (i.e. threat footprint) are likely to be affected. Overall risk posed by each threat was then assessed using the consequence and likelihood ratings in a standard risk matrix (Supplementary Material).

*Aim 2: develop a monitoring protocol to provide baseline population data for refuges*

There is currently no systematic monitoring program for the forty-spotted pardalote. To account for false absences (i.e. imperfect detection) we adopted a standard occupancy modelling approach (MacKenzie et al. 2002). We undertook baseline surveys on known pardalote refuges Maria Island, North Bruny Island and Flinders Island (Figs. S1, S2 & S3), which combined supports ~79 % of the species contemporary area of occupancy, with the remainder occurring on South Bruny Island and Tinderbox Peninsula (calculated in ArcMap 10.2 using the spatial layer of habitat outlined above (Natural Values Atlas 2015). The number of sites and site visits is summarized in Table 5. As our objective was to estimate occupancy in critical habitat (i.e. forest containing white gum, *E. viminalis*), we used the spatial layer of refuge habitat outlined above as a guide for site selection. All sites had at least one white gum present, and were selected as follows: from a random starting point the nearest white gum was located which became the first sampling site. Subsequent sites were established by following a random compass bearing to the nearest white gum ≥200m from the previous site. For logistical reasons the locations of sites on North Bruny Island were influenced by access and on Maria Island sites were restricted to within ~100m of existing walking tracks (Fig. S1). We used repeated five-minute visits to record the presence/absence of birds within 100m of the site (based on calls and observation). Monitoring was conducted intermittently between 2010 and 2016. Other locations in the historical range were surveyed opportunistically.

The forty-spotted pardalote is extremely cryptic owing to its soft call, small size, and two other sympatric pardalote species (*P. striatus and P. punctatus*) (Rounsevell and Woinarski 1983). During the species' breeding season (i.e. spring/summer), several avian migrants and other resident species, can form noisy aggregations that can drown out the soft vocalizations of the forty-spotted pardalote. To increase and control for variation in detectability, we restricted our surveys to still, clement weather in the non-breeding season (i.e. autumn/winter, when migratory species had left the study area) to maximize the likelihood of detecting the soft calls of the target species. We used occupancy modelling to estimate overall occupancy ($\Psi$) in critical habitat for each refuge. We fitted simple constant occupancy models using the package *unmarked* in R (Fiske and Chandler 2011; R Development Core Team 2011). We used estimates of detectability ($p$) to assess the reliability of absences at other locations where data were too sparse.

**Results**

*Aim 1: quantifying the historical and future impact of threats and updating conservation assessments of refuge habitat*

The species' area of occupancy based on mapped habitat (Natural Values Atlas www.naturalvaluesatlas.tas.gov.au, accessed 1 September 2015) was estimated as ~ 42 $km^2$, but only 35.5 $km^2$ of this area is currently eucalypt forest and woodland. According to our overall risk assessment, all refuges face high, very high, or extreme risks from multiple threats (Table 2). Consequence and likelihood ratings for each threat in each refuge are provided in Appendix A.

Only 0.82 $km^2$ (< 2 %) of refuge habitat has been affected by deforestation since ~1996. Overall, deforestation through habitat clearance is likely to be relatively low risk to refuge populations, as 77% (Bryant 2010) of refuges has some level of statutory reservation and risk level was identified to vary depending on the location (Table 2). Furthermore, fire is likely the cause for ~75% of the disturbance classified as deforestation (Hansen *et al.* 2013).

Historical fire mapping indicates that of all refuge habitat has burned since 1969 (17 %, 7.1 $km^2$), with most of this (62 %, 4.1 $km^2$) attributable to the 2003 fire on Flinders Island (Fig. S3). Other fires in refuge habitat were smaller (mean 0.12 $km^2$; range 0.0002 – 1.2 $km^2$) and 83% of extant habitat has not burned for > 45 years. The Tasmanian Bushfire Risk Assessment Model identifies 83% of refuge habitat as having a moderate to very high ignition potential (Table 3).

Our MaxEnt model of noisy miner distribution indicates that an area of 10,587 $km^2$ across Tasmania is climatically suitable for the generalist noisy miner (see Supplementary Material for model details). Environmental suitability for noisy miners is high across most of the former and present distribution of the forty-spotted pardalote and they are well established < 4km from all refuges except Flinders Island (Fig 2). The percentage area above the threshold value of noisy miner environmental suitability for each pardalote refuge varied from 0 – 81% (Table 4).

*Aim 2: develop a monitoring protocol to provide baseline population data for refuges*

On North Bruny Island and Maria Island estimates of pardalote $\Psi$ were high in all years (range 0.75-0.96, Table 5). Detectability for a single site visit was also high but more variable (0.43-0.77). Over the entire study period the species was recorded at 59 of 67 sites (88 %) on Maria Island, 55 of 61 sites (90 %) on Bruny Island, and only 7 of 115 of sites (6 %) on Flinders Island. The mean number of birds counted at a site (given presence) was 2.2 (range 1-6).

No birds were detected at any previously known forty-spotted pardalote sites on Flinders Island despite visiting these sites more often than other areas (up to 5 site visits in each year). A 'new' location was discovered on Flinders Island but is separated from the previously known refuge by >20 km of primarily agricultural land (Fig. S3). The species was also found in small patch of habitat (~10 ha) near Southport, on the Tasmanian mainland (Fig. 1). The last record of the species in the vicinity of Southport was > 120 years ago. Too few data (and birds) were available to model $\Psi$ or $p$ at these locations (Table 5).

## Discussion

The forty-spotted pardalote is now predominantly confined to island refuges. The species is at risk from multiple threats across this highly restricted range . We have established baseline population data and quantified the historical impacts and future potential risks of threats to refuge populations. We demonstrate that occupancy rates are very high at two refuges (Maria and Bruny Islands) and that the Flinders Island population is almost extinct. This provides the first standardized quantitative assessment of refuge populations providing a baseline for assessing change in population size using $\Psi$ as a surrogate for abundance (MacKenzie and Nichols 2004). Deforestation in refuges has abated in recent decades and these areas appear to currently support viable populations. However, our threat risk assessment (Table 2) found all refuges are extremely vulnerable to multiple threats including wildfire, colonization by the hyper-aggressive noisy miner and climate change. Islands have clearly provided critical refuges from threatening processes; however, our results indicate that these refuges are not secure from these threats despite being extensively reserved.

Fire frequency, intensity, and extent are expected to increase with climate change in this ecosystem (Fox-Hughes *et al.* 2014; Grose *et al.* 2014). In this case, the islands have clearly provided protection from fire; however, most refuge habitat has not burnt for a long time(and therefore currently support high fuel loads) and has a high ignition potential suggesting severe fire(s) are likely under suitable weather conditions (Table 3 & Fig. S4). Hence, refuges have only provided temporary protection at different spatial scales, but not security. The impact of fire will depend on fire severity, frequency and the spatial configuration and extent of burned and unburned habitat (Prowse *et al.* 2017). For example, a single severe fire on Flinders Island in 2003 (Fig. S3) that burned an entire patch of refuge habitat has likely resulted in another local extinction. Despite some forest recovery, the location remains unoccupied by forty-spotted pardalotes over a decade later. In contrast, several decades ago a fire burned all of south Maria Island (Fig. S1), but was recolonized two years later likely due to immigration from nearby refuge habitat (< 1 km) on the north of the island (Rounsevell and Woinarski 1983). Importantly, when compared to the size of many large fires the small size of refuges means they are all at risk of being totally destroyed with little chance of recolonisation.

The value of a refuge for forty-spotted pardalotes post fire will also depend on interactions with other biota including competition, predation, and parasitism (Kirkpatrick *et al.* 2011; Lindenmayer *et al.* 2006). Under post-fire conditions introduced herbivores may suppress regrowth and structural complexity of forest (Driscoll *et al.* 2010; Kirkpatrick *et al.* 2011), thus increasing environmental suitability for noisy miners (MacDonald and Kirkpatrick 2003; Maron and Kennedy 2007; Maron *et al.* 2011) or result in increased predator abundance (Hradsky *et al.* 2017). While high nestling mortality is caused by the newly discovered native parasitic fly (Edworthy 2018) it is unknown what the overall potential threat this poses. However, its effect likely varies in time and space depending on environmental conditions (e.g. Antoniazzi *et al.* 2010) and may be exacerbated under post fire conditions and climate change (Møller *et al.* 2014). Longitudinal (and larger scale) studies are required to determine the role of the parasitic fly on population dynamics for the forty-spotted pardalote..

We identify a large area of climatically suitable habitat for noisy miners across Tasmania (Fig. 2). The high bioclimatic suitability of most forty-spotted pardalote refuges for noisy miners, and their proximity to refuges (< 4 km) suggests there is a very high likelihood of colonization. Given that noisy miners favor fragmented environments (MacDonald and Kirkpatrick 2003; Maron *et al.* 2013), the impacts of colonization of refuges may vary depending on local forest fragmentation (Fig. S1 & S2). Since most occupied habitat on Bruny Island is adjacent to fragmented agricultural land, noisy miners could penetrate most pardalote refuges. By contrast, forest on Maria Island is more intact providing less opportunities for miner expansion, but historically cleared areas maybe ideal for noisy miners. Furthermore, intense grazing by introduced herbivores across large parts of Maria Island severely suppresses understory vegetation, reducing (or eliminating) cover which may advantage noisy miners (Maron and Kennedy 2007; Maron *et al.* 2011). Thus, our use of vegetation mapping likely provides an optimistic view of the area of 'intact' forest.

### ***Historical range contraction***

Failure to account for historical processes that have resulted in a species' current range can lead to misleading inferences about a species' ecological niche (Warren *et al.* 2014). Since European settlement, waves of local extinctions caused by large scale land clearance, subsequent habitat fragmentation and stochastic events (e.g. wildfire) and habitat fragmentation most likely resulted in no refuge populations to recolonize recovering habitat. We argue these processes probably disrupted pre-existing extinction-colonization dynamics, causing the species' range contraction. Some potential habitat in the species' historical range appears to be suitable forty-spotted pardalote habitat (M.H.W personal observations). However, the threatening processes (outlined above) allowed the concomitant expansion of noisy miners (and other aggressive birds with a similar niche), thus preventing dispersal through the agricultural matrix and recolonization of suitable habitat. Considering the spatial and temporal nature of the processes that caused the species range contraction, We suggest that suitable habitat may be available, but natural recolonisation is no longer possible.

***Translocations in the species historical range***

We call for immediate action to identify and prioritize potential reintroduction sites for the forty-spotted pardalote and attempt to establish new populations while apparently viable source populations exist within refuges. Moreover, reintroducing individuals from wild sources can be more effective since even small amounts of genetic adaptation in captive-bred individuals may negatively impact long-term wild population size and genetic diversity (Willoughby & Christie 2018). We propose that any attempt would undertake a structured decision-making process to identify an optimal source population (as per Wauchope et al. *in press*). There are well established protocols to inform conservation reintroducitons (IUCN/SSC 2013) and many precedents to inform a pardalote program (e.g. Taylor et al. 2005; Ortiz-Catedral & Brunton 2010; Collen et al. 2014).

Revegetation programs usually result in small areas of the landscape being revegetated (Thomson *et al.* 2015), require large investments (Atyeo and Thackway 2009; Menz *et al.* 2013) and take many years to achieve their objectives. Targeted revegetation programs (Understorey Network 2011) at refuges may eventually increase the area of occupancy, but this will not address the immediate threats to these refuges.

The creation of new populations via translocation may provide substantial opportunities to secure the species, particularly we are proposing reintroductions into the species former range. There is currently >1100 $km^2$ of white gum forest across the species former range, 610 $km^2$ of which occurs in patches >1 $km^2$ in area (mean, 3.1 $km^2$; S.D. 4.4 $km^2$) and often form part of larger forest remnants (Harris and Kitchener 2005) (Fig. S5). Despite the high climatic suitability of much of the former range for noisy miners, they rarely occur in the intact interior of larger forest patches (Maron *et al.* 2013); these areas may be ideal for creating new populations. In this context, a common failure in conservation planning is that locations designated as critical habitat rarely include suitable but unoccupied locations (Camaclang *et al.* 2014) and currently unoccupied potential habitat within the species' former range is afforded no legislative protection.

While reintroductions may be perceived as a 'risky' strategy (Ricciardi and Simberloff 2009) and the outcomes uncertain in some instances (e.g. persistence, population growth rate), they may be essential for the species' long-term survival and knowledge gained from undertaking such actions may be extremely valuable (Rout *et al.* 2009). Because of the current threats to refuges we believe any risks associated with translocations far outweigh the risks of not acting. Moreover, our assessments show this opportunity could rapidly be lost due to collapse of refuge populations (e.g. Flinders Island), or clearance of potential reintroduction sites and action must be undertaken promptly.

***Conclusion***

Our study highlights the need to consider the processes that create refuges for endangered species, and if they provide long-term security or merely represent the final locations to be affected by threatening processes. Diagnosing the processes that have led to a species current distribution is extremely valuable because previous local extinctions does not necessarily mean these sites remain permanently unsuitable, and vice-versa.

## Literature Cited


Antoniazzi L. R., Manzoli D. E., Rohrmann D., Saravia M. J., Silvestri L. & Beldomenico P. M. (2010) Climate variability affects the impact of parasitic flies on Argentinean forest birds. *Journal of Zoology* **283**, 126-34.

Atkinson I. (2002) Recovery of wildlife and restoration of habitats New Zealand. *Pacific Conservation Biology* **8**, 27-35.

Atyeo C. & Thackway R. (2009) Mapping and monitoring revegetation activities in Australia – towards national core attributes. *Australasian Journal of Environmental Management* **16**, 140-8.

Blackburn T. M., Cassey P., Duncan R. P., Evans K. L. & Gaston K. J. (2004) Avian extinction and mammalian introductions on oceanic islands. *Science* **305**, 1955-8.

Brown P. (1986) The forty-spotted pardalote in Tasmania. Technical Report 86/4. National Parks and Wildlife Service,, Hobart, Tasmania.

Bryant S. (2010) Conservation assessment of the endangered forty-spotted pardalote 2009-2010. In: *Report to Treatened Species Section, DPIPWE and NRM South*, Hobart, Tasmania.

Camaclang A., Maron M., Martin T. & Possingham H. (2014) Current practices in the identification of critical habitat for threatened species. *Conservation Biology* **29**, 482-92.

Caughley G. (1994) Directions in conservation biology. *Journal of Animal Ecology* **63**, 215–44.

Collen, R., B. Cash, L. Adams, L. Oritz-Catedral, M. Booth, R. Gray, D. Fastier, K. Nagakawa and T. Ward-Smith. (2014). Best practice techniques for the translocation of red-crowned parakeet (kakariki), Cyanoramphus novaezelandiae novaezelandiae and yellow-crowned parakeet (kakariki, Cyanoramphus auriceps). Department of Conservation, Wellington, New Zealand.Department of Primary Industries P., Water and Environment, . (2013) TASVEG 3.0. Tasmanian Vegetation Monitoring and Mapping Program. (ed T. Government), Hobart.

Driscoll D. A., Lindenmayer D. B., Bennett A. F., Bode M., Bradstock R. A., Cary G. J., Clarke M. F., Dexter N., Fensham R., Friend G., Gill M., James S., Kay G., Keith D. A., MacGregor C., Russell-Smith J., Salt D., Watson J. E. M., Williams R. J. & York A. (2010) Fire management for biodiversity conservation: Key research questions and our capacity to answer them. *Biological Conservation* **143**, 1928-39.

Edworthy A. B. (2016) Avian hosts, prevalence and larval life history of the ectoparasitic fly Passeromyia longicornis (Diptera : Muscidae) in south-eastern Tasmania. *Australian Journal of Zoology* **64**, 100-6.

Edworthy A. B. (2016). Native fly parasites are the principal cause of nestling mortality in endangered Tasmanian pardalotes. Animal Conservation. doi:10.1111/acv.12444

Edworthy A. (2017). Ecology and conservation of the endangered forty-spotted Pardalote. PhD thesis, Australian National University.

Fiske I. & Chandler R. (2011) unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. *Journal of Statistical Software* **043**.

Fox-Hughes P., Harris R., Lee G., Grose M. & Bindoff N. (2014) Future fire danger climatology for Tasmania, Australia, using a dynamically downscaled regional climate model. *International Journal of Wildland Fire* **23**, 309-21.

Grose M. R., Fox-Hughes P., Harris R. M. B. & Bindoff N. L. (2014) Changes to the drivers of fire weather with a warming climate – a case study of southeast Tasmania. *Climatic Change* **124**, 255-69.

Hansen M. C., Potapov P. V., Moore R., Hancher M., Turubanova S. A., Tyukavina A., Thau D., Stehman S. V., Goetz S. J., Loveland T. R., Kommareddy A., Egorov A., Chini L., Justice C. O. & Townshend J. R. G. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science* **342**, 850-3.

Harris S. & Kitchener A. (2005) From Forest to Fjaeldmark: Descriptions of Tasmania'sVegetation. . (ed D. o. P. I. a. Water), Hobart.

Hart B., Burgman M., Webb A., Allison G., Chapman M., Duivenvoorden L., Feehan P., Grace M., Lund M., Pollino C., Carey J. & McCrea A. (2005) Ecological Risk Management Framework for the Irrigation Industry, Report to National Program for Sustainable Irrigation (NPSI) Water Studies Centre, Monash University.

Heinsohn R., Webb M. H., Lacy R., Terauds A., Alderman R. & Stojanovic D. (2015) A severe predator-induced decline predicted for endangered, migratory swift parrots (*Lathamus discolor*). *Biological Conservation* **186**, 75-82.

Hradsky B. A., Robley A., Alexander R., Ritchie E. G., York A. & Di Stefano J. (2017) Human-modified habitats facilitate forest-dwelling populations of an invasive predator, Vulpes vulpes. *Scientific Reports* **7**, 12291.

IUCN/SSC. (2013). Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Gland, Switzerland

Keppel G. & Wardell-Johnson Grant W. (2012) Refugia: keys to climate change management. *Global Change Biology* **18**, 2389-91.

Kirkpatrick J. B., Marsden-Smedley J. B. & Leonard S. W. J. (2011) Influence of grazing and vegetation type on post-fire flammability. *Journal of Applied Ecology* **48**, 642-9.

Lentini P. E., Stirnemann I. A., Stojanovic D., Worthy T. H. & Stein J. A. (2018) Using fossil records to inform reintroduction of the kakapo as a refugee species. *Biological Conservation* **217**, 157-65.

Lindenmayer D. B., Franklin J. F. & Fischer J. (2006) General management principles and a checklist of strategies to guide forest biodiversity conservation. *Biol Cons* **131**, 433-45.

Liu C., White M. & Newell G. (2013) Selecting thresholds for the prediction of species occurrence with presence-only data. *Journal of Biogeography* **40**, 778-89.

Lomolino M. V. & Channell R. (1995) Splendid Isolation: Patterns of Geographic Range Collapse in Endangered Mammals. *Journal of Mammalogy* **76**, 335-47.

MacDonald M. A. & Kirkpatrick J. B. (2003) Explaining bird species composition and richness in eucalypt-dominated remnants in subhumid Tasmania. *Journal of Biogeography* **30**, 1415-26.

MacKenzie, D., Nichols, J., Lachman, G., Droege, S., Royle, J., and Langtimm, C. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology* **83**, 2248-2255.

MacKenzie D. & Nichols J. (2004) Occupancy as a surrogate for abundance estimation. *Animal Biodiversity and Conservation* **27**, 461-7.

Maron M., Grey Merilyn J., Catterall Carla P., Major Richard E., Oliver Damon L., Clarke Michael F., Loyn Richard H., Mac Nally R., Davidson I. & Thomson James R. (2013) Avifaunal disarray due to a single despotic species. *Diversity and Distributions* **19**, 1468-79.

Maron M. & Kennedy S. (2007) Roads, fire and aggressive competitors: Determinants of bird distribution in subtropical production forests. *Forest Ecology and Management* **240**, 24-31.

Maron M., Main A., Bowen M., Howes A., Kath J., Pillette C. & McAlpine C. A. (2011) Relative influence of habitat modification and interspecific competition on woodland bird assemblages in eastern Australia. *Emu* **111**, 40-51.

Martin T. G., Nally S., Burbidge A. A., Arnall S., Garnett S. T., Hayward M. W., Lumsden L. F., Menkhorst P., McDonald-Madden E. & Possingham H. P. (2012) Acting fast helps avoid extinction. *Conservation Letters* **5**, 274-80.

McCarthy Michael A., Thompson Colin J. & Possingham Hugh P. (2005) Theory for Designing Nature Reserves for Single Species. *The American Naturalist* **165**, 250-7.

Menz M. H. M., Dixon K. W. & Hobbs R. J. (2013) Hurdles and Opportunities for Landscape-Scale Restoration. *Science* **339**, 526.

Møller A. P., Merino S., Soler J. J., Antonov A., Badás E. P., Calero-Torralbo M. A., de Lope F., Eeva T., Figuerola J., Flensted-Jensen E., Garamszegi L. Z., González-Braojos S., Gwinner H., Hanssen S. A., Heylen D., Ilmonen P., Klarborg K., Korpimäki E., Martínez J., Martínez-de la Puente J., Marzal A., Matthysen E., Matyjasiak P., Molina-Morales M., Moreno J., Mousseau T. A., Nielsen J. T., Pap P. L., Rivero-de Aguilar J., Shurulinkov P., Slagsvold T., Szép T., Szöllősi E., Török J., Vaclav R., Valera F. & Ziane N. (2014) Assessing the Effects of Climate on Host-Parasite Interactions: A Comparative Study of European Birds and Their Parasites. *PLOS ONE* **8**, e82886.

Morris K. D. (2000) The status and conservation of native rodents in Western Australia. *Wildlife Research* **27**, 405-19.

Ortiz-Catedral, L., S and D. H. Brunton. 2010. Success of translocations of red-fronted parakeets Cyanoramphus novaezelandiae novaezelandiae from Little Barrier Island (Hauturu) to Motuihe Island, Auckland, New Zealand. Conservation Evidence **7,** 21-26.

Pavey, C. R., Addison, J., Brandle, R., Dickman, C. R., McDonald, P. J., Moseby, K.E., Young, L. I., 2017. The role of refuges in the persistence of Australian dryland mammals. *Biological Reviews* 92, 647-664.

Phillips S. J., Anderson R. & Schapire R. (2006) Maximum entropy modeling of species geographic distributions. *Ecological Modelling* **190**, 231-59.

Prowse T. A. A., Collard S. J., Blackwood A., O'Connor P. J., Delean S., Barnes M., Cassey P. & Possingham H. P. (2017) Prescribed burning impacts avian diversity and disadvantages woodland-specialist birds unless long-unburnt habitat is retained. *Biological Conservation* **215**, 268-76.

R Development Core Team. (2008) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reside A., Welbergen J., Phillips B., Wardell-Johnson G., Keppel G., Ferrier S., Williams S. & VanDerWal J. (2014) Characteristics of climate change refugia for Australian biodiversity. *Austral Ecology* **39**, 887-97.

Ricciardi A. & Simberloff D. (2009) Assisted colonization: good intentions and dubious risk assessment. *Trends in Ecology & Evolution* **24**, 476-7.

Rounsevell D. E. & Woinarski J. C. Z. (1983) Status and conservation of the 40 spotted pardalote, *Pardalotus quadragintus* (Aves, Pardalotidae). *Australian Wildlife Research* **10**, 343-9.

Rout T., Hauser C. & Possingham H. (2009) Optimal adaptive management for the translocation of a threatened species. *Ecological Applications* **19**, 515-26.

Schultz Courtney A., Sisk Thomas D., Noon Barry R. & Nie Martin A. (2013) Wildlife conservation planning under the United States Forest Service's 2012 planning rule. *The Journal of Wildlife Management* **77**, 428-44.

Seddon P. J. (2015). Using the IUCN critirea to assess reintroduction success. Animal Conservation 18, 407-408

Smith F. P. (2008) Who's planting what, where and why – and who's paying?: An analysis of farmland revegetation in the central wheatbelt of Western Australia. *Landscape and Urban Planning* **86**, 66-78.

Stojanovic D., Webb nee Voogdt J., Webb M., Cook H. & Heinsohn R. (2016) Loss of habitat for a secondary cavity nesting bird after wildfire. *Forest Ecology and Management* **360**, 235-41.

Stojanovic D., Alves A., Cook H., Crates R., Heinsohn R., Peters A., Rayner L., Troy S. N., & Webb M. H. (2017). Further knowledge and urgent action required to save Orange-bellied Parrots from extinction. Emu **118**, 126-34.

Tasmanian Fire Service. (2017) State Fire History. (ed T. F. Service), https://www.thelist.tas.gov.au.

Taylor S. S., Jamieson I. G. & Armstrong D. P. (2005) Successful island reintroductions of New Zealand robins and saddlebacks with small numbers of founders. *Animal Conservation* **8**, 415-20.

Tershy B. R., Shen K.-W., Newton K. M., Holmes N. D. & Croll D. A. (2015) The Importance of Islands for the Protection of Biological and Linguistic Diversity. *BioScience* **65**, 592-7.

Thomson J., Maron M., Grey M., Catterall C., Major R., Oliver D., Clarke M., Loyn R., Davidson I., Ingwersen D., Robinson D., Kutt A., MacDonald M. & Mac Nally R. (2015) Avifaunal disarray: quantifying models of the occurrence and ecological effects of a despotic bird species. *Diversity and Distributions* **21**, 451-64.

Threatened Species Scientific Committee. (2014) Advice to the Minister for Sustainability, Environment, Water, Population & Communities from the Threatened Species Scientific

Committee (the Committee) on Amendments to the List of Key Threatening Processes under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). (ed T. S. S. Committee), http://www.environment.gov.au/biodiversity/threatened/key-threatening-processes/overabundant-noisy-miners.

Threatened Species Section. (2006) Fauna recovery plan: forty-spotted pardalote 2006-2010.

Understorey Network. (2011) Habitat Plan for the Endangered Forty-Spotted Pardalote Pardalotus quadragintus, Caring For Our Country Program. Understorey Network, Tasmania.

Warren D. L., Cardillo M., Rosauer D. F. & Bolnick D. I. (2014) Mistaking geography for biology: inferring processes from species distributions. *Trends in Ecology & Evolution* **29**, 572-80.

Wauchope H., Fuller R.A., Shanahan D.F. & Shaw J.D. (*in press*) Restoring Islands and identifying source populations for species introductions. *Conservation Biology*

Webb M. H., Holdsworth M., Stojanovic D., Terauds A., Bell P. & Heinsohn R. (2016) Immediate action required to prevent another Australian avian extinction: the King Island Scrubtit. *Emu* **116**, 223-9.

Willoughby J. R. & Christie M. R. (2018). Long-term demographic and genetic effects of releasing captive-born individuals into the wild. Conservation Biology, https://doi.org/10.1111/cobi.13217

Wilson K. A., Underwood E. C., Morrison S. A., Klausmeyer K. R., Murdoch W. W., Reyers B., Wardell-Johnson G., Marquet P. A., Rundel P. W., McBride M. F., Pressey R. L., Bode M., Hoekstra J. M., Andelman S., Looker M., Rondinini C., Kareiva P., Shaw M. R. & Possingham H. P. (2007) Conserving Biodiversity Efficiently: What to Do, Where, and When. *PLOS Biology* **5**, e223.

Woinarski J. C. Z. (2011) The mammal fauna of the Sir Edward island group, Northern Territory, Australia: refuge and death trap. *Wildlife Research* **38**, 307-322

Woinarski J. C. Z. (2016) A very preventable mammal extinction. *Nature* **535**, 493.

Woinarski J. C. Z. & Bulman C. (1985) Ecology and breeding biology of the 40-spotted pardalote and other pardalotes on North Bruny Island. *Emu* **85**, 106-20.

**Table 1.** Key threatening processes for the forty spotted pardalote, derived from Threatened Species Section (2006) and Brown (1986).

| **Threat** | **Description** | **Current threat extent** | **Potential extent of impact** |
|---|---|---|---|
| Deforestation | The species is reliant on white gums (Brown 1986; Woinarski and Bulman 1985). Habitat loss at refuges and across the historical range through deforestation for agriculture, logging and urban development is strongly implicated in the species decline (Threatened Species Section 2006). | Entire range outside of reserves | Entire range outside of reserves |
| Wildfire | The effect of wildfire can be devastating on wildlife (Webb *et al.* 2016). Fire has been implicated in local extinctions (Bryant 2010). Intense fire can kill white gums; lower intensity fire can scorch tree crowns reducing or eliminating food availability. Too frequent burning may exacerbate these issues (Brown 1986). Tree cavity abundance can also decline after wildfire (Stojanovic *et al.* 2016). | Entire range | Entire range |
| Competitive exclusion by noisy | Noisy Miners negatively impact bird communities via hyper-aggressive competitive exclusion of other bird species, and are listed as a ‘key | Tasmania mainland | Unknown |

| | | | |
|---|---|---|---|
| miner (*Manorina melanocephala*) | threatening process (Threatened Species Scientific Committee 2014). Currently noisy miners are absent from all remaining forty-spotted pardalote refuges. Noisy miner occurrence has been implicated in recent local extinctions (Brown 1986). Noisy miner distribution has increased with landscape modification (MacDonald and Kirkpatrick 2003; Thomson *et al.* 2015). | | |
| Climate change | Climate change has the potential to exacerbate the threats listed above, particularly wildfire and tree dieback. | Unknown | Entire range |

**Table 2. Threat risk assessment for Forty-spotted Pardalote refuges and habitat in its former range in the next 30 years.**

| Location | Fire | Noisy miner colonisation | Deforestation | Climate Change |
|---|---|---|---|---|
| Maria Island | Very High | Moderate | Moderate | Very High |
| North Bruny Island | Very High | Very High | High | Very High |
| Tinderbox | Very High | Very High | Very High | Very High |
| South Bruny Island | Very High | Very High | High | Very High |
| Flinders Island | Extreme | Low | High | Very High |
| Southport | Extreme | Moderate | High | Very High |
| Large patches of intact habitat in former range | Unknown | Low | Unknown | Very High |

**Table 3.** Ignition potential of Forty-spotted Pardalote refuge habitat (km²) as per the Tasmanian Bushfire Risk Assessment Model (DPIPWE 2017).

| Location | Ignition potential area (km²) | | | | |
|---|---|---|---|---|---|
| | Very low | Low | Moderate | High | Very high |
| Maria Island | 1.8 | 0 | 18.5 | 0 | 0 |
| Bruny Island | 0 | 1.1 | 2.8 | 0 | 9.6 |
| Tinderbox Peninsula | 0 | 0 | 0 | 0 | 4.4 |
| Flinders Island | 0 | 0 | 0 | 3.3 | 0 |
| Total area | 1.8 | 1.1 | 21.3 | 3.3 | 14 |

**Table 4.** Total area of each forty-spotted pardalote refuge and the percentage of each refuge above the equal test sensitivity and specificity threshold for Noisy Miner environmental suitability.

| **Location** | **Area (km²)** | **Area above environmental suitability threshold** |
|---|---|---|
| Maria Island | 20.3 | 81 % |
| North Bruny Island | 8.6 | 91 % |
| South Bruny Island | 6.9 | 17 % |
| Tinderbox Peninsula | 4.4 | 16 % |

| | | |
|---|---|---|
| Flinders Island | 1.2 | 0 % |
| Total area | 41.4 | 63 % |

**Table 5. Occupancy (*Ψ*) and detectability (*p*) estimates in Forty-spotted Pardalote refuges surveyed between 2010-2016.**

Naïve *Ψ* (proportion of sites birds detected), *Ψ* (modelled occupancy), *p* (detectability); occupied locations at Southport and Flinders Island were discovered during this study.

| Location | Year | No. sites | Site visits | Naïve *Ψ* | *Ψ* | s.e. | *p* | s.e. |
|---|---|---|---|---|---|---|---|---|
| Maria Island | 2010 | 37 | 3 | 0.784 | 0.96 | 0.114 | 0.432 | 0.069 |
| | 2011 | 67 | 2 | 0.806 | 0.869 | 0.059 | 0.730 | 0.054 |
| | 2012 | 66 | 2 | 0.667 | 0.750 | 0.075 | 0.667 | 0.067 |
| | 2016 | 66 | 2-3 | 0.727 | 0.757 | 0.058 | 0.773 | 0.046 |
| North Bruny Island | 2011 | 61 | 3 | 0.754 | 0.937 | 0.094 | 0.420 | 0.055 |
| | 2016 | 61 | 3 | 0.787 | 0.814 | 0.055 | 0.678 | 0.433 |
| Flinders Island | 2010, 2011, 2012 | 115 | 2-10 | 0.061 | - | - | - | - |
| Southport | 2014, 2015 | 6 | 4 | 1.0 | - | - | - | - |

**APPENDIX A**

*Consequence* was defined as the magnitude to which the species is affected by the potential threat and takes into account the size of the threat footprint. *Consequence* was rated as:

Minimal – no long-term effect on individuals or the species

Minor – individuals are affected but no effect at a species level

Moderate – species recovery stalls

Major – species declines

Catastrophic – species extinction

Likelihood (how likely the threat is to occur) was defined as the likelihood that the identified consequence will occur, with ratings of Almost certain, Likely and Unlikely. These were interpreted as relating to the timeframe of 30 years:

Uncertain – more information required

Almost certain – high probability of occurring with next 30 years

Likely – medium probability of occurring in next 30 years

Unlikely – low probability of occurring in next 30 years

**Table S1. Likelihood of each threat affecting Forty-spotted Pardalote refuges and its former range in the next 30 years.**

| Location | Fire | Noisy miner colonisation | Habitat clearance | Climate Change |
|---|---|---|---|---|
| Maria Island | Almost certain | Likely | Unlikely | Likely |
| North Bruny Island | Almost certain | Almost certain | Unlikely | Likely |
| Tinderbox | Almost certain | Almost certain | Likely | Likely |
| South Bruny Island | Almost certain | Likely | Unlikely | Likely |
| Flinders Island | Almost certain | Unlikely | Unlikely | Likely |
| Southport | Almost certain | Unlikely | Unlikely | Likely |
| Intact habitat in former range* | Almost certain | Likely | Almost certain | Likely |

*intact habitat refers to ‘large’ forest patches

**Table S2. Consequence of each threat for Forty-spotted Pardalote refuges and its former range if it occurs.**

| Location | Fire | Noisy miner colonisation | Habitat clearance | Climate Change |
|---|---|---|---|---|
| Maria Island | Major | Moderate | Moderate | Major |
| North Bruny Island | Major | Major | Moderate | Major |
| Tinderbox | Major | Major | Major | Major |
| South Bruny Island | Major | Major | Moderate | Major |
| Flinders Island | Catastrophic | Low | Moderate | Major |
| Southport | Catastrophic | Moderate | Major | Major |
| Intact habitat in former range* | Unknown | Minimal | Minor | Major |

*intact habitat refers to 'large' forest patches

**Table S3.** Threat risk matrix for impacts of threats to the Forty-spotted Pardalote.

| Likelihood | Consequence | | | | |
|---|---|---|---|---|---|
| | Minimal | Minor | Moderate | Major | Catastrophic |
| Almost certain | Low | Moderate | High | Very High | Extreme |
| Likely | Low | Moderate | High | Very High | Very High |
| Unlikely | Low | Low | Moderate | High | High |

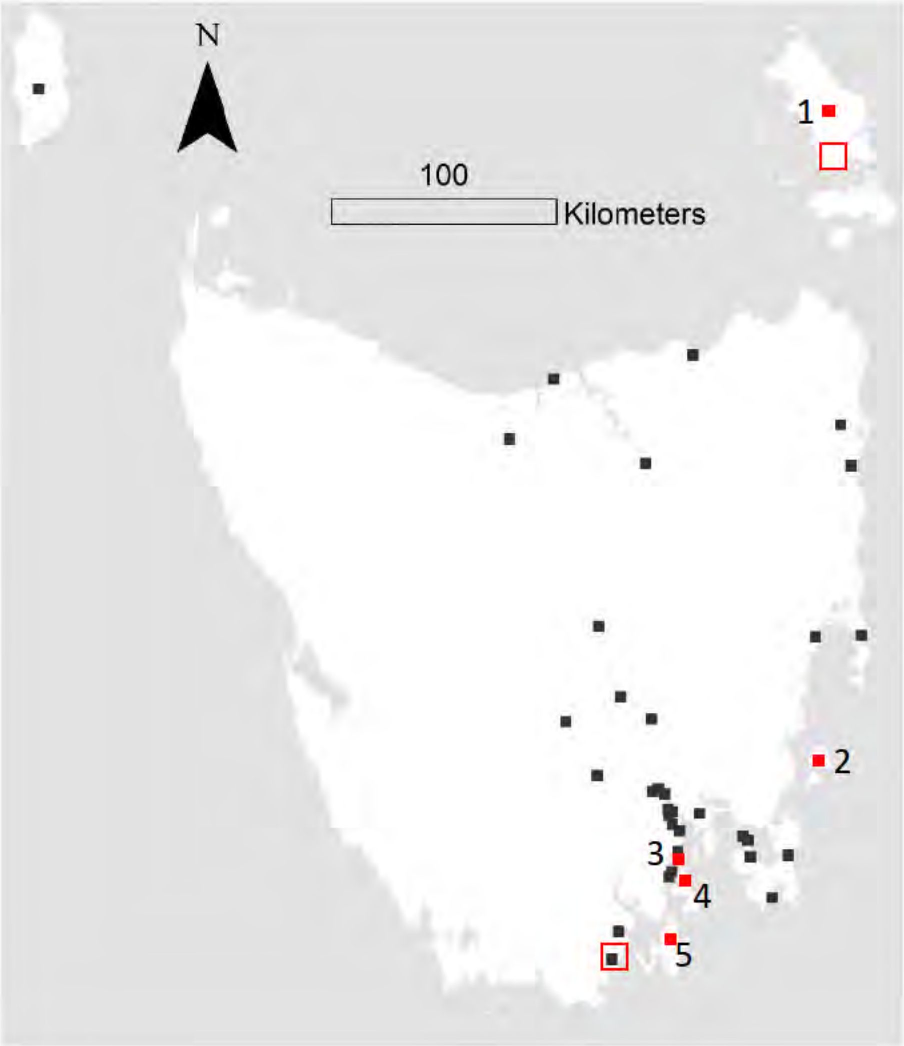



Figure 1. Current refuges and historical locations of the forty-spotted pardalote; refuges (solid red squares), historical sites from Brown (1986) (black squares); 1, Flinders Island; 2, Maria Island; 3, Tinderbox; 4, North Bruny Island; 5, South Bruny Island; new sites identified during this study (open red squares).

Historical locations obtained from (Table 1, Brown 1986)

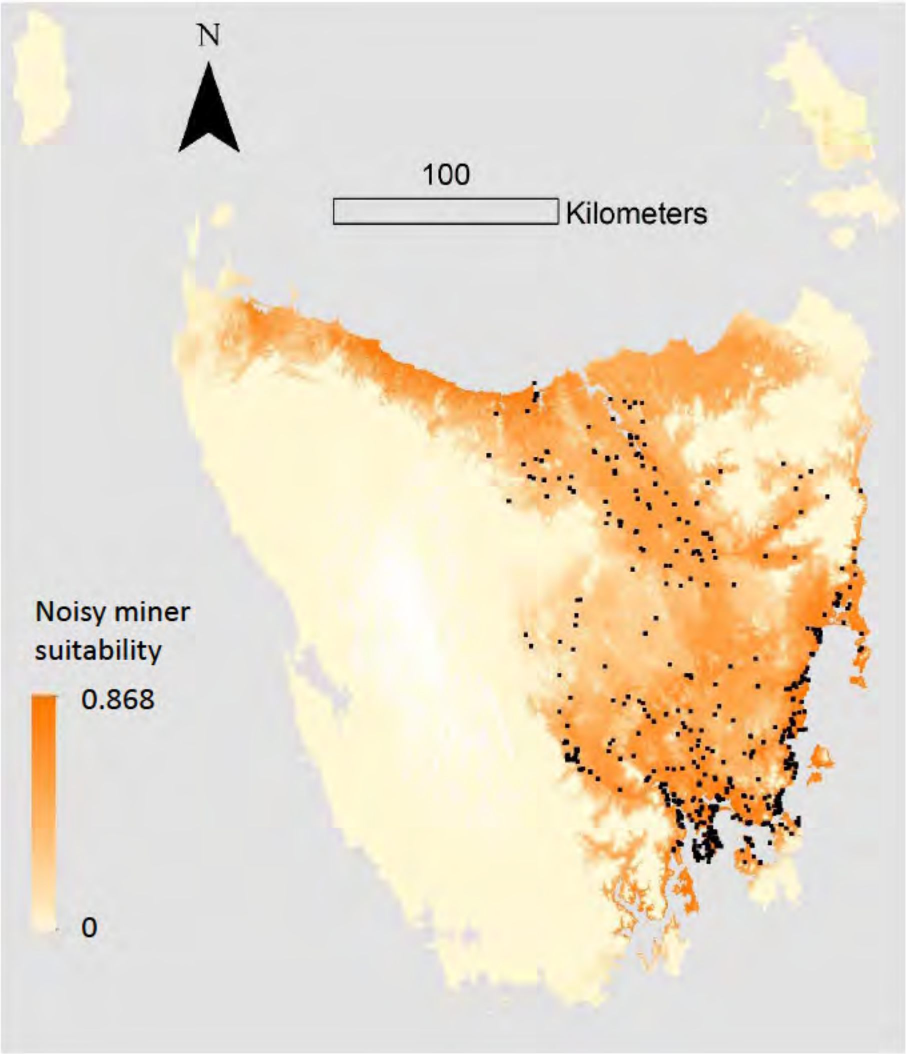



Figure 2. Estimated environmental suitability for noisy miners in Tasmania; noisy miner records (black squares).

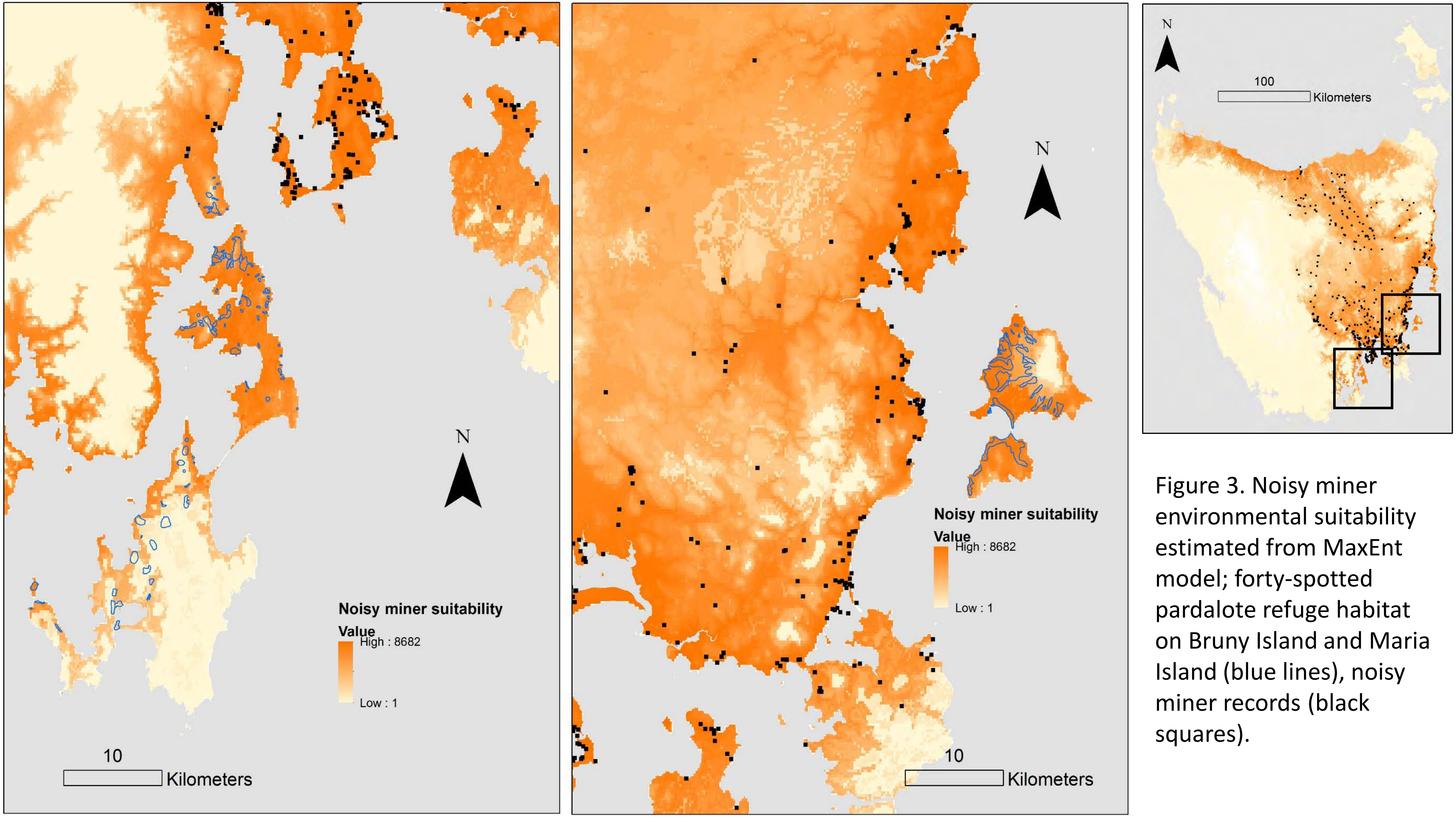



Figure 3. Noisy miner environmental suitability estimated from MaxEnt model; forty-spotted pardalote refuge habitat on Bruny Island and Maria Island (blue lines), noisy miner records (black squares).