PROCEEDINGS

of the

5th NATIONAL MALLEEFOWL FORUM

September 12 – 15, 2014
Dubbo, New South Wales

M.G. Bannerman & S.J.J.F. Davies (Editors)

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March 2016

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Preface

The 5th National Malleefowl Forum held at the Taronga Western Plains Zoo in Dubbo, New South Wales from 12th to 15th September 2014, was attended by 140 people. It was a project of the National Malleefowl Recovery Team and was funded by Iluka Resources Ltd, NSW National Parks and Wildlife Service and Western Local Land Services NSW. The Forum began with a review of the progress of Malleefowl conservation across Australia, showing progress in each state with improved methods of mound monitoring. Several new and valuable techniques developed since 2011 were described, including the use of modelling to predict where mallee was suitable for Malleefowl, the possibility of using new aerial survey techniques to locate Malleefowl mounds, and the development of ground survey techniques for locating mounds in arid areas where few mounds occur. Progress with the Adaptive Management Project was reported on, as was some useful experimental work assessing the impact of predators and competitors on Malleefowl populations. Three important papers reviewed the genetics of Malleefowl, making recommendations about the bird's management for conservation, and results from the Victorian Mallee HawkEye project were presented with potential implications for Malleefowl. Walter Boles from the Australian Museum, Sydney, as guest speaker, presented a brief history of Megapodes through time.

The forum attracted 31 papers from a wide range of sources, universities, state agencies, volunteer groups, consultants, zoos, mining companies and private naturalists, giving a comprehensive review of issues and achievements in the conservation of Malleefowl since 2011. These contributions should provide a useful baseline against which future progress can be assessed. Six poster displays were also presented at the forum. Abstracts of these were published in the programme and are included in these proceedings.

New life: a Malleefowl chick just emerged from the mound, resting. Innes National Park, SA. Photos: S Gillam

Acknowledgements

The National Malleefowl Recovery Team is grateful to Melanie Bannerman and Tim Burnard who organised the forum and to the Steering Committee consisting of Sharon Gillam, Sally Cail, Peter Stokie, Marc Irvin, Milton Lewis and Peter Ewin, who assisted in its planning. The team is also grateful to the Scientific Review Team who reviewed and selected the presentations for the forum. The team consisted of Sharon Gillam, Stephen Davies, Joe Benshemesh and Melanie Bannerman.

Thank you to Uncle John Hill for his Welcome to Country on behalf of the local Tubba-Gah Aboriginal people and to Sharon Gillam, Chair of the National Malleefowl Recovery Team for opening the forum. A special thank you also to Sally Cail who provided a moving pictorial tribute to Ann Stokie, wife to Peter, former Secretary of the Victorian Malleefowl Recovery Group and passionate Malleefowl conservationist, who sadly passed away in 2013.

Iluka Resources, the New South Wales National Park and Wildlife Service Northern Plains Region and the Western Local Land Services are gratefully acknowledged in providing the funding for the forum and Taronga Western Plains Zoo for providing such a lovely venue and catering for the forum.

Thanks to everyone who helped with the preparation, set-up and running of the event, including Sally Cail, Donna Higgins, Sharon Gillam, Lesley Forward and many others.

A sincere thanks to all those who presented at the Forum including those who gave poster presentations and our Guest Speakers, Dr Walter Boles and Ian Fraser, who both provided us with interesting and entertaining talks.

Thank you to our session Chairs: Blair Parsons, Michael Bode, Stephen Davies, Sharon Gillam and Peter Stokie; to our photographers: Andy McQuie and Peter Waterhouse and to our technical assistant Graeme Tonkin, who helped with the smooth flowing of presentations.

Thanks also to those who assisted with the field trips on the Monday including staff from the NPWS Baradine and Dubbo offices, especially Joel Hatch and Jillian Norton; Janis & Tim Hosking from the Dubbo Field Naturalist Society and TWPZ staff, especially Steve Kleinig, who organised the behind the scene tours and kindly volunteered to drive us around. Thank you also to those who assisted in catering for these trips including NPWS staff and Freckles Coffee Shop at Baradine, and to our bus drivers who got everyone there safely and back.

Colin Cichon is acknowledged in providing final formatting and editing services.

And finally, thank you to everyone who attended the forum and who is involved in Malleefowl conservation around the country. Your passion for this iconic bird is truly amazing and gratefully acknowledged.

NSW GOVERNMENT | Office of Environment & Heritage | NSW National Parks & Wildlife Service

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NATIONAL Malleefowl RECOVERY TEAM

5th NATIONAL MALLEEFOWL FORUM

12th – 15th September 2014
Taronga Western Plains Zoo, Dubbo, New South Wales

PROGRAM

Friday 12th September

4.00 – 7.00pm Registration, Savannah Room, Taronga Western Plains Zoo

5.30 – 6.30pm Pre-forum drinks & nibbles, Savannah Room, Taronga Western Plains Zoo

Saturday 13th September

8.00am Registration

Chair: Blair Parsons, Member National Malleefowl Recovery Team

9.00am ***Welcome to the 5th National Malleefowl Forum***
Sharon Gillam, Chair, National Malleefowl Recovery Team; SA Department of Environment, Water and Natural Resources

9.10am ***Welcome to Country***
Uncle John Hill on behalf of the local Tubba-Gah Aboriginal Community

9.15am ***Tribute to Ann Stokie***
Sally Cail on behalf of the National Malleefowl Recovery Team

9.25am ***Introduction to the National Forum***
Joe Benshemesh, Member National Malleefowl Recovery Team

9.45am ***Performance Evaluation of the National Recovery Plan for Malleefowl and Resolutions from Renmark***
Tim Burnard, National Malleefowl Recovery Program Coordinator; Member National Malleefowl Recovery Team

10.00am ***Update from the National Malleefowl Recovery Program Coordinator***
Tim Burnard

10.07am **State by state round-up of conservation actions since Renmark**

Report from the North Central Malleefowl Preservation Group WA
Sally Cail, North Central Malleefowl Preservation Group; Member National Malleefowl Recovery Team

10.15am Morning Tea

10.40am ***Malleefowl Preservation Group WA Report – Establishing new directions***
John DeJose, CEO Malleefowl Preservation Group; Member National Malleefowl Recovery Team

Malleefowl conservation activities in NSW 2012 – 2014
Melanie Bannerman, NSW Office of Environment and Heritage, National Parks and Wildlife Service; Member National Malleefowl Recovery Team

Malleefowl conservation in SA: activities from 2012 – 2014
Sharon Gillam, SA Department of Environment, Water & Natural Resources; Member National Malleefowl Recovery Team

Malleefowl conservation action in Victoria 2011 – 2014
Peter Stokie, Victorian Malleefowl Recovery Group; Member National Malleefowl Recovery Team

11.12am Questions for state-wide presenters

Chair: Dr Michael Bode, Member National Malleefowl Recovery Team

11.20am ***Saving Our Species - Malleefowl Iconic Species Project***
Marc Irvin, NSW Office of Environment and Heritage

11.40am ***Western Australia Malleefowl Network Update***
Blair Parsons, Outback Ecology; Member National Malleefowl Recovery Team

12.00pm Questions

12.10pm ***Reproductive outputs of two comparable regions of the SA Murray–Darling Basin – Results and learnings for recovery***
Chris Hedger, Natural Resources SA Murray-Darling; Member National Malleefowl Recovery Team

12.30pm Lunch

Poster Presentations

Mallee fires in the South Australian Murray–Darling Basin – Losses, learnings and linings
Chris Hedger and Jared Pippos, SA Department of Environment, Water & Natural Resources

Is road kill the greatest threat to Malleefowl survival in bushland remnants?
Gordon McNeill, North Central Malleefowl Preservation Group

Emergency Summit for threatened mallee birds
Janelle Thomas, Birdlife Australia

1.30pm ***An investigation of potential landscape links to enhance Malleefowl conservation in northwest Victoria***
Geoffrey G. Allen, Ogyris Pty Ltd

1.50pm ***How mining offsets can provide support towards meeting National Recovery Plan objectives***
Stephanie Mitchell, Iluka Resources

2.00pm Questions

2.10pm ***A proposed release of Malleefowl at Taronga Western Plains Zoo: for discussion***
Paul Andrew, Taronga Western Plains Zoo

2.30pm Questions / Discussion

Chair: Professor Stephen Davies, Member National Malleefowl Recovery Team

2.40pm ***Conservation Genetics of Malleefowl Part 1: Phylogeography and population genetics***
Taneal Cope, PhD candidate, Melbourne University

3.00pm ***Conservation Genetics of Malleefowl Part 2: Mating systems and relatedness of mound siblings***
Taneal Cope, PhD candidate, Melbourne University

3.20pm Afternoon tea

3.40pm ***Conservation Genetics of Malleefowl Part 3: Landscape genetics of Malleefowl***
Taneal Cope, PhD candidate, Melbourne University

4.00pm Questions

4.10pm ***A brief history of Megapodes through time***
Guest Speaker: Dr Walter Boles, Australian Museum

4.45pm Questions

4.55pm ***Close of presentations and directions for Data Handlers gathering and Forum Dinner***
Melanie Bannerman, Member National Malleefowl Recovery Team

5.15pm ***Data Handlers gathering – Zoo Friends Room***
Joe Benshemesh, Member National Malleefowl Recovery Team

7.00pm ***Forum Dinner, Savannah Room, Taronga Western Plains Zoo***

How Australian Birds got their English names
Guest Speaker: Ian Fraser

Presentations and Thankyou to Guest Speakers and Chairs
Melanie Bannerman, Member National Malleefowl Recovery Team

Sunday 14th September

Chair: Professor Stephen Davies, Member National Malleefowl Recovery Team

9.00am ***Welcome to Day 2***
Sharon Gillam, Chair National Malleefowl Recovery Team

9.10am ***Update on the National Malleefowl Monitoring Database: recent developments and new gear***
Joe Benshemesh, La Trobe University; Member National Malleefowl Recovery Team

9.25am ***Malleefowl (Nganamara) as a flagship species for Indigenous land management in the Great Victoria Desert of WA***
Adam Pennington, Natural Resources Alinytjara Wilurara and Pila Nguru Aboriginal Corporation

9.45am ***Progress towards a method of monitoring Malleefowl in the Maralinga Tjarutja Lands, South Australia***
Joe Benshemesh, La Trobe University; Member National Malleefowl Recovery Team

10.05am ***The use of LiDAR to determine the presence of Malleefowl mounds***
Vi Saffer and Travis Peake, Umwelt Pty Ltd

10.25am Morning tea

10.45am ***Motion-sensitive cameras for monitoring a range of animals in Malleefowl monitoring sites***
Joe Benshemesh, La Trobe University and Peter Stokie, Victorian Malleefowl Recovery Group; Members National Malleefowl Recovery Team

11.05am ***Using high definition aerial photography to search for Malleefowl mounds***
Julia Sparks, Aerometrex Pty Ltd

11.25am ***Comparison of three survey techniques for locating Malleefowl mounds***
John Read, Ecological Horizons

11.55am Questions

Chair: Sharon Gillam, Chair National Malleefowl Recovery Team

12.05pm ***The Mallee Hawkeye Project: assessing most suitable habitat for threatened mallee birds using predictive fire history mapping***
Jemima Connell, La Trobe University

12.35pm Questions

12.45pm Lunch

Poster Presentations

Thinking outside the jerry can
John DeJose, Malleefowl Preservation Group

Malleefowl at Monarto Zoo
Vaughan Wilson, Monarto Zoo and Mal Norman, Adelaide Zoo

Malleefowl mound building: Effects on fire behaviour and habitat
Amy Smith, La Trobe University

1.35pm ***Do we need better questions?***
John DeJose, Malleefowl Preservation Group; Member National Malleefowl Recovery Team

1.50pm Questions

2.00pm ***Applying adaptive management techniques to ongoing management of the mallee***
Dr Cindy Hauser, Melbourne University; Member National Malleefowl Recovery Team

2.15pm ***Analysing the effects of ongoing and historical fox control on Malleefowl population viability***
Dr Cindy Hauser, Melbourne University; Member National Malleefowl Recovery Team

2.30pm ***Camera trapping analysis of mallee wildlife***
Rosanna van Hespen, Melbourne University

2.40pm ***What's going on in the mallee? Constructing competing models of mallee ecosystem dynamics and using expert knowledge to decide between them***
Dr Michael Bode, Melbourne University; Member National Malleefowl Recovery Team

3.00pm Questions

Chair: Peter Stokie, Chair National Malleefowl Recovery Team

3.10pm **_A brief history of Malleefowl conservation and monitoring efforts in the Goonoo forest_**
Alison Towerton, University of Sydney

3.30pm Afternoon tea

3.50pm **_Malleefowl activity at nesting sites increase fox and other feral animal visitation rates_**
Dr Milton Lewis, Central Tablelands Local Land Services; Member National Malleefowl Recovery Team

4.05pm **_Feral Goat removal to restore habitat quality within Malleefowl nesting areas in the western rangelands of New South Wales_**
Dr Milton Lewis, Central Tablelands Local Land Services; Member National Malleefowl Recovery Team

4.20pm Questions

4.30pm **_Forum Wrap-up – how it all fits together_**
Dr Joe Benshemesh, Member National Malleefowl Recovery Team

4.50pm **_Official Close_**
Sharon Gillam, Chair National Malleefowl Recovery Team

5.00pm **_Directions for National Malleefowl Recovery Team Meeting and Field Trips_**
Melanie Bannerman, Member National Malleefowl Recovery Team

5.15pm **_National Malleefowl Recovery Team Meeting – Zoo Friends Room_**
Sharon Gillam, Chair National Malleefowl Recovery Team

Monday 15th September

Field Trips

7.00am – 12.00pm **Goonoo National Park bird watching and wildflowers**
Meet at Dubbo Visitor Centre carpark 6.30am

7.00am – 6.30pm **Pilliga Discovery Tour**
Meet at Dubbo Visitor Centre carpark 6.30am

9.00am – 11.30am **Behind the Scenes Tour, Taronga Western Plains Zoo**
Meet at Savannah Room, TWPZ 8.45am

2.30pm – 5.00pm **Behind the Scenes Tour, Taronga Western Plains Zoo**
Meet at Savannah Room, TWPZ 2.15pm

5th NATIONAL MALLEEFOWL FORUM

PRESENTATIONS – ORAL

1. Welcome

Sharon Gillam, Chair, National Malleefowl Recovery Team; Department of Environment, Water and Natural Resources South Australia

On behalf of the National Malleefowl Recovery Team and the Forum Organising Committee, I would like to welcome everyone to the fifth National Malleefowl Forum.

In the words of Harold Frith, "The Malleefowl is unique to Australia, and one of the continent's wonders." It is through the pioneering work of Frith in the 1950's, who studied this unique species and brought to light the strange, hardworking life of the Malleefowl and the threats it was facing then in the 1950's, that has over time endeared us to this amazing bird and given reason to promote the conservation of this species across the southern half of the country.

We have come a long way since Frith's work some 60 years ago, with more pioneering studies undertaken, the formation of a national recovery team in the late 1980's, and eventually a national recovery plan. At the same time, community groups have also come together to promote the cause of the Malleefowl, ranging all the way through Western Australia to Victoria. The 1000's of hours that are collectively contributed each year by volunteers alone are a tribute to their dedication to the bird's ongoing preservation.

Previous national forums have been held in Adelaide, South Australia (1995), Mildura, Victoria (2004), Katanning, Western Australia (2007), Renmark, South Australia (2011), and now Dubbo, New South Wales (2014), with continued and, in many areas, growing support for the Malleefowl shown across the breadth of its range. The progress over the last three forums in particular has been significant, particularly through the successful acquisition of a number of Commonwealth and state-funded grants, and more recently, through offset funding via a mining company. Important achievements during this time include a well-established national monitoring system complimented by a national monitoring manual, and a formidable national Malleefowl monitoring database which continues to be improved. These two initiatives have formed the basis for an Adaptive Management Framework, which has gained considerable momentum since the 2011 Forum with funding achieved through an ARC Linkage Grant. Two other noteworthy initiatives are the successful re-establishment of the national Malleefowl newsletter, Around the Mounds, and our very first part-time paid National Malleefowl Recovery Program Coordinator, which came into fruition in April 2013. During the course of this weekend, many of these initiatives will be described in more detail to give you a better understanding of how they are contributing to the conservation of Malleefowl.

At a national level, the Malleefowl is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation* (EPBC) *Act* 1999, and is recognised as threatened in all the States in which it occurs. The species is threatened by a range of factors, with loss and fragmentation of habitat a major contributor to small and isolated populations. Extensive monitoring of Malleefowl populations over the last few decades has shown declines across SA, Victoria and NSW. As with many threatened species, populations are continuing to decline, ranges are contracting, and threats are increasing, calling for immediate management actions to preserve them. Whilst we continue to improve our understanding of ecosystems and species, there are still many information gaps and uncertainties in exactly how these systems work and the threatening processes that impact upon them, leading scientists and managers to be unsure of what needs to be undertaken to preserve them. The Adaptive Management Project offers a solution to this dilemma through a more formal process of mathematical techniques that assists managers to experiment with and learn from their management while keeping the goal of conservation firmly in sight. The Adaptive Management Project features in the forum program on Sunday, where we will learn more about how this process can provide an effective way forward for Malleefowl conservation and management.

Around the states various programs and projects are being conducted by agencies, landholders and community groups, often working cooperatively together, with current knowledge and technologies that are available, and often limited resources, on recovery actions that in some way aim to provide benefit to Malleefowl. We will hear today through our state-wide updates and other presentations throughout the weekend, exactly what some of these programs and projects are and what they involve.

Our interest in conserving Malleefowl has brought us together and provides an opportunity for community groups, conservation agencies, industry and interested individuals to hear the latest updates on research, technologies and conservation activities, as well as discuss strategies and actions to further progress the cause of Malleefowl conservation. Overall the forum will hopefully provide motivation to continue in the work that we do, provide inspiration to look at and tackle new ways to help this species, and provide an avenue to meet new people and catch up with others, who have a shared interest in this special bird.

I would like to thank Tim Burnard and Melanie Bannerman for coordinating our fifth National Malleefowl Forum, and for putting together a wide-ranging program, that will have something of interest for everyone.

2. Introduction to the National Forum

Joe Benshemesh, Member National Malleefowl Recovery Team; Tim Burnard, National Malleefowl Recovery Program Coordinator

Abstract

Malleefowl are special birds: universally loved and admired for unique and bizarre habits and their unexpectedly confiding nature. This fifth Forum attendance demonstrates the enduring interest from community, industry and government that has driven great advances in Malleefowl conservation over the past decade or so. Also evident is how far we have come. We have seen a shift from looking at data from small scale studies with little knowledge of how most populations were going, to a large scale monitoring program with over 120 sites scattered across the nation, annually 'taking the pulse' of the Malleefowl populations. Monitoring is now core business for the recovery team and the large and committed army of volunteers that undertake this essential activity.

Monitoring a threatened species is fundamental to recovery but our monitoring is also now forming a basis for our Adaptive Management Project, making the best use of the data in what is essentially annual analysis of the highest order. This is a grand undertaking in evidence-based citizen-science that we should be proud of, and the surest way to build our understanding of how to conserve Malleefowl.

Presentations to this forum will of course cover various aspects of monitoring: its achievements, tools, and value-adding fruits, such as the Adaptive Management Project. But even more is on offer at this forum. The organisers have assembled a stimulating and varied program covering genetics, evolution, aboriginal involvement, new survey techniques and threats to Malleefowl survival.

A quick glance at the program will show a variety of subjects and issues from across Australia, sometimes as seemingly disconnected actions. The National Recovery Team is guided by the National Recovery Plan. It is the task of the Recovery Team to ensure (wherever possible) that actions taken are guided by the Recovery Plan. We believe that all delegates here will see how the presentations delivered tie in to a grand plan for species survival.

Indeed, the program shows that great advances are underway in Malleefowl conservation and understanding. While we can't guarantee that every threat will be removed (such as climate change) we can, and demonstrably are, organising ourselves to be in the best position to identify and mitigate threats wherever they occur.

Introduction

Malleefowl are special

Malleefowl are special birds: universally loved and admired for unique and bizarre habits and their unexpectedly confiding nature. Many of us here today have a good understanding of what makes Malleefowl particularly special, but there are some newcomers to the Malleefowl family that may benefit from a quick recap.

Perhaps the most striking thing about our birds is their nests; the mounds. While there are three megapodes in Australia that use mounds to incubate eggs (rather than sitting on eggs), only the Malleefowl does this in the arid zones. This makes the job particularly complicated because the rotting of moist compost that creates the warmth required to hatch an egg, cannot be relied upon in the drier areas of Australia. This means that Malleefowl have to constantly measure the temperature inside the mound and make adjustments to keep the mounds at around 35 degrees.

In the early stages of incubation heat from the compost is too great for incubation and mounds are opened to allow heat to disperse but as the compost dries, the birds must use heat from the sun to warm the nest. This requires the movement of about a cubic metre of matter some days, amounting to the movement of maybe one or two hundred tonnes of material each breeding season. Because of this, Malleefowl are considered to be the hardest working birds in existence.

This leads to the next remarkable thing; Malleefowl are loved by humans. Perhaps this was emphasised in the early European pioneering days when new settlers to the mallee saw a bird working as hard as themselves.

Added to this already strong impression of how special Malleefowl are, we will hear from **Walter Boles** later today with a talk titled 'A brief history of megapodes through time'. This insight is bound to impress that Malleefowl are from truly amazing stock and definitely warrant the interest they garner.

Updates on the activities by the Victorian Malleefowl Recovery Group (VMRG), Malleefowl Preservation Group (MPG), North Central Malleefowl Preservation Group (NCMPG), Western Australian Malleefowl Network, NSW Office of Environment and Heritage (OEH) and South Australian Department of Environment, Water and Natural Resources (DEWNR) and attendance at this forum demonstrates the enduring interest from community, industry and government that has driven great advances in Malleefowl conservation over the past decades. **Sally Cail, John DeJose, Melanie Bannerman, Sharon Gillam, Peter Stokie** and **Blair Parsons** will each be presenting summaries of progress by their organisations after morning tea. We'll also be hearing from **Stephanie Mitchell** from Iluka mining about how her organisation has provided funds for Malleefowl recovery and conservation and set a high bar and a valuable model for offset programs.

Malleefowl as a threatened species

There are many classifications for threatened species used in Australia's states and territories. Malleefowl are listed nationally as Vulnerable; Endangered in New South Wales and Victoria; Critically Endangered in Northern Territory; Vulnerable in South Australia and 'Fauna That Is Rare or Is Likely to Become Extinct' in Western Australia.

Malleefowl are found in semi-arid to arid shrublands and low woodlands, especially those dominated by mallee and/or acacias. A sandy soil and abundance of leaf litter are required for breeding. Densities of the birds are generally greatest in areas of higher rainfall and on more fertile soils where habitats tend to be thicker and there is an abundance of food plants. Much of the best habitat for Malleefowl has already been cleared or has been modified by grazing by sheep, cattle, rabbits and goats.

The species has been shown to be highly sensitive to grazing by sheep, and is probably similarly sensitive to grazing by other introduced herbivores. The effect of fire on Malleefowl is severe, and breeding in burnt areas is usually reduced for at least 30 years. Predation, especially by the introduced fox, may also be limiting the abundance of Malleefowl and in many areas might be a cause of decline. The degree of fragmentation of the remaining Malleefowl habitat is of particular concern and presents a major limiting factor to halting and reversing the decline of the species.

We will be hearing from several speakers over the next two days with information on threats to Malleefowl and how we best deal with them. **Marc Irvin** will talk about the Save Our Species program in NSW. **Jemima Connell** from Latrobe University will present on outcomes from the Mallee Hawkeye Project on the relationship to fire, a threat that jeopardises a range of species and habitats and requires skilful management and politics. **Alison Towerton** will present on Malleefowl conservation work in Goonoo forest, **Milton Lewis** is talking about the impressive work on goat control in the Mount Hope (NSW) region. We will also hear from **Geoff Allen** who will look at ways of identifying where linkages in the landscape may be most cost effective and beneficial to Malleefowl.

The National Malleefowl Recovery Team and the Recovery Plan

While there has been strong interest in Malleefowl for a century or more, this was limited to various individual studies and an uncoordinated approach to their survival. The National Malleefowl Recovery Team was convened in 1989 to address this problem.

The National Malleefowl Recovery Team has members representing a wide range of interests. This includes farmers, scientists, community groups and government agencies. There are members from the Australian Capital Territory, New South Wales, South Australia, Victoria and Western Australia. The Recovery Team's main role is to coordinate and prioritise actions across the range of the species.

It is important to recognise that the National Recovery Team is not alone in the fight to save Malleefowl. As can be seen here today, there are many players involved. What the National Recovery Team seeks is to ensure there is a unified approach. Our main tool in achieving this is the National Recovery Plan.

The Recovery Plan sets out the actions necessary to stop the decline of, and support the recovery of Malleefowl and aims to maximise the long term survival in the wild of the species. A little later in the forum **Tim Burnard** will look more closely at the Recovery Plan and how we are progressing toward achieving our objectives.

It is fair to say that the National Recovery Team doesn't play a hands-on role with a lot of the work that is undertaken to protect Malleefowl: the Recovery Team has neither the authority nor the means to undertake land management. What the Recovery Team can do is advise on what actions are needed using the most reliable information available. This includes actions like habitat protection and restoration, predator and pest animal control and much more. There are so many on-ground actions needed across so many land management jurisdictions that the Recovery Team can only provide general guidance.

Over the next two days we will hear of some of these on-ground actions. They will provide an idea of how much is being done by so many agencies and individuals, while noting that this is just the tip of the iceberg. This raises another important issue and role of the Recovery Team, which is in bringing together the many people involved in on-ground actions so that we can all learn from each other to reap the benefits of cooperation in obtaining, testing and distributing knowledge, and maintaining high standards in management and research.

Another basic function of the Recovery Team is to communicate the national effort to the Malleefowl family at a national level. Our two main instruments in achieving this are the national newsletter, 'Around the Mounds' which is produced and distributed twice a year and the national website. You will find the web address on the magnet in your forum 'show bag' and you can be included on the mailing list for 'Around the Mounds' via the website or for people without web access by forwarding your details to Tim or Sharon.

Monitoring Malleefowl and the Adaptive Management Project

With any threatened species we want to know how they are going. Are numbers increasing or declining? What are the long term trends in populations? Are we approaching a crisis point? Do we need to take emergency actions?

In the case of the Malleefowl, the best way of doing this is to monitor mounds. If mounds are active then we expect breeding to be occurring and this is a good sign. If no mounds are active we become particularly concerned and look for reasons why. Without monitoring we have no idea how the birds are faring in the wild. Nor can we measure the success or otherwise of management actions, or hope to understand where or why populations in one area may decline whereas others increase. In short, without monitoring we would be running blind.

Monitoring may not seem as 'proactive' as getting out there and killing ferals or revegetating scrub, but it is essential.

So regardless of anything else…we must monitor! With a species that crosses state and territory boundaries, an activity such as monitoring needs to be undertaken on a national scale. Monitoring is now core business for the Recovery Team and the large and committed army of volunteers that undertake this essential activity. Without you, we simply would not be able to do it! Your collective efforts are essential to the steady stream of monitoring data we rely on.

Technology moves at a rapid pace and there have been a number of great steps toward improving Malleefowl monitoring since the last forum. This includes exciting new search methods like LiDAR, which will be discussed by **Vi Saffer** from Umwelt Pty Ltd, and photogrammetry which will be introduced by **Julia Spark** from Aerometrex. These are stunning technologies that offer great promise in Malleefowl conservation: they have the potential of not only locating mounds, but also of describing the structure of habitats that are important to Malleefowl. **John Read** will also talk about a comparison of survey techniques such as LiDAR and ground searches on the Eyre Peninsula.

Joe Benshemesh will be talking on new use of cameras in the field and **Rosanna van Hespen** will talk about how we analyse this data.

And it's not all about improved technology. Our methodology for monitoring is also improving and evolving, as is our reach into arid Australia where Malleefowl occur over vast areas but at very low densities. **Adam Pennington** and **Liam Mulcahey** will talk about the significance of Malleefowl to the Spinifex People of the Great Victoria Desert and how work on the species has benefited local communities while providing valuable insights into the distribution of Malleefowl in the arid zone. **Joe Benshemesh** and his Aboriginal colleagues from the Maralinga Lands will talk about new understanding in methods for gathering information on indigenous lands.

Another example of how monitoring can be used to better understand Malleefowl survival will be presented by **Chris Hedger** in a comparison of breeding success and monitoring results in the Murray–Darling Basin.

The National Malleefowl Monitoring Database is evidence of how far we have come in the last few years. We have seen a shift from looking at data from small scale studies with little knowledge of how most populations were going, to a large scale monitoring program with over 120 sites measuring over 3000 mounds scattered across the nation, annually 'taking the pulse' of the Malleefowl populations.

Monitoring is all recorded in the national database and managed on a national level however, input into the national database is not an end to the process. When information is fed into the database, it doesn't just sit there as a lovely set of numbers. It is accessible to all contributors and now forms the foundation to the Adaptive Management Project.

The Adaptive Management Project is being conducted by a team from Melbourne University in conjunction with the National Recovery Team and Parks Victoria with the assistance of land managers from all states. As the Adaptive Management Project starts to deliver answers, these will be shared with land managers across Australia as guidance for on ground works.

While the building of the national database is an example of a really impressive collaboration it will be surpassed in scale by the Adaptive Management Project. This is a massive undertaking. In order to truly understand which of the threats to Malleefowl are most important to address, the Adaptive Management Project has set a goal of establishing some twenty sites across Australia to conduct experiments. Each of these sites requires land managers to identify sites of around several thousand hectares with nearby control sites of similar size and then record outcomes for several years for each experiment. The first of this round of experiments are already being organised and will be using outcomes from fox control programs. The project is likely to be continuing for many years to come.

We will hear a lot more detail on the national database and the Adaptive Management Project in tomorrow's presentations by **Michael Bode** and **Cindy Hauser** from Melbourne University.

Aims of this Forum

Another activity defined in the Recovery Plan is to conduct a national forum every three years. One of the greatest challenges for a threatened species with a range that extends across the nation is to unify the actions that are taken by four state governments, several non-government agencies and hundreds of individuals. The national forum is considered an important step in obtaining the unified approach needed.

The forum is also the perfect time to introduce new information that is of interest to all of us working with Malleefowl. **Taneal Cope's** presentation on genetics of Malleefowl is a great example of this. This sort of research is essential to our overall understanding of Malleefowl and is relevant to all future discussion on Malleefowl conservation. Taneal has a fascinating story to tell, the result of many years of research in the field and in the lab. Understanding the genetic structure of Malleefowl populations is essential for management, especially for considerations of supplementing populations with birds from other areas and from captive breeding programs, actions that could do more harm than good if genetics is not understood.

While breed-for-release programs involving captive Malleefowl are less popular now than they were in the past, the issues of translocation are still relevant. **Paul Andrew** will be leading a discussion later today on a legacy issue facing the Taronga Western Plains Zoo: what to do with offspring from the 16 Malleefowl that remain at the zoo?

The forum program shows that great advances are underway in Malleefowl conservation and understanding. While we can't guarantee that every threat will be removed (such as climate change) we can, and demonstrably are, organising ourselves to be in the best position to identify and mitigate threats wherever they occur.

Finally, this forum is the once in a three year opportunity for everyone who cares about Malleefowl to come together, catch up with old friends, make new ones and enjoy the camaraderie of a group with a unified concern.

3. How we have progressed as measured against the National Recovery Plan for Malleefowl and Resolutions from Renmark

Tim Burnard, National Malleefowl Recovery Program Coordinator

Abstract

This presentation will provide an update on Recovery Team progress toward objectives detailed in the National Malleefowl Recovery Plan as well as resolutions determined at the 2011 Renmark National Malleefowl Forum.

It is generally recognised that best business practice requires a business plan to guide an organisations direction forward. In the case of the National Malleefowl Recovery Team, the Recovery Plan fills this purpose. In the Recovery Plan, we have 16 objectives, each with a number of proposed actions. The National Forum is an ideal opportunity for the Recovery Team to report to the broad Malleefowl community on how we are progressing toward achieving these objectives.

Introduction

In this presentation I will provide a brief update on our progress toward objectives detailed in the National Malleefowl Recovery Plan as well as resolutions determined at the 2011 Renmark National Malleefowl Forum.

It is generally recognised that best business practice requires a business plan to guide organisations. In the case of the National Malleefowl Recovery Team, the Recovery Plan fills this purpose.

When reporting on our progress against all of the plan's objectives we need to keep in mind that the objectives are not just the responsibility of the Recovery Team. Malleefowl recovery is a task that involves a huge effort from many agencies and organisations across Australia. The current political climate is such that environmental issues are seen as a lesser priority by all governments in terms of funding and resources than was the case three years ago. Also, it is important to recognise that most of the objectives are the responsibility of individual states, but in every case, the states have experienced a reduced capacity to deliver outcomes and report on them. Because of this reduced capacity to report, many of the outcomes discussed below are assumptions rather than fact.

We need to also be mindful that a Recovery Plan describes the actions needed to take a species from a threatened status to non-threatened. This requires a massive effort and in the case of Malleefowl it requires a massive effort in five states and territories (NSW, VIC, SA, NT and WA). Achieving some of the objectives, for instance increasing net available habitat, are nigh on impossible but that doesn't mean we won't recognise the needs and strive toward them.

Summary of Recovery Plan

The Recovery Plan has an overall objective to "Down-list Malleefowl from Vulnerable to a lower category based on IUCN criteria"

With two Recovery Criteria to measure success:

- Breeding densities remain stable or increase above those at present over a ten-year period or three generations (whichever is longer) at a representative sample of at least 40 monitoring sites across the species' range. These monitoring sites should be located in representative habitats in both large and small (<5,000 ha) habitat fragments.
- The existing distribution is shown to be stable or increasing over a ten-year period or three generations (whichever is longer).

Following the criteria we have 18 Specific Objectives, under three broad headings:

- *Managing populations*
- *Planning, research and monitoring*
- *Community involvement and project coordination.*

and each of these objectives has one or more performance criteria and actions. The objectives are:

Managing populations

1. Reduce permanent habitat loss
2. Reduce the threat of grazing pressure on Malleefowl populations
3. Reduce fire threats
4. Reduce predation
5. Reduce isolation of fragmented populations
6. Promote Malleefowl-friendly agricultural practices
7. Reduce Malleefowl mortality on roads

Planning, research and monitoring

8. Provide information for regional planning
9. Monitor Malleefowl and develop an adaptive management framework
10. Determine the current distribution of Malleefowl
11. Examine population dynamics: longevity, recruitment and parentage
12. Describe habitat requirements that determine Malleefowl abundance
13. Define appropriate genetic units for management of Malleefowl
14. Assess captive breeding and re-introduction of Malleefowl
15. Investigate infertility and agrochemicals

Community involvement and project coordination

16. Facilitate communication between groups
17. Raise public awareness through education and publicity
18. Manage the recovery process.

Summary of Resolutions from the 2011 National Malleefowl Forum

At the conclusion of the 2011 National Malleefowl Forum, a review of discussions and presentations was conducted. A list of Resolutions was drawn up from this review. They are:

Managing Populations

1. Seek opportunities to identify, protect, improve, and re-establish large areas of contiguous habitat for Malleefowl over the long term (under the Malleefowl Adaptive Management Framework).

Planning and Monitoring for Recovery

2. Collate a list of priority research questions to guide the recovery effort and engage others.
3. Secure funding to ensure the uploading and analysis of WA community data is equal to the rest of the country.
4. Secure funds and implement a national Malleefowl Adaptive Management Framework (MAMF) for national Malleefowl conservation recovery.
5. Establish a national fire project under the auspices of the Recovery Team (and MAMF) to consolidate existing information/learning including available traditional burning knowledge, identify priority applied research and opportunities to learn i.e. on the back of government prescribed burning programs and stimulate further research and funding.
6. Seek funding to appoint a National Malleefowl Recovery Coordinator that reports to the National Recovery Team to drive the application of the MAMF, supports national coordination, drives the Plan’s implementation, supports and recruits database coordinators and seeks additional funding for Malleefowl conservation nation-wide.
7. Prioritise Recovery Team activities and national reporting to be more closely aligned to the national Recovery Plan.

8. Reinstate ‘Around the Mounds’ (or equivalent) to provide project updates, monitoring feedback and show how data is applied to achieve recovery to the Malleefowl conservation community in particular volunteers – suggestions received this could be achieved by a newsletter or national website.
9. Convene a national remote camera (web cam) working group under the auspices of the Recovery Team to look at existing use, best opportunities to use the technology to further recovery and to establish guidelines for use with minimal impacts on the birds.

Engaging communities

10. Establish under the national database a database of interested individuals, volunteer groups and their activities so that groups can better share information and promote their volunteer opportunities.
11. Pursue options for links with volunteer organisations to increase access to volunteers particularly for low populated regional areas e.g. city, scouts, CVA.
12. Secure resources to enable a further print run of the VMRG Malleefowl Education Kit in a format that can be distributed to other regions.
13. Follow up on the Regional NRM Malleefowl Guide and establish working partnerships with all key NRM/CMAs across the Malleefowl’s range.

Results of review

In this review I have combined the 18 Recovery Plan objectives, the respective performance criteria and the 13 Resolutions from 2011. Specific actions have not been included. Each Recovery Plan objective also has the results from the 2011 review conducted by Peter Copley and presented at the 2011 National Malleefowl Forum to allow a quick reference to our progress since 2011.

Managing populations

Performance Criteria: P1.1 The total area of Malleefowl habitat protected in reserves, conservation covenants and similar management agreements, increases over the life of the plan.

From the 2011 review. This increase in protection appears to have occurred in WA, SA, Victoria and NSW. For example, in Victoria there have been several private properties with new conservation covenants. However, no statistics have been collated to demonstrate the extent to which this has occurred, either in total, or by reserve type.

2014 Comment: It is likely that the area in reserves, conservation covenants and similar has increased simply because we are unaware of any losses whilst being aware of some increases. However, there has been no attempt to document this. This is perhaps understandable because it would require gathering data on all new reserves, covenants, etc. and then going over each one to determine if they contain Malleefowl habitat and how much. At this stage the Recovery Team lacks the resources to undertake this work.

Performance Criteria: P1.2 No decline in the known area of occupied or mapped potential Malleefowl habitat over the life of the plan.

From the 2011 review. There does not appear to have been any collation of data on loss of known or suspected Malleefowl habitat since the recovery plan was first drafted (or over any time-frame for that matter). The data almost certainly exist in people's heads or various databases, and it should be possible to report against this target. A start year and baseline measure would need to be agreed upon as a starting point.

2014 Comment: To establish this, a baseline is required detailing what area is occupied or mapped as potential Malleefowl habitat, and this does not exist. Following the establishment of a baseline, extensive survey work would be required and at this stage the Recovery Team lacks the resources to undertake this work. There has almost certainly been a decline because we know that clearing continues.

Performance Criteria: P2.1 Goat and sheep are removed or in low numbers in conservation reserves.

From the 2011 review. While there has been some goat control work on Gluepot Reserve in South Australia, there are many areas within the Malleefowl range where feral goats are an ongoing issue. Feral deer are also an increasing problem in a few conservation reserves. While there are feral goat (and deer) control programs in conservation reserves in each state, the outlook for ongoing and improved levels of control does not look positive.

2014 Comment: There are very good examples where goats have been removed in reserves and attempts to control them have taken place over the past three years e.g. in Mount Hope (NSW) region and numerous reserves in SA. As for recording and reporting this, it is considered a possibility but has not been done across the total Malleefowl range. The Recovery Team lacks the resources to undertake this work but would be keen to obtain data where it already exists.

Performance Criteria: P2.2 Artificial sources of water in conservation reserves are closed or fenced.

From the 2011 review. Closure of artificial waters has happened in a major way on Gluepot and on Calperum and Taylorville Reserves in South Australia and more water closures are proposed on the latter two properties. Similar actions have occurred through the closure of irrigation channels as a result of the Wimmera / Mallee pipeline project.

2014 Comment: There are examples of where this work continues but again, there has been no national recording and at this stage the Recovery Team lacks the resources to undertake this work.

Performance Criteria: P2.3 The area of known Malleefowl habitat protected from stock grazing (e.g. through fencing) increases over the life of the plan.

From the 2011 review. Significant areas of Malleefowl habitat continue to be fenced as part of various national and state funding schemes. However, as for many other objectives in this plan, there are no readily available statistics to report on the scale of this activity.

2014 Comment: There are examples of where this has been achieved but again no national recording. The Recovery Team lacks the resources to undertake this work but would be keen to obtain data if it is available.

Performance Criteria: P2.4 Rabbit numbers are reduced where they are abundant in or near Malleefowl habitat.

From the 2011 review. There does not appear to have been any significant action on this objective and, in fact to the contrary, recent rabbit population increases after the good rains over much of the Malleefowl range are likely to have negated any such works many times over. It seems unlikely that reduction of rabbit numbers is a sustainable activity at the scale of areas required to support viable Malleefowl populations. However, strategic rabbit control efforts around a selected number of active Malleefowl 'nesting territories', or broad-scale control in selected years may be adequate to encourage increased recruitment of Malleefowl.

2014 Comment: This work is assumed to continue in many reserves and on private land but again no national recording and at this stage the Recovery Team lacks the resources to undertake this work.

Performance Criteria: P3.1 Fire management plans which consider the habitat requirements of Malleefowl are developed and implemented for all reserves in which Malleefowl occur.

From the 2011 review. Increasing numbers of fire management plans are being prepared for areas/reserves occupied by Malleefowl and most of these plans do address issues of risk to Malleefowl. However, the implementation of these plans, especially where pro-active habitat protection burns are proposed, does not occur in many areas or very often. An example of where such plans are implemented for the protection of Malleefowl habitat is the South East of South Australia. The assessment of achievability (above) is based on the likelihood of resources being provided to implement the conservation-based actions for at least half of the fire management plans for reserves where Malleefowl are known to occur over a 5-year period. In fact, the Victorian Malleefowl Recovery Group has concerns that annual prescribed burn targets, for example in Little Desert National Park (Victoria), has very little unburnt habitat left, yet is a park with ongoing prescribed burn targets.

2014 Comment: Fire management plans are in place for many areas/reserves occupied by Malleefowl and most of these plans do address issues of risk to Malleefowl. However it appears that in Vic and NSW at least, environmental outcomes are eclipsed by government policies to burn areas based on area targets and asset protection. This goal is also severely impacted by increased wildfire e.g. in the Victorian and SA Mallee during the 2013 summer. There has been no attempt to establish if all relevant reserves are covered by these plans and at this stage the Recovery Team lacks the resources to undertake this work.

Performance Criteria: P3.2 Broad-scale agricultural burning is reduced in areas that harbour Malleefowl.

From the 2011 review. It is not clear where this is an issue and who needs to address it.

2014 Comment: The practice of broad-scale agricultural burning in areas that harbour Malleefowl is no longer promoted and thus not thought to threaten Malleefowl habitat in the form of bushland on private land. There has been no attempt to establish if all relevant reserves are covered by these plans and at this stage the Recovery Team lacks the resources to undertake this work.

Performance Criteria: P3.3 Fires in Malleefowl habitat are mapped and their effects monitored to inform future planning.

From the 2011 review. Fire-scar mapping data are now very good in each jurisdiction. However, not all Malleefowl habitat has been identified and mapped in each state and the effects of mapped fires on Malleefowl and their habitat are seldom monitored. The fire data exist; the Malleefowl habitat data either exist or could be extrapolated. However, analyses of spatial and temporal effects of fires on Malleefowl are not undertaken. The point is, the analyses could be done.

2014 Comment: Fire mapping does occur and often of high quality. Mapping this against Malleefowl habitat is not done. At this stage the Recovery Team lacks the resources to undertake this work, however it is anticipated that the Adaptive Management Project will include fire in future experiments and analyses.

Forum Resolution 5. Establish a national fire project under the auspices of the Recovery Team (and MAMF) to consolidate existing information/learning including available traditional burning knowledge, identify priority applied research and opportunities to learn, i.e. on the back of government prescribed burning programs, and stimulate further research and funding.
2014 Comment: This project was considered to be over ambitious for the Recovery Team. There are a number of projects being conducted (Western LLS and Hawkeye are two) and the Adaptive Management team will be including fire as a future component in experiments.

Performance Criteria: P4.1 Fox control efforts are adequately documented near monitoring sites.

From the 2011 review. Fox-baiting data are now recorded in a more systematic manner where this activity occurs on, or in the vicinity, of Malleefowl monitoring sites. However, there is considerable room for improvement, especially in terms of working this in with an active Adaptive Management monitoring program. This is still proposed for the near future. As the VMRG point out, there is also a need to coordinate any baiting programs across neighbouring properties to improve efficacy and efficiency.

2014 Comment: Documentation occurs at most reserves near monitoring sites but is not gathered nationally and at this stage the Recovery Team lacks the resources to undertake this work at a national scale. However, there will be an increased data gathering effort at Adaptive Management sites as experiments progress.

Performance Criteria: P4.2 Fox numbers are reduced where Malleefowl show decline and fox predation is a likely explanation for this decline.

From the 2011 review. This objective is still difficult to define realistic activities and targets for. The active Adaptive Management Project aims to clarify these issues.

2014 Comment: The link between fox control and Malleefowl trends has recently been shown to be very weak, but nonetheless the issue is now being thoroughly examined by carefully designed experiments in the Adaptive Management Project. We expect the results from the Adaptive Management experiments to clarify this issue, and these experiments will involve increased fox control in many areas. Until these results are available and in light of recent studies, there is little justification for wide scale fox control to conserve Malleefowl.

Performance Criteria: P5.1 Habitat links between remnants are increased in priority areas as identified in regional Malleefowl conservation plans.

From the 2011 review. This objective does not appear to have been addressed.

2014 Comment: There are several examples of this occurring e.g. in the Mount Hope region (NSW), Gondwana link (WA), Habitat 141 (Vic/SA). Establishing the criteria for prioritised links will also be informed by work being presented at the 2014 Forum from the project conducted by Geoffrey Allen and Ian Sluiter.

Forum Resolution 1. Seek opportunities to identify, protect, improve, and re-establish large areas of contiguous habitat for Malleefowl over the long term (under MAMF).
2014 Comment: There have been some significant steps in this direction (Western LLS and Gondwana link are mentioned).

Performance Criteria: P6.1 Increased adoption of asynchronous fallowing by farmers in areas adjacent to Malleefowl habitat.

From the 2011 review. There does not appear to have been any strategic action on this objective. However, there are isolated examples of farmers who do consider the needs of Malleefowl, when they are working in paddocks adjoining known Malleefowl habitat.

2014 Comment: Unaware of a strategic approach to this but know that some farmers adopt this approach. There is no national recording and at this stage the Recovery Team lacks the resources to undertake this work.

Performance Criteria: P7.1 Occurrence of road kills is recorded each year, patterns analysed and frequency reduced.

From the 2011 review. While there have been EPBC Act conditions placed on proposed road upgrade developments likely to increase risks of road mortalities of Malleefowl, no systematic recording system has been established to monitor road kills and, as such, there are no data to analyse for patterns.

2014 Comment: This does happen at some sites e.g. mines and the importance is discussed by NCMPG in their poster presentation at the 2014 Forum. There is no national recording and at this stage the Recovery Team lacks the resources to undertake this work.

Performance Criteria: P7.2 Signs are erected where needed to warn drivers that Malleefowl may be on the road ahead.

From the 2011 review. A few road signs have been erected in South Australia, Victoria and Western Australia but there has been no monitoring of their effectiveness. While there are several further areas where more signs could be erected, it would seem prudent to assess their usefulness and to determine site priorities.

2014 Comment: Certainly this does happen (note the prompt signage response to canola spills that attracted Malleefowl to roadsides near Ouyen in 2013) but others that have been proposed (Eyre Peninsula) are yet to be achieved.

Planning, research and monitoring

Performance Criteria: P8.1 Regional conservation plans for Malleefowl are prepared.

From the 2011 review. In early 2008, Joe Benshemesh's "Advice to Regional Natural Resources Management Bodies regarding Management and Monitoring of Malleefowl" for each of the 15 NRM and CMA regions across the Malleefowl's range was printed and forwarded to contacts in each of these regions. While there have been no regional conservation plans prepared for Malleefowl, per se, there have been increasing incidences of the National Recovery Plan and the National Monitoring Manual being used as a basis for more localized management plans – especially, associated with new mine site operations.

2014 Comment: Partially achieved with the 2008 'Advice to Regional Natural Resource Management Bodies regarding Management and Monitoring of Malleefowl', local plans are not in place across the range. This is considered a task for the national coordinator as relationships are developed with NRM agencies across the Malleefowl range.

Forum Resolution 13. Follow up on the Regional NRM Malleefowl Guide and establish working partnerships with all key NRM/CMAs across the Malleefowl's range.
2014 Comment: There are already close relationships with a number of NRM (note that Western LLS are a sponsor of the Forum). This is especially so in SA and Vic where NRM agencies fund the National Coordinator position. National Coordinator is working to include all NRMs in monitoring.

Performance Criteria: P9.1 Monitoring data is analysed and reviewed and national Adaptive Management design is developed through collaboration by 2008.

From the 2011 review. Monitoring data for Victoria and South Australia have been reviewed and analysed and more data from Western Australia and New South Wales have been reviewed and are gradually being incorporated into the national database in readiness for development of the Adaptive Management Project. The ARC Linkage Adaptive Management Project has recently been funded by ARC and other partners, so the project can now proceed.

2014 Comment: The monitoring data was initially analysed in 2007 to produce the Trend Analysis paper by Joe Benshemesh. A similar project is currently being undertaken with results expected in 2015. The monitoring database is also being utilised to develop modelling as a foundation for the Adaptive Management Project currently underway.

Performance Criteria: P9.2 Monitoring continues at existing sites across Australia according to national standards, with:

- monitoring completed in each state by 1 February each year (data for each monitoring site recorded as described in manual, entered in database, and provided to Birds Australia in electronic format);
- monitoring data analysed by state and nationally by 31 May each year; and
- summary report distributed to participants by 30 June each year.

From the 2011 review. While the annual time-frames for completion of these tasks are usually later and nearer June, they are up to date for Victorian and South Australian sites. There are still some issues around catch-up for WA and NSW monitoring data. (The database is not managed by Birds Australia). Annual summaries are usually completed by the end of June each year. This is happening reasonably effectively in most areas, with reports distributed to volunteers in Victoria and South Australia, to National Recovery Team members, and to others with an interest through the VMRG web-site and/or in Western Australia, through the Malleefowl Preservation Group's newsletter, Malleefowl Matters. The VMRG also hold an annual reporting-back meeting for their volunteers.

2014 Comment: Results are similar as those discussed in 2011 (above). The work is ongoing with variable outcomes each year depending on available resources. The most notable outcome in past last three years is that all data from WA is now uploaded to the database. New sites are being established. More work is needed to produce timely national annual reports and distribute the information.
Performance Criteria: P9.3 Effectiveness of fox baiting at increasing Malleefowl breeding density is adequately tested.

From the review by PC (2011). Effectiveness of fox-baiting is still to be tested however, this is intended to be a significant aspect of the ARC Linkage Adaptive Management design project.

2014 Comment: As stated in P4.1 and 4.2 (above) the link between fox control and Malleefowl decline has recently been examined and is being even more thoroughly examined by experiments as part of the Adaptive Management Project.

Performance Criteria: P9.4 The Malleefowl monitoring effort is facilitated, standardised and coordinated at a national level.

From the 2011 review. This has been a very significant focus of volunteer groups across the range. States of the Malleefowl, and the level of facilitation and coordination within each jurisdiction is a credit to all involved. However, seamless facilitation and coordination of a standardized approach across four States and many regions remains an issue while there is no national coordinator/facilitator role.

2014 Comment: This remains a core activity for the Recovery Team because the data are essential for understanding threats and the effectiveness of management actions. The outcomes are remarkable for the effort involved. Improvements are expected as increased training such as the recent NCMPG project occurs. There is room for improvement with more work by the National Coordinator required in all states except Victoria where the effort is extremely well managed by the VMRG.

Forum Resolution 3. Secure funding to ensure the uploading and analysis of WA community data is equal to the rest of the country.
2014 Comment: This has been achieved largely through Iluka MMC funds and a grant from Gunduwa RCA. All available WA data has been standardised and is now on the NMMD.

Forum Resolution 4. Secure funds and implement a national Malleefowl Adaptive Management Framework (MAMF) for national Malleefowl conservation recovery.
2014 Comment: Funding for the Adaptive Management Project has been achieved and the project is currently being implemented.

Performance Criteria: P10.1 The distribution and status of Malleefowl in remote areas is clarified and local involvement is encouraged.

From the 2011 review. While there has been some progress on this activity; there are still many gaps in survey coverage.

2014 Comment: Progress has been made in the Maralinga Tjarutja Lands with new monitoring guidelines developed by Joe Benshemesh specifically designed for remote areas. Examples of increased local involvement will be discussed in a presentation by Adam Pennington at the 2014 Forum. Prospects exist for more work through the recently established Great Victoria Desert Biodiversity Trust.

Performance Criteria: P10.2 The distribution and status of Malleefowl in settled rural areas is clarified.

From the 2011 review. There has also been ongoing progress for this activity across much of the Malleefowl's known range, although there are almost certainly sites where Malleefowl are assumed to still occur, but may well now be locally extinct.

2014 Comment: There are still significant gaps in knowledge of distribution and status of Malleefowl in settled rural areas. Large gaps in monitoring in NSW are hoped to be addressed by the National Coordinator over the coming years.

Performance Criteria: P11.1 The feasibility of automatic recorders for identifying Malleefowl is examined and efficient capture techniques are developed, with a report available by 30 June 2008.

From the 2011 review. This action did not eventuate, except through the deployment of trip cameras at nest mounds in a few separate locations.
2014 Comment: Considered a low priority action and no action taken since the 2011 Forum. Developments in camera-traps and genetic 'finger-printing' technology may provide less labour intensive and expensive alternatives to the proposed automatic recorders.

Performance Criteria: P11.2 The longevity of breeding Malleefowl and the turnover of the breeding population is measured for areas with and without fox control.

From the 2011 review. Not implemented.

2014 Comment: Considered a low priority action and no action taken since the 2011 Forum. (see comment at 4.1 & 4.2).

Performance Criteria: P11.3 Recruitment of young into breeding populations is measured for areas with and without fox control.

From the 2011 review. Not implemented.

2014 Comment: Considered a low priority action and no action taken since the 2011 Forum. However recent development in remote camera technology may advance this work.

Performance Criteria: P12.1 The habitat requirements and preferences of Malleefowl are described, critical habitat components are identified, and a habitat suitability model is produced.

From the 2011 review. Not implemented.

2014 Comment: At this stage the Recovery Team does not have the resources to pursue this work however the Adaptive Management Project is expected to address this question at some level.

Performance Criteria: P13.1 Genetic structure of Malleefowl populations is determined at a national level.

From the 2011 review. Taneal Cope's research project addresses this objective; thanks in no small part to all who assisted by collecting feather samples from across the Malleefowl range.

2014 Comment: Anticipate that the work being presented at the 2014 Forum by Taneal Cope will address this objective.

Performance Criteria: P14.1 Past and current translocation, captive-rearing and breeding programs are reviewed; studbook and husbandry manual produced, and the future directions are clarified.

From the 2011 review. Translocation / reintroduction project details have now been published. A stud book and captive-rearing / husbandry manual were prepared as a basis for the re-introduction trials conducted over many years by Priddel and Wheeler (NSW NP&WS). These still need to be revised and made web-accessible. Current captive management within the zoos system should also be reviewed in light of Taneal Cope's research findings on population genetics.

2014 Comment: Translocation, captive-rearing and breeding programs are considered to be a very low priority for the Recovery Team compared to actions such as habitat improvements. This subject will be addressed during the 2014 Forum more by Taronga Western Plains Zoo and SA Zoos presentations.
Performance Criteria: P15.1 The extent of infertility of Malleefowl in small reserves is investigated.

From the 2011 review. Some measures of egg fertility / infertility have been obtained through Taneal Cope's genetics research project and a few other smaller projects monitoring egg-laying and egg-hatching rates in active nest mounds on some monitoring grids.

2014 Comment: The Recovery Team has not had the resources to specifically address this objective however some answers are expected from the presentation by Chris Hedger at the 2014 Forum.
Forum Resolution 2. Collate a list of priority research questions to guide the recovery effort and engage others.
2014 Comment: Considered that relevant research questions are detailed in the Recovery Plan and have been prioritised in the implementation of the Adaptive Management Project, however, a formal prioritised list has not been developed.

Forum Resolution 9. Convene a national remote camera (web cam) working group under the auspices of the Recovery Team to look at existing use, best opportunities to use the technology to further recovery and to establish guidelines for use with minimal impacts on the birds.
2014 Comment: The rate of technology overtook the need to have a working group to look into this. Before we knew it, everyone was using cameras. Joe Benshemesh will be talking about camera work and how he has developed a process that involves volunteers at this 2014 Forum.

Community involvement and project coordination

Performance Criteria: P16.1 A national Malleefowl community forum is held every three years and the national newsletter continues to provide a national perspective.

From the 2011 review. The fourth national Malleefowl forum has occurred at Renmark (SA). The national newsletter 'Around the Mounds' has not been produced for several years and needs to be either revived or replaced.

2014 Comment: The 2014 Forum is evidence that this objective is a high priority and is being met. The National Newsletter 'Around the Mounds' has been produced and distributed twice a year since autumn 2012.

Forum Resolution 8. Reinstate 'Around the Mounds' (or equivalent) to provide project updates, monitoring feedback and show how data is applied to achieve recovery to the Malleefowl conservation community in particular volunteers – suggestions received this could be achieved by a newsletter or national website.
2014 Comment: both the magazine and website provide project updates, monitoring feedback and make the link between monitoring and the Adaptive Management Project.

Forum Resolution 10. Establish under the national database a database of interested individuals, volunteer groups and their activities so that groups can better share information and promote their volunteer opportunities.
2014 Comment: The 'Important Links' on the website provides links to all groups identified. The list can be added to at any stage. The newsletter also exists precisely to share information and promote volunteer opportunities and the National Coordinator is another way for people to connect.

Forum Resolution 11. Pursue options for links with volunteer organisations to increase access to volunteers particularly for low populated regional areas e.g. city, scouts, CVA.
2014 Comment: Where possible, this is done by National Coordinator, however it has to be driven locally. The National Coordinator is a good contact when people want to discuss how to involve volunteers.

Performance Criteria: P17.1 Increased public awareness of the Malleefowl recovery effort, beneficial management practices, and the contributions made by community groups.

From the 2011 review. There has been ongoing raising of public awareness about Malleefowl biology and conservation needs across the four States. This has focused largely on the contributions made by community groups and their many volunteers.

2014 Comment: On a national level this is being achieved through the website and visitation by the National Coordinator to many regions across the Malleefowl range. (3 WA visits, 2 NSW and numerous in Vic and SA). This is also achieved through the efforts of many regional groups such as information boards installed by VMRG, training days by NCMPG, VMRG and MPG, and publications such as "Malleefowl Matters" and "Lowan Behold".

Forum Resolution 12. Secure resources to enable a further print run of the VMRG Malleefowl Education Kit in a format that can be distributed to other regions.
2014 Comment: VMRG still have copies available and this is being further publicised on the national website 'Library' page but only as a reference to VMRG as supplier of discs (it's too big for the website in current format).

Performance Criteria: P18.1 Recovery process is coordinated and managed effectively by the Recovery Team, which:

- meets at least annually;
- ensures that all key stakeholders are aware of, and support, planned actions, and are kept informed of progress; and
- ensures that the results of actions in this plan are assessed, reported and reviewed.

From the 2011 review. The National Malleefowl Recovery Team has met on a 2-3 times per year basis through phone link-ups. The ongoing success of the national monitoring effort and in achieving the fourth National Malleefowl Forum is testament to this. Peter Sandell has coordinated and chaired the team, and these meetings, in an efficient and effective manner now for many years. For these efforts the rest of the Recovery Team is extremely grateful. The recent forum in Renmark has provided several issues which the National Recovery Team should now look at addressing. This review paper has also identified a range of issues for the National Recovery Team to consider. National Recovery Team members inform some, but not all, stakeholders of progress being made with recovery efforts. The national newsletter 'Around the Mounds', which used to keep all interested persons up-to-date, has not been produced now for several years and it, or a new version, needs to be re-instated as soon as possible. In the meantime, the VMRG web-site has acted as the main repository of national Malleefowl project updates. The draft performance review presented here is the first such review undertaken for the current National Malleefowl Recovery Plan. It is now up to the National Recovery Team to guide the improvements and new directions indicated.

2014 Comment: The Recovery Team continues to meet regularly via phone linkup and is extremely well managed by current Chair Sharon Gillam. The appointment of a part time National Coordinator is another step in the right direction to engaging relevant stakeholders. This review, the second of its nature satisfies the third sub-objective.

Forum Resolution 6. Seek funding to appoint a National Malleefowl Recovery Coordinator that reports to the National Recovery Team to drive the application of the MAMF, supports national coordination, drives the Plan's implementation, supports and recruits database coordinators and seeks additional funding for Malleefowl conservation nation-wide.
2014 Comment: Funding has been achieved and a part time Coordinator is in place.

Forum Resolution 7. Prioritise Recovery Team activities and national reporting to be more closely aligned to the National Recovery Plan.
2014 Comment: This review satisfies this resolution.

Review Summary

<u>Managing populations</u>

The Recovery Plan identifies a range of measures aimed at physical management of habitat for the benefit of Malleefowl and in almost all cases this is being achieved to some extent. This includes:

- the area in reserves, conservation covenants has increased
- goats have been removed in reserves and attempts to control them have taken place
- artificial sources of water have been closed
- habitat has been protected from stock grazing through fencing
- rabbit numbers reduced
- fire management plans are in place in many areas/reserves
- documentation of fox control occurs at most reserves near monitoring sites
- there are examples of Malleefowl habitat links being established
- occurrence of road kills is recorded at some sites and signage that warns of Malleefowl presence does happen

However, mapping of fire occurrence against Malleefowl habitat has not been undertaken nor has a national fire project as suggested in resolution 5 from 2011 been established. Also, in Victoria and NSW at least, environmental outcomes are eclipsed by government policies to burn areas based on quotas and hectare targets aimed at asset protection. This goal is also severely impacted by increased wildfire such as those in the Victorian and SA Mallee during the 2013 summer.

As stated, we have achieved many of the goals identified in the Recovery Plan but what we have not been able to do is to record this work on a national scale. This is due mostly to the lack of resources to do this work.

Planning, research and monitoring

Regional conservation plans are not in place across the range but is a goal for the National Coordinator as relationships are developed with NRM agencies across the Malleefowl range in the coming years.

The monitoring data was initially analysed in 2007 to produce the "Trend Analysis" paper by Joe Benshemesh, and the fox and Malleefowl data was re-analysed and published by Jessica Walsh *et al.*. A similar project is currently being undertaken with all the data collected to date and results expected in 2015. The monitoring database is also being utilised to develop modelling as a foundation for the Adaptive Management Project.

Annual monitoring summaries are usually completed by the end of June each year. This is happening reasonably effectively in most areas, with reports distributed to volunteers in the national newsletter 'Around the Mounds'. The VMRG also hold an annual reporting-back meeting for their volunteers. The most notable outcome in the last three years is that all data from WA is now uploaded to the database. More work is needed to produce timely national annual reports and distribute the information.

Malleefowl monitoring effort is facilitated, standardised and coordinated at a national level and remains a core activity for the Recovery Team and outcomes are remarkable considering the effort involved. Improvements are expected as increased training such as the recent NCMPG project occurs. There is room for improvement with more work by the National Coordinator required in all states except Victoria where the effort is extremely well managed by the VMRG.

Progress has been made in understanding distribution and status of Malleefowl in remote areas in the Maralinga Tjarutja Lands with new monitoring guidelines developed by Joe Benshemesh specifically designed for remote areas. Prospects exist for more work through the recently established Great Victoria Desert Biodiversity Trust.

There are still gaps in knowledge of distribution and status of Malleefowl in settled rural areas. Large gaps in monitoring in NSW are hoped to be addressed by the National Coordinator over the coming years.

There is more that can be done to understand:

- the longevity of breeding Malleefowl and the turnover of the breeding population
- recruitment of young into breeding populations
- the habitat requirements and preferences of Malleefowl.

At this stage the Recovery Team does not have the resources to pursue these directly. However the Adaptive Management Project is expected to address some of these questions.

The work being presented at the 2014 Forum by Taneal Cope will increase our understanding of genetic structure of Malleefowl populations.

Translocation, captive-rearing and breeding programs are considered to be a low priority for the Recovery Team compared to actions such as habitat improvements. This subject will be further addressed during the 2014 Forum by Taronga Western Plains Zoo and SA Zoos presentations.

The Recovery Team has not had the resources to specifically address the extent of infertility of Malleefowl in small reserves, however some answers are expected from the presentation by Chris Hedger at the 2014 Forum.
The rate of technology overtook the need to have a national remote camera working group (resolution 9 from 2011). Joe Benshemesh will be talking about camera work and how he has developed a process

that involves volunteers at the 2014 Forum and Rosanna van Hespen will be talking about how these data will inform the Adaptive Management Project.

Community involvement and project coordination

The 2014 Forum and the resurrection of the National Newsletter ‘Around the Mounds’ provide strong evidence that community involvement is a very high priority for the Recovery Team.

Around the Mounds has been produced and distributed twice a year since autumn 2012 and we now have a website. Between them they provide a comprehensive round up of project updates, monitoring feedback, an avenue to share information and promote volunteer opportunities and make the link between monitoring and the Adaptive Management Project. The ‘Important Links’ on the website provides links to all currently recognised stakeholders, but the list can be added to at any stage.

Increased public awareness of the Malleefowl recovery effort, beneficial management practices, and the contributions made by community groups is being achieved on a national level through the website and visitation by the National Coordinator to many regions across the Malleefowl range. Mostly however, this is achieved through the efforts of many regional groups such as information boards installed by VMRG, training days by NCMPG and publications such as “Malleefowl Matters” by the MPG.

As requested in Resolution 12 from 2011, VMRG Malleefowl Education Kit is still available and is being further publicised on the national website ‘Library’ page.

The Recovery Team continues to meet regularly via phone linkup and is extremely well managed by current Chair, Sharon Gillam. The appointment of a part time National Coordinator is another step to improving engagement of relevant stakeholders.

Finally, this review, the second of its nature, satisfies the final sub-objective in the National Malleefowl Recovery Plan to review and report on progress.

In conclusion, we can say that actions to manage populations are occurring around Australia but we don’t have the capacity to gather the data. The Recovery Team is improving planning, does extremely well with monitoring and continues to implement impressive research projects. The Recovery Team can be proud of achievements in community involvement and project coordination.

References

Gillam S.D. editor. (2012) ‘Proceedings of the 4th National Malleefowl Forum 2011: Renmark, South Australia.’ Department of Environment and Natural Resources, Adelaide.

Benshemesh J. (2007) National Recovery Plan for Malleefowl. Department for Environment and Heritage. South Australia.

4. Update from the National Malleefowl Recovery Program Coordinator

Tim Burnard, National Malleefowl Recovery Program Coordinator

Abstract

Tim Burnard has been employed by the Recovery Team since April 2013. This update will inform the Malleefowl community what has been achieved in this time.

The Malleefowl is listed nationally as Vulnerable and for every threatened species in Australia there is a Recovery Plan. Our Recovery Plan sets out all of the actions necessary to stop the decline of, and support the recovery of Malleefowl. Basically, my role is to assist in implementing actions from the National Malleefowl Recovery Plan. In the short term this includes assisting people across Australia in the National Monitoring Program. Over the years, the number of people involved in Malleefowl monitoring has grown to hundreds of volunteers that gather data from over 3,500 mounds each year. One of my jobs is to ensure data is gathered in a uniform way and fed into the National Malleefowl Monitoring Database. This underpins the Adaptive Management Project, which will use database information to help answer the question of why a population might have gone up or down. Assisting the Adaptive Management Team to identify sites where we can implement experiments is another major part of my work. Other tasks have included raising the profile of the National Malleefowl Recovery Team through establishment of a website and coordination of the 2014 National Malleefowl Forum.

Update

When I started as National Coordinator to the Recovery Team I was excited because I hoped the job may involve a bit of travel into Mallee country where I might get to see a Malleefowl if I was lucky. It has certainly exceeded those hopes. While 90% of the job is seated behind a desk at home in Casterton Victoria, I have managed to get out and about and meet many people and even a few Malleefowl.

A bit of background to this position first. While the Recovery Team has been operating since 1989, it was only 18 months ago that the team employed me as its first ever staff member to assist in delivery of its objectives. On reflection that's quite amazing because the team had already established the Recovery Plan, the National Monitoring Database, an Australia wide network of monitors and commenced the Adaptive Management Project.

It took a little while, but I now understand how big this project is. In summary, the input from people around Australia is phenomenal. One hundred and twenty odd sites have been searched by foot and about 150 people go to these sites and record about 25 measurements at 3,500 mounds each year. All of this data is uploaded to the database where it is gone over and verified that the data is clean. Here it sits as beautiful clean data ready to be analysed. It was thoroughly scrutinised in 2007 to produce a trend analysis and is in the process of being gone through again to tell us where we stand today in the face of a changing environment. This would be a magnificent achievement for any endangered species but our project goes further. We are now using the database as a foundation for far greater understanding of the threats to Malleefowl. I suspect this is the greatest example of citizen science and endangered species monitoring in the country.

In essence my position is about communication. You could say that my job is simple…to ensure that we keep getting the data into the database and then assist the Adaptive Management Team to use the data. So, in order to justify myself to all the people who trusted me to do this I am presenting a quick roundup of what we have done over the past 18 months.

There have been three trips to WA; the first as a general meeting of people with a visit to Babakin for the MPG training days, Yongergnow Malleefowl Centre in Ongerup, Kalgoorlie to meet GEMG people who sponsor some of my position, Koolyanobbing with Cliffs Natural Resources, and then to Dalwallinu to meet NCMPG people and visit the AWC Mt Gibson Sanctuary. Next trip, Joe and I attended the GEMG conference to further spread the National Team word, and finally just last month we attended the NCMPG training days.

This is my second trip to New South Wales this year. In March I met up with Milton at Mt Hope to see the amazing work being done there and then on to Dubbo to meet Mel and help select the zoo here as the venue for this Forum. In Victoria where there is such a strong community voice in the VMRG I have taken part in a site search at Tooan near Mt Arapilles, attended a Committee meeting near Bendigo and the Wyperfeld training days. In South Australia I have attended a search in Cowell (Eyre Peninsula), and been monitoring with Vicki in the South East, Karte with David and the Sporting Shooters SA group, monitoring at Innes NP, and even managed a visit to Lew Westbrooks property. I also went to Mildura to meet the Iluka team that have a large impact on our funding.

During all of this I have attempted to spread the word of the importance of ongoing monitoring and how it is all heading toward the grand Adaptive Management Project that will eventually answer some of those nagging questions on the main threats facing Malleefowl. The Adaptive Management Project has also been a big challenge. Working with the team from Melbourne University has been an honour. I'm extremely excited that the project has advanced to the point where we are about to engage in our first experiments. We'll hear more about this in their presentations tomorrow.

In between all this travelling about the nation we have also produced two Fact Sheets, the Malleefowl banner, distributed numerous articles for a range of publications and established the website. I recommend that anyone wanting to know more about Malleefowl, visit the site which is regularly updated with fresh news and is home to an extensive Malleefowl library.

Looking forward, I hope that my work will grow the already strong monitoring base across Australia. There are still a number of areas that are not covered by our monitoring. I hope that we get all 20 sites for the Adaptive Management Project established and that as the results start coming in, I will be spreading the word on what management actions are important to pursue. The most enjoyable part of this position is meeting all of the great people involved in Malleefowl work. The downside is the feeling that I am never quite doing enough. There are so many people with such differing issues that it is a real challenge to match their effort.

None of this would have been possible without the support and guidance of many people. Sharon, as Chair of the Recovery Team spends a huge amount of time managing the team, seeing that articles come in for our national newsletter 'Around The Mounds' and ensuring the money flows so that I can get paid. Individuals from each state have helped tremendously: Peter Stokie in Victoria, Sally, Gordon and Glenda from the NCMPG and Joy, June and Carl from MPG in Western Australia and Graeme Tonkin in South Australia who very patiently guides me through the database entry stuff. And Mel here in Dubbo who has worked so hard to make this Forum work. And then of course there's Joe who has never complained about my endless stream of phone calls asking for advice.

I must also thank the organisations that fund my position. They are: Goldfields Environmental Management Group, Gunduwa Regional Conservation Association, five Natural Resource Management Boards from SA, the Foundation for National Parks and Wildlife and Iluka Resources.

Many of you that I have met on my travels will know that I rarely travel alone. Donna's input into so many parts of the job has freed me up to the main tasks. Donna would never seek or expect any recognition for her work but I can assure all here that her input is as great as any PA.

Finally I have to thank all of the volunteers or as you are sometimes called, Citizen Scientists. I cannot express how greatly I admire your commitment to this great task. Your efforts are truly remarkable.

5. Report from the North Central Malleefowl Preservation Group (NCMPG) Western Australia

Sally Cail, Secretary North Central Malleefowl Preservation Group; Member National Malleefowl Recovery Team

Authors: Glenda McNeill, Sally Cail and Gordon McNeill, NCMPG

Abstract

From 2011 to 2014 the North Central Malleefowl Preservation Group (NCMPG) of Western Australia has been involved in four main activities. The group has continued to monitor four sites of remnant bushland comprising 143 mounds in the Dalwallinu and Perenjori Shires of the wheat belt of WA. Malleefowl activity has varied across the four sites, with two sites having less activity and two sites maintaining previous levels of activity. Recently members of the group have received training to validate data from NCMPG sites for the National Malleefowl Monitoring Database. The NCMPG has also strengthened its ties with Mt Gibson Iron by providing monitoring equipment and expertise to their environment officer. Group members also attend meetings where decisions about the management of the environment of the Mt. Gibson Iron Ore mine are discussed. The NCMPG's third undertaking has been to participate as a founding member with partners in the development of a new regional conservation association known as Gundawa which has been funded by mining companies in the region. Through a successful grant application to Gundawa the NCMPG has provided direct support for the role of National Malleefowl Recovery Program Coordinator and for Dr Joe Benshemesh for the processing of WA data in the national database. The grant has also provided funding for a program developed in the US, which can be used in the Cybertracker monitoring software to enable extraction and naming of photos. In 2014 the NCMPG intends to conduct a training weekend in monitoring for new volunteers interested in continuing the work of the group.

Background

The North Central Malleefowl Preservation Group (NCMPG) WA has operated as a not for profit group of volunteers for over twenty years and is based in the Dalwallinu Shire of Western Australia. Its work in Malleefowl conservation extends into the Perenjori and Yalgoo Shires. These shires are in the central wheat belt in the case of Dalwallinu and Perenjori and the pastoral area in the case of Yalgoo.

NCMPG WA over the years has been involved in activities such as:

- raising the awareness of threats to Malleefowl in the region through the use of display boards at agricultural shows and in permanent locations in information bays in the townships;
- coordinating farmers in the area to synchronise fox baiting, with up to 6,000 baits being distributed in any one year;
- encouraging farmers to fence bushland remnants to protect Malleefowl habitat with the aid of grants from various agencies;
- erecting Malleefowl warning signs on roads adjacent to known Malleefowl habitat; and
- identifying suitable sites to survey and monitor for Malleefowl activity.

Current Activities

The NCMPG WA has undertaken four main activities since the last forum in 2011. These are: the continued monitoring of mounds; the strengthening of ties with mining companies; the development of conservation partnerships and the renewal of group membership.

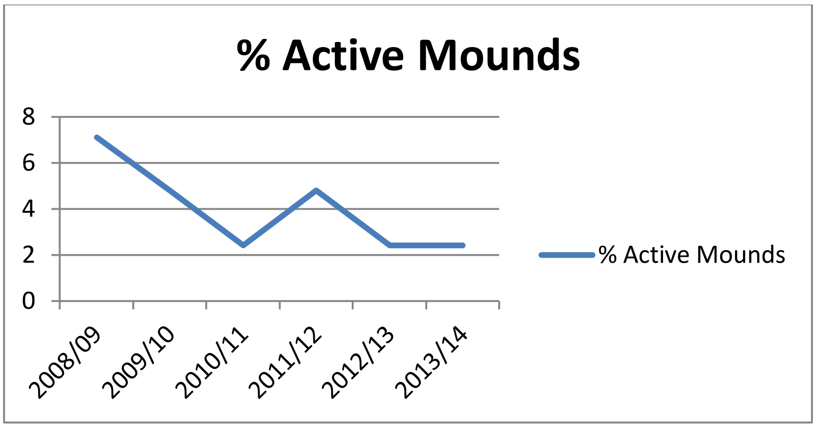
Figure 1. NCMPG covers agricultural, pastoral and mining areas northeast of Perth.

Mound Monitoring

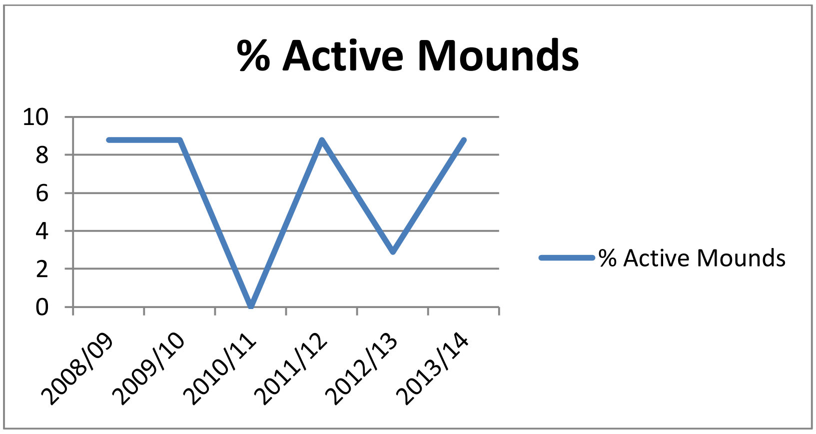
NCMPG is currently monitoring four sites: Nugadong (Site: W 01), Old Well (Site: W 02), Carters (Site: W 04) and Reudaveys (Site: W 07) and assists in the monitoring of two other sites: Mt Gibson Mine (Site: W 08) and Charles Darwin Reserve (Site: W 09). Data from these sites are uploaded onto the National Malleefowl Monitoring Database and recently NCMPG WA members have undertaken training to validate their own data on the database.

Three of the sites, Old Well (Site: W 02), Reudaveys (Site: W 07) and Mt Gibson (Site: W 08) have maintained activity levels since data have been collected, while at Nugadong (Site: W 01) and Carters (Site: W 04) there has been a decline in activity. For the last two seasons there have been no data collected at Charles Darwin (Site: W 09). While lack of rainfall at the critical time of May to September may affect the total number of active mounds over all sites in any one year as we presented at the last forum, it does not explain the variation in activity between the monitored sites in a given year. Based on evidence from our four remnant vegetation sites, our poster presentation at this forum suggests that road kill of adult Malleefowl is the major threat in agricultural areas where populations are confined to bush remnants.

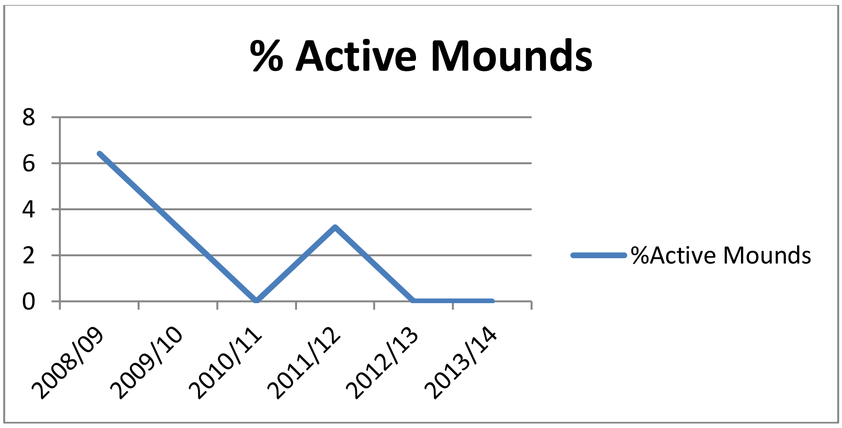
The following graphs show the percentage of active mounds in the four NCMPG WA monitoring sites for the years 2008-09 to 2013-14.



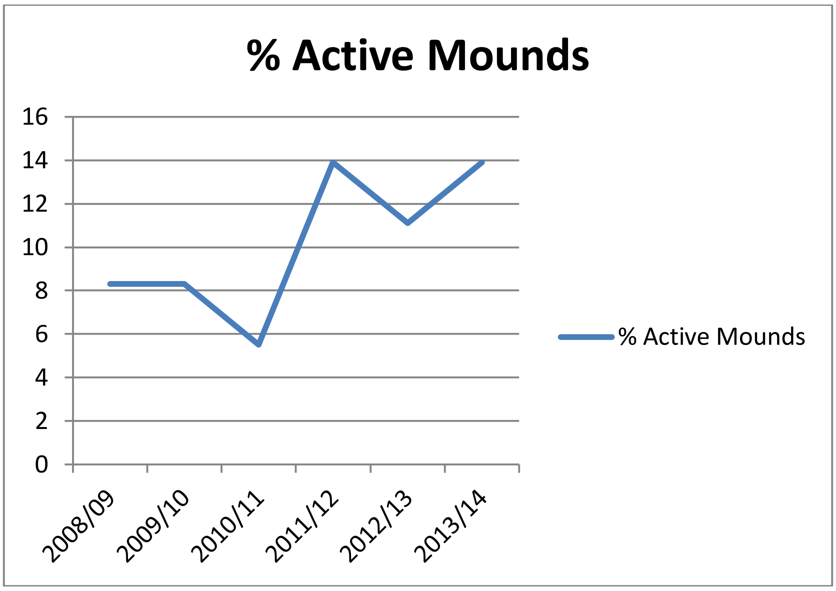
Graph 1. Nugadong (Site: W 01).



Graph 2. Old Well (Site: W 02).



Graph 3. Carters (Site: W 04).



Graph 4. Reudaveys (Site: W 07).

While all other factors such as predation, recruitment, natural deaths and wildfire appear similar across all of these sites, the sites in bush remnants at Nugadong (Site: W 01) and Carters (Site: W 04), where the percentage of active mounds has been decreasing, differ in that they are on busier roads than those in bush remnants at Old Well (Site: W 02) and Reudaveys (Site: W 07).

Strengthening of Ties with Mining Companies

NCMPG WA has continued to work collaboratively with Mount Gibson Iron and Asia Iron strengthening the relationship through the sharing of Malleefowl expertise and monitoring equipment with the Senior Environmental Engineer and through attendance at meetings where updates about the management of the environment of the Mount Gibson Iron Ore mine are discussed.

From the perspective of NCMPG WA these mining companies are not only providing funding for conservation management but are helping to shape conservation initiatives by providing expertise to develop policies and address environmental issues in our region. For example, this year Mount Gibson Iron funded the trial use of a winged aircraft to survey for Malleefowl mounds on their lease. The results were very promising and may have positive ramifications for future surveys of sites in our region. NCMPG WA is also grateful to have received funding from Mount Gibson Iron to assist members to attend this national forum and the previous forum held in Renmark.

The Development of Conservation Partnerships

NCMPG WA is a founding member of the Gunduwa Regional Conservation Association which is a new regional conservation group engaging with local government, non-government organisations, pastoral businesses, mining companies, community groups and state government agencies to stimulate practical biodiversity and conservation initiatives across the region. Gunduwa is funded through the lease agreements and interests of Asia Iron and Mount Gibson Iron. Its coordinating committee intends to develop strategic research and landscape conservation within the region. Participation in this new association has allowed NCMPG WA to build stronger partnerships with conservation groups and government sectors working in the region, in particular Bush Heritage Australia (BHA), the Northern Agricultural Catchment Council (NACC) and the Shires of Dalwallinu, Perenjori and Yalgoo.

In 2013-14 Gunduwa offered grants of up to $20,000 for conservation work in the region and the NCMPG WA, with the assistance of Tim Burnard, was one of four groups successful in gaining a grant. Through the grant NCMPG WA has provided assistance to Dr Joe Benshemesh for the processing of WA data in the National Malleefowl Monitoring Database. The grant has also provided funding for an extraction and naming project completed at Cybertracker in the US which enhances all monitoring in

Australia and has provided some support for the role of a National Malleefowl Recovery Program Coordinator in Australia.

Renewal of Group Membership

The Gunduwa grant also funded a training weekend in Dalwallinu in August 2014 to attract new volunteers to NCMPG WA. The emphasis was on the use of iPhones for the monitoring and collection of data for the National Malleefowl Monitoring Database. National Malleefowl Recovery Program Coordinator, Tim Burnard and Principal Researcher, Dr Joe Benshemesh, were guests at the workshop and the training was provided by Carl Danzi. This training will ensure that areas in our region will continue to be monitored and that new conservation regions such as Charles Darwin Reserve will be monitored again this year and into the future. The strengthened partnerships with other conservation groups built through involvement in the Gunduwa Regional Conservation Association and with mining companies in the region have provided NCMPG WA with the opportunity to renew its membership and as a result continue and expand its work.

6. Establishing new directions for the Malleefowl Preservation Group, Western Australia

John DeJose, CEO Malleefowl Preservation Group; Member National Malleefowl Recovery Team

Abstract

A strategic review conducted by the Malleefowl Preservation Group (MPG) Board has reflected that the condition of Western Australia's natural resources, including threatened species like the Malleefowl, continues to decline despite much effort and expenditure both public and private. We listened to our members concerns 'not to monitor the Malleefowl into extinction' and that 'we should be out there doing something positive for conservation more broadly'. With a strong landholder base, we are well-placed to understand viscerally that both the problems and the possible pathways to better futures lie in holistically addressing the social-ecological system, not just the ecosystem.

Examining the twenty-two year history of the MPG allows us to understand what is required to shift our trajectory as a community organisation. We learned much about natural resource management more broadly and strongly desire to help reverse the decline in the resource base over which we, as a society, have presided for two centuries. In 2013, the MPG Board resolved to adopt adaptive management processes as the default framework in which we do our work. Aiming to increase our influence this way, we have sought the requisite experience and thinking to support the development of interdisciplinary and cross-scale approaches internally and to enable focused and effective collaboration with the community, civil society groups, academia and government in working towards common objectives.

Introduction

I just want to say we're all in this together and in this presentation, I'm going a little bit up scale, I'm sorry Uncle John Hill isn't here with us any longer as I wanted to thank him personally for opening his heart up to us. I know there are a lot of people with big hearts in this room, most people here are volunteers and you've got to have a big heart to do this kind of work. Like Uncle John Hill, I'd like to pay tribute to my ancestors, not my own personal ancestors but those who had custody of Malleefowl conservation efforts before me, particularly at the MPG, I mention Susanne Dennings, who most of you will know, if you have been around the Malleefowl scene for any time at all, I've only been here for about 14 or 15 months myself. It takes a very special and particular kind of person to create, grow and maintain a conservation NGO and having done so for twenty-two years is an amazing feat.

The Strategic Review

So going up scale with this talk, I wanted to ask you if you wanted the good news or the bad news. We were 21 years old when I came on board and the Board asked me to do a strategic review and we decided we'd better set ourselves in the context of what was going on out there in the wider world. We've all read that, and we saw that, Malleefowl were really part of the bigger system and all, not all, but most of the environmental indicators were trending south despite our best efforts. That's what was coming out of the northern hemisphere but I guess it still applies here. And the reason why those indicators are trending south are known and apparent to all of us. It's because of the dominant paradigm in our society. I find it interesting that people have been talking about these problems in the US. For example there were some dreadful floods in the mid-west in 1883 and it was obviously a god or Green Peace or the Malleefowl group or somebody telling those horrible timber cutters that it's all your fault. There was a drowned city so it was a very important social and economic problem of the time. That's one of the things that in my work with the MPG we are trying to understand and bring those social and economic dimensions in to what we do, because there's another big element in this system and it's sitting here right in front of me, all of us, and it's what we do that's caused problems that have bought us here to work on Malleefowl, so in attempting to solve these problems it's pretty important for us to focus on people. It's people that are going to do the work but by focusing only on the animals we're ignoring a big part of the problem and a big part of that problem is how we're organised and the paradigms under which we work. This takes a shot at big business, you can have a bit of a chuckle at that before we see more figures of how badly we're doing here in Australia, but remember even the greenest amongst us have that particular human trait that is cognitive distance. You can believe 'this' absolutely but at the same time you can believe 'that', and the 'this' and 'that' have no overlap and your mental system can harbour both equally well. That is one of our biggest problems, I reckon. So, for example this slide is of a lady who is trying to save the whales and rescue the elephants but she's applying pesticides to kill the slugs in her garden. We all know these situations but it is something that worries me a bit. Another problem is that we are treating the planet more or less as if we have to get everything out and solve straight away.

You know we're trying to be able to do things a bit better in the future and I'm feeling it might be nice to save a few of these things until we can deal with them a bit better. Because we are going to need to, if we have a look at the graph of population growth. And if that doesn't tell you how urgent everything is, well, nothing will. But against all that, we looked at this background and we decided we can only start where we are used to what we have, and do what we can, and that came from the famous Aussie environmentalist Arthur Ash. Okay, we decided that we could sit here and do nothing or stay here and do more of the same. We decided the government isn't going to save us and there must be a better way. You can see how corporates enjoy government regulation so much and we're seeing it in our strategic landscape these days. We also decided single species conservation was really not going to float anyone's boat anymore. It's the way people think. It's not the way government and funders think and nor is it the way landscapes work. So increasingly, people are talking about systems and landscape and realise that Malleefowl are only a small part of the system and people are a bigger part, and sometimes we don't understand what we're doing. We have kind of a perverse conscience.

Do you recognise we are intimately tied to what's going on here? I remember members telling us don't monitor the Malleefowl into extinction, let's do something about it and, yes Joe and Tim, we are still going to continue monitoring because that's essential as you say, but we have to add these other things in and our members want us to. They want to go bush and they want to work with likeminded people, people that don't have dissident views.

The future

So in conclusion, I say we need to work on and in the system where the Malleefowl live, we need to work with and for the people there and, I'm refusing to use the word stakeholder, we need to work on our organisation, not only do our Malleefowl work, but try and get our organisation better adapted to new piecework. Never losing focus on the Malleefowl, which is what brings people together, we're going to focus on the future through the lens of the Malleefowl. In order to do that I reckon we have to enhance its iconic status, until the Malleefowl is as popular as the koala nobody in this room should rest. Because, although we can say it is unique and wonderful and everybody loves it, that is a very small everybody. They might be everybody in this room and everybody who hears about it. Many of the groups are doing a lot of public awareness work and agencies are as well, but I reckon it should be a much more popular powerful icon. And we are part of the bigger system too, the whole world is concerned about the things that we're concerned about, so we've decided we're going to focus more on becoming a doing organisation and on being better collaborators. We're always going to try and give more than we get from collaborations, to learn better to look at our data, analyse it and try and grow what we know. The Board accepted these principles as our default operating system just a year ago and to inspire others, especially the young. I look around this group and it's really great there are some young people here, I spoke to Birdlife Australia in Perth the other day and 60% of the people, sorry 90% of the people were over 60 the other 10% were over 50 and I know that many conservation NGOs share a similar demographic, so we're all facing that death by demographics. If we can't find ways to make our stuff relevant to the younger people we're going to be in trouble, but you can make a difference, thank you.

7. Malleefowl conservation activities in New South Wales 2012 – 2014

Melanie Bannerman, NSW Office of Environment and Heritage (OEH); Member National Malleefowl Recovery Team

Abstract

There have been many new, as well as many ongoing programs to aid Malleefowl recovery across New South Wales over the past few years. Some of the new programs include the implementation of the Saving Our Species program by the NSW Office of Environment and Heritage with Malleefowl as an Iconic Species; the introduction of a supplementary pest control program in a number of national parks specifically for Malleefowl and a number of large-scale fencing and pest control projects on private lands for the protection of Malleefowl, facilitated by local Catchment Management Authorities (now Local Land Services - LLS).

Some of the ongoing programs that have been progressed over the past few years include the use and trialling of remote cameras to monitor Malleefowl activities and recovery efforts; the continued implementation of the Fox TAP 2 program, with a review of some of the aspects of the program and an increase in the use of M44 bait ejectors; landscape scale predator control programs across both private and publics lands and aerial and land based monitoring of Malleefowl. In addition, the Taronga Western Plains Zoo is currently assessing their Malleefowl breeding facilities and program to determine future directions.

Some of the notable achievements since the last forum have been the input of the first set of monitoring data for NSW into the National Malleefowl Monitoring Database, with a view to encourage further input of data into the system from areas across the state; the fencing of some very large mallee properties by the Western LLS to create predator and goat free exclusion areas for Malleefowl with support from local landholders and, the injection of around $200,000 by the state government to implement recovery actions for the species across various tenures and programs in the state via the Saving Our Species program.

Saving Our Species program

The Saving Our Species program is a NSW state government initiative introduced in 2012 that aims to maximise the number of threatened species that can be secured in the wild in NSW for the next 100 years. Unlike previous threatened species programs, Saving our Species:

- allocates all threatened species to one of six management streams that identify the types of actions required for each species;
- provides targeted conservation projects that set out the actions required to save specific plants and animals on mapped management sites;
- prioritises projects based on their benefit to the species, feasibility and cost, to help decision-makers and investors make the most effective investments in threatened species conservation;
- regularly monitors the effectiveness of projects so they can be improved over time; and
- encourages community, corporate and government participation in threatened species conservation by providing a website and a database with information on project sites, volunteering and research opportunities.

There are almost 1,000 threatened species in NSW and these have been allocated to one of six management streams depending on their distribution, ecology, security and what is known about them. The six management streams are:

1. site-managed species (401 species)
2. iconic species (5 species)
3. data-deficient species (183 species)
4. landscape-managed species (132 species)
5. partnership species (155 species)
6. keep watch species (95 species).

Priorities for action under Saving our Species are species in the site-managed, iconic, data-deficient and landscape-managed species management streams. Direct action will be considered for nationally listed partnership species but is not expected for keep watch species unless threats substantially increase.

The Malleefowl has been assigned to the Iconic Species management stream. Iconic species are considered important to the community socially, culturally and economically and the community expects them to be effectively managed and protected. Only four other species have been listed as Iconic. These are the Brush-tailed Rock-wallaby, Koala, Southern Corroboree Frog and Wollemi Pine.

Through the Saving our Species program, $1.2 million in funding up to 2016 has already been allocated to implement actions for these Iconic Species. In terms of Malleefowl projects, this has equated to $133,000 in funding for the past 2 years, with similar amounts planned for the coming years (Irvin, M. 2014 pers. comm., OEH 2014a).

Projects have been prepared for these species based on existing recovery plans. Projects for all Iconic Species will be undertaken and will not be prioritised. The projects undertaken for Malleefowl include remote camera monitoring, mound digs and contributions to fox control programs on both private and public lands (Irvin, M. 2014 pers. comm.). **Marc Irvin** will be speaking a little later in this forum on the Malleefowl Iconic Species Project.

Supplementary Pest Control Program

The NSW National Parks and Wildlife Service (NPWS) undertakes one of the largest pest management programs in Australia, with more than 650 targeted control activities on reserves and neighbouring land every year. This includes baiting, aerial shooting, mustering, fencing, trapping, ground shooting and more. Pest animals targeted through NPWS Regional Pest Management Strategies include feral goats, feral pigs, rabbits, deer, wild dogs, feral cats and foxes (OEH 2014b).

In 2013 the NSW government announced a proposal to introduce recreational hunting in all national parks in NSW. The proposal was to allow recreational hunters (including children 12 years and over) into national parks with registered firearms, including black powder muskets as well as bows and arrows, to hunt feral animals. The aim was to assist in controlling feral animals in national parks in order to help protect threatened species. The proposal however did not take into account the safety of national park visitors, staff, researchers and other people that may be visiting the reserves, involved no planning or supervision by NPWS staff and enabled little, if any, regulatory control over the process and the shooters. Fortunately the proposal as it stood was withdrawn.

Later in 2013, a new proposal was agreed upon, called the Supplementary Pest Control (SPC) Program. In this program, NPWS is partnering with experienced and skilled volunteer shooters to supplement current NPWS control programs and help reduce pests for the protection of threatened species. A three-year trial program is currently being undertaken in 12 national parks and reserves across western NSW covering an area of around 485,000 hectares (Figure 1). These reserves are:

- Cocopara Nature Reserve
- Coolbaggie Nature Reserve*
- Goonoo National Park*
- Goonoo State Conservation Area*
- Gundabooka National Park
- Gundabooka State Conservation Area
- Murrumbidgee Valley State Conservation Area
- Murrumbidgee Valley National Park (Yanga Precinct)
- Nombinnie Nature Reserve*
- Nombinnie State Conservation Area*
- Woomargama National Park
- Yathong Nature Reserve*

* Reserves where Malleefowl occur

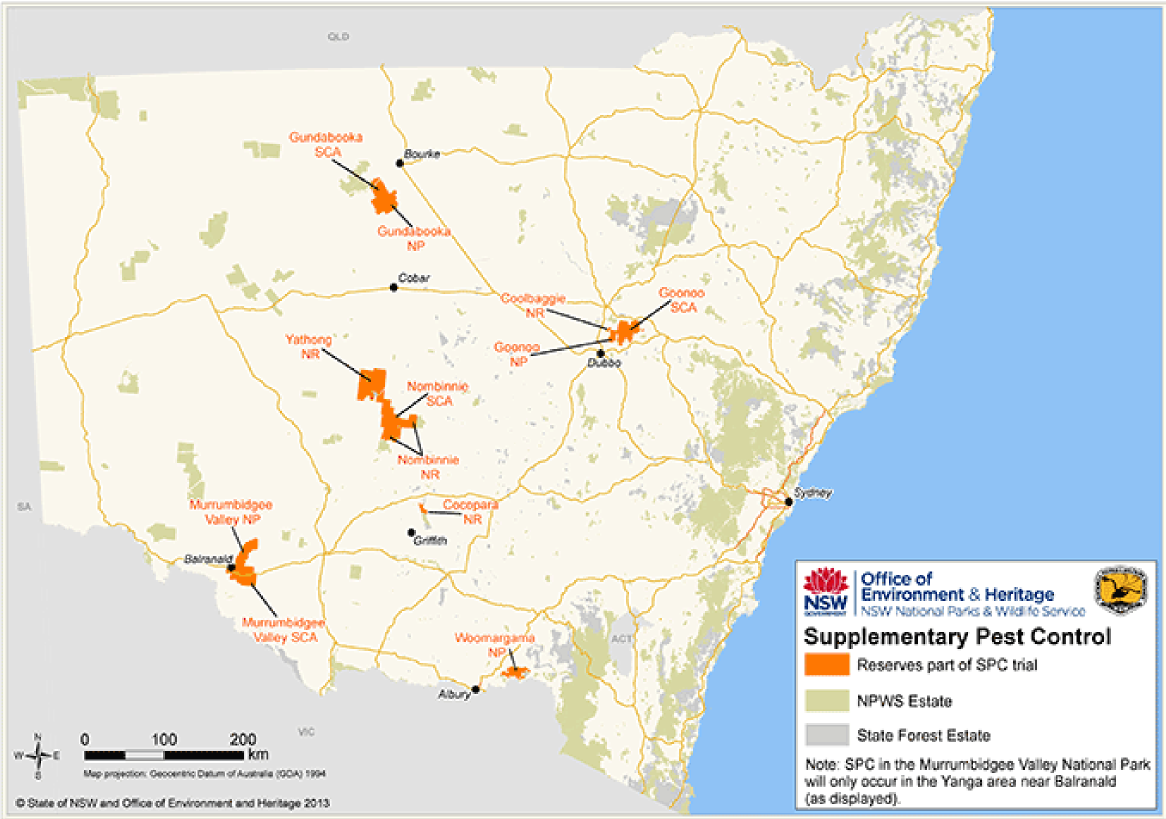


Figure 1. NPWS reserves included in the SPC Program (OEH 2014b).

These reserves were selected because they have ongoing pest management programs that could be complemented by additional ground shooting by experienced and skilled volunteers. Six of the parks contain Malleefowl records and have ongoing feral animal control programs for the protection of Malleefowl, which strongly influenced their selection for this program.

Experience has shown that pest animal management works best as part of an integrated program using a variety of techniques, including shooting, baiting and trapping. This is because individual animals that are not susceptible to one technique can be removed using another (OEH 2014b). For this reason, the current fox baiting and goat trapping programs being undertaken in the six Malleefowl reserves will be complemented by on-ground shooting programs to eliminate bait-shy and trap-shy individuals.

The program is being welcomed by NPWS staff as it is a safe program, volunteers work under the direct supervision of NPWS staff and the program's procedures and safeguards will be implemented in the same way as existing pest control operations in NPWS reserves. The initial selection and recruitment of the volunteers involves robust procedures to ensure that they are appropriately qualified and skilled to ensure the effectiveness and humaneness of the shooting program. The volunteers taking part must have high level training and competency testing in safe firearms handling and shooting proficiency that is equivalent to that of trained NPWS staff (OEH 2014b).

The operational phase of the trial began in mid-2014 with a number of programs already completed and others being planned. The programs completed so far have been undertaken in Goonoo SCA, Gundabooka, Woomargama NP and the Murray Valley NP (Yanga Precinct). Some have had limited success, whilst others have had more success. In Goonoo SCA for example, a two day shoot was planned and undertaken but no target species (foxes and goats) were shot.

The three year Supplementary Pest Control trial is a first for NSW. It will be monitored and evaluated to determine how effective the contribution of this new approach is in reducing pest animal populations and protecting our native species. The Natural Resources Commission (NRC) is undertaking an independent evaluation of the trial program to provide recommendations to the NSW government on its future after three years. This evaluation will consider ecological, social and economic outcomes of the trial and will involve input from the NPWS and the Sporting Shooters Association of Australia (NSW) Inc. (OEH 2014b).

NSW Fox Threat Abatement Plan (Fox TAP) review

In 2009/2010 a review of all fox control and monitoring programs implemented since 2001 under the NSW Fox Threat Abatement Plan (Fox TAP) was conducted. The review found that there were a number of issues regarding data collection and monitoring and that there was little communication between different agencies undertaking or overseeing fox control programs around the state. This made it difficult to collate, analyse and compare the results of fox control programs across NSW and prompted a revision of the plan.

The revised NSW Fox Threat Abatement Plan (FoxTAP2) was developed in 2010 and is one of the largest biodiversity conservation programs in NSW. It mirrors similar efforts in other states such as the Western Shield program in Western Australia, Southern Ark in eastern Victoria and Operation Bounceback in South Australia (OEH 2011).

The primary actions in the plan are the control and monitoring of foxes at priority sites across NSW, with a number of small changes to these sites and priority species. The plan also proposes the development of individual plans for each site, the centralised collation of all data, a mechanism for ongoing review of priority sites and species, the use of best practice guidelines for control and monitoring and improved communication between agencies.

Priority sites are the sites in NSW where fox control actions will be focused under the FoxTAP2 program to protect target threatened species, such as Malleefowl. Actions at these sites, however does not mean that fox control cannot also be undertaken at other sites by individuals or agencies but these sites are the priority for control. Priority sites were identified for each target threatened species by considering three site attributes:

1. The potential for impact at a site (based on fox density and habitat fragmentation);
2. The significance of the site to the species overall (with a higher priority for larger or outlying populations); and
3. The ability to achieve effective fox control (depending on the size of the area and complexity of land tenure).

Based on these attributes, 61 priority sites over almost 1 million hectares of public and private lands were identified. These are shown in Figure 2.

Nine of these sites are designated nil-treatment for the purposes of measuring the response of native fauna to fox control. Five sites have been identified for the protection of Malleefowl, with one of those sites a nil-treatment site. These are listed in Table 1. For each priority site a site plan has been developed in consultation with all public land managers involved including Forests NSW, local pest management authorities and catchment management authorities (now Local Land Services) and other relevant groups. Each site plan:

- identifies the target species for protection at the site, e.g. Malleefowl;
- proposes the extent, frequency and methods of fox control to be undertaken;
- describes the specific objectives for the site and the monitoring methods;
- assigns responsibilities (and cost estimates) for all the actions in the plan; and
- provides a date for review of the plan.

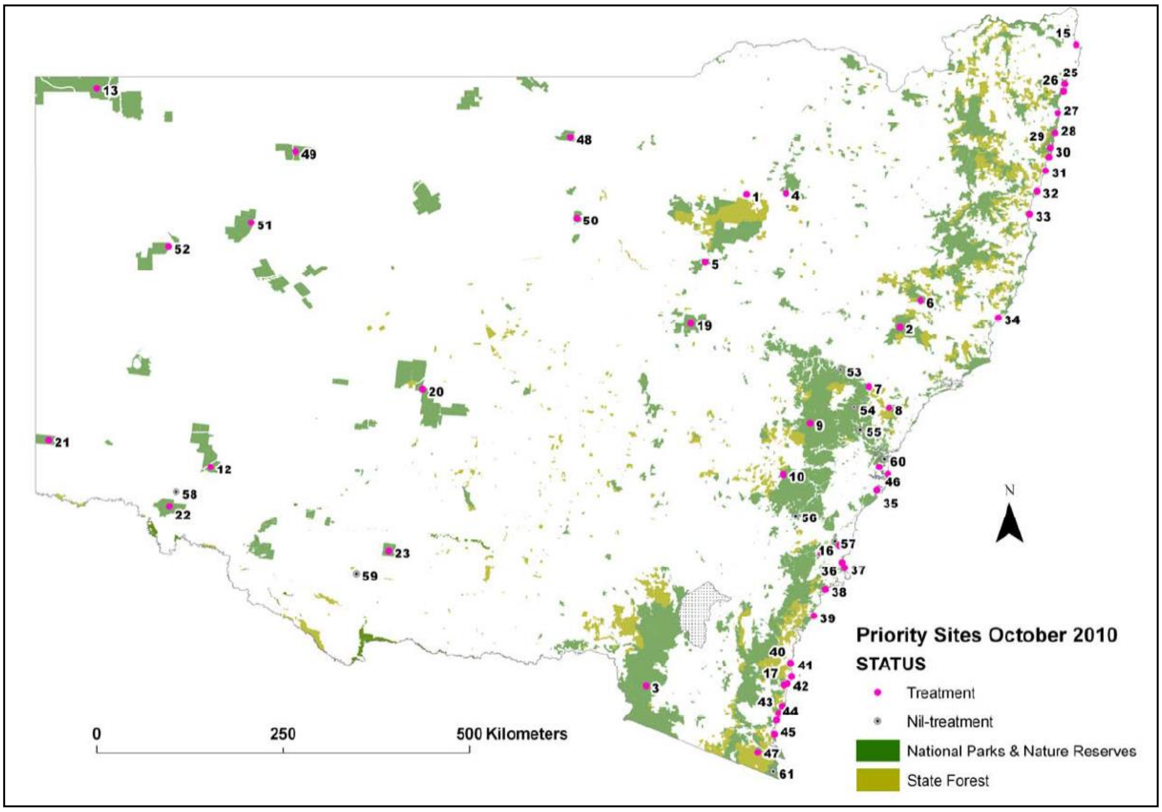


Figure 2. Priority sites for fox control under the NSW Fox Threat Abatement Plan (FoxTAP2) 2010 (OEH 2011).

Table 1. FoxTAP2 priority sites for Malleefowl.

Site Number	Site Name	Threatened Species impacted	Tenure	Treatment
19	Goonoo	**Malleefowl**	NPWS/ SF /Private	Fox control
20	Central Mallee	**Malleefowl,** Chestnut Quail-thrush, Southern Scrub-robin	NPWS	Fox control
21	Tarawi	**Malleefowl**, Chestnut Quail-thrush, Southern Scrub-robin	NPWS	Fox control
22	Mallee Cliffs	**Malleefowl**, Chestnut Quail-thrush, Southern Scrub-robin	NPWS	Fox control
58	Wamberra	**Malleefowl**	Private	nil

At the four Malleefowl priority sites, fox control methods are being undertaken including ground baiting using various bait types and M44 ejectors, some aerial baiting and ground shooting by NPWS staff and/or via the SPC program. Foxes and native fauna are being monitored using sand-pads and motion-triggered cameras and Malleefowl are being monitored using motion-triggered cameras, aerial (when resources permit) and ground-based surveys and individual mound monitoring.

For many sites, including the Malleefowl sites, data is yet to be collated centrally and analysed to determine the effectiveness of fox control on the target threatened species and other native fauna.

National Parks and Wildlife Area Programs

The restructure of the National Parks and Wildlife Service over the past few years has affected funding and resources with some impacts on Malleefowl protection efforts. In addition, with the review of the Fox Threat Abatement Plan, funding for the implementation of FoxTAP2 has been transferred to the various regional offices, resulting in reduced fox baiting and Malleefowl monitoring capacity. Funding under the Saving Our Species (SOS) program has however, enabled some supplementation of fox baiting and monitoring efforts where needed.

In the Central Mallee (Mid West NPWS Area) the fox baiting program has been reduced from three times to twice per year, with the second round being funding dependent. Yathong, Nombinnie and Round Hill Nature Reserves are all included in the program, which involves ground and aerial baiting and supplying baits to neighbouring landholders. SOS funding has enabled the purchase of 190 M44 ejectors (a bait delivery system) which will hopefully compensate to some degree the drop in aerial baiting (Douglas, L. 2014 pers. comm.).

There is currently no Malleefowl monitoring being undertaken in the reserves. Given the size of the area and number of mounds, it is difficult to monitor all of the mounds on the ground and aerial surveys have been halted due to funding shortages. In 2012, a partial aerial survey was conducted but due to time constraints was unable to be completed. Fortunately, the spatial data of each mound visited was recaptured as there were queries regarding the projection of the data. Of the 90 mounds visited, 14 were active, 28 inactive, 18 not found, 29 remnant mounds and 1 uncertain. The aim for the Area is to fly transects in order to survey all of the three parks (approx. 245, 000ha) in the near future (Douglas, L. 2014 pers. comm.).

In the Lower Darling NPWS Area, in the south-west of NSW, traditional ground based fox baiting is undertaken within the Area's three large mallee reserves, Tarawi Nature Reserve, Mallee Cliffs National Park and Mungo National Park, four times per year. In addition, 100 M44 ejector stations have been established within Tarawi NR and Mallee Cliffs NP and are checked every month. Fox (and other pest species) numbers are monitored through bait take and spotlight transects at Mallee Cliffs and Mungo NP, while bait take and sand pads are utilised within Tarawi NR (Dayman, R. 2014 pers. comm.).

Ground based mound monitoring has been undertaken within Mallee Cliffs National Park since aerial surveys were discontinued in 2009. Surveys are now undertaken every two years of the 25 historically most active mounds across the reserve. Results are shown in Figure 3 below (note that no surveys were completed in 2009 or 2013).

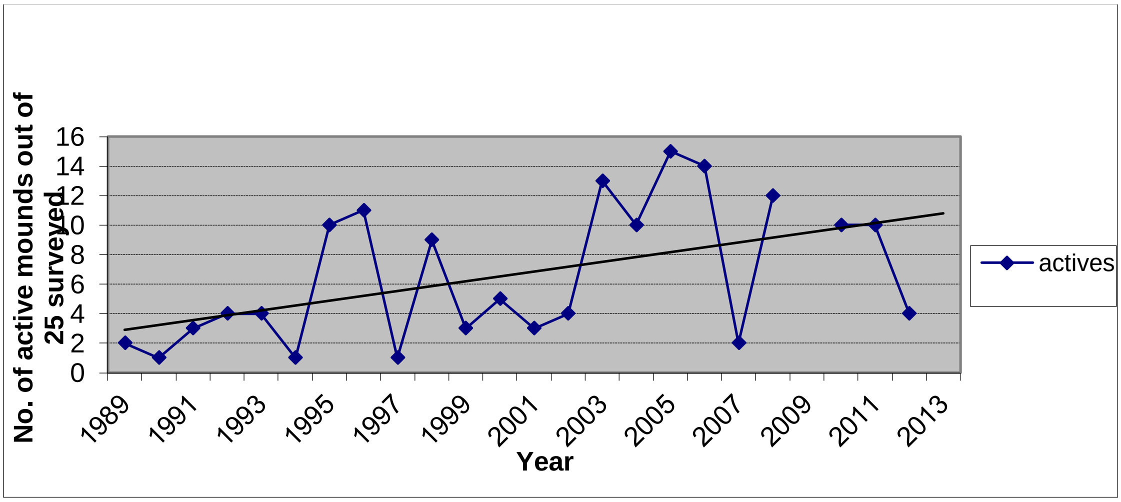


Figure 3. Malleefowl mound activity (25 historically most active mounds) in Mallee Cliffs National Park (note 2009 and 2013 not surveyed) (Source: NPWS Lower Darling Area).

Two remote cameras have been established on mounds within Mallee Cliffs NP in an attempt to quantify mound visits from pest species such as foxes, cats and feral goats. Preliminary results show that while fox activations vary significantly through time they do account for a substantial number of overall animals captured on cameras in Mallee Cliffs NP. One camera is also situated on a mound in Tarawi Nature Reserve and it is anticipated that more cameras will be established on other mounds in the near future (Dayman, R. 2014 pers. comm.).

In the Goonoo site (Coonabarabran NPWS Area) ground based fox baiting is conducted on an ongoing basis across Goonoo State Conservation Area (SCA) and National Park (NP), Coolbaggie Nature Reserve, Breelong NP and Cobbora SCA, equalling almost 75,000 hectares. The use of M44 ejectors will begin in 2015, with around 100 ejectors planned to be installed across the area. Monitoring of foxes is undertaken twice per year for a month, utilising 40 remote camera sites and capturing on average around 5,000 photos per monitoring period. Initial analysis of the photos as well as bait take data have indicated very low numbers of foxes throughout the area, but has identified an increase in goat numbers. Hopefully the Supplementary Pest Control Program in Goonoo will assist in eradicating this increasing goat population.

Malleefowl mound monitoring in the Goonoo site has been undertaken over a number of years, with data being entered into the National Malleefowl Monitoring Database for the first time in recent years. Around 25 mounds are known to occur across the area, with three of these being active over the past few years. These mounds have been monitored using remote cameras, with over 100,000 photos collected but yet to be properly catalogued and analysed. In 2012 one of the mounds was excavated to determine whether it contained eggs, with six newly laid eggs being found. Unfortunately this mound was abandoned shortly after the excavation and the other two known active mounds had become inactive the year prior, resulting in currently no known active mounds in the Goonoo site. This has prompted actions through the SOS program to undertake aerial surveys possibly using LiDAR technology as well as potential foot based surveys to attempt to identify further mounds across the area and hopefully discover other active mounds. A history of Malleefowl conservation and monitoring efforts in Goonoo forest will be presented by **Alison Towerton** at this forum.

A proposed coal mine 30km southeast of the Goonoo site may result in around 7,000 hectares of offset lands being added to the Goonoo site, increasing the area of potential Malleefowl habitat, some of which may include recently active mounds.

All of the reserves mentioned above are currently included as priority sites under the FoxTAP2 program for the protection of Malleefowl, whilst the Central Mallee and Goonoo sites are also included in the Supplementary Pest Control Program for the protection of Malleefowl.

Local Land Services Programs

The Western and Central West Local Land Services (LLS) have undertaken a number of large habitat fencing and feral animal control programs in the west of the state to protect Malleefowl.

Near Nymagee, the Western LLS has assisted two families who have fenced a combined area of 3,130 hectares on their properties to protect Malleefowl and their nests from goats and foxes. Ongoing fox baiting in the area will help to reduce predation on Malleefowl eggs and chicks and the exclusion of goats and stock will reduce competition for food and the destruction of habitat thus improving habitat for Malleefowl and overall biodiversity (Baker, M. 2014 pers. comm.).

Eight Malleefowl mounds (active and inactive) have been identified in the area and mound shape and size and evidence of shells or feathers has been recorded, along with any calls heard or behaviour observed. Fifty fox baiting stations have been set up around and within the area and baits are checked and replaced every three weeks. In addition, 50 sand plot monitoring sites have been established at the bait stations to identify the animals visiting the stations. Motion sensing cameras have also been deployed in a 1km x 1km grid system across the block. Cameras are deployed for two weeks at a time before they are retrieved and the images analysed. To date, foxes, goannas, goats, emus, kangaroos, rabbits, pigs, ravens, pigeons, shingleback lizards, people and vehicles and of course Malleefowl have all triggered the cameras. The data collected is utilised in conjunction with the National Malleefowl Monitoring System. Preliminary results of the project have been positive and have shown that fox activity has been reduced (Baker, M. 2014 pers. comm.).

In central NSW large areas of mallee have been fenced with the aim of protecting Malleefowl. Near Hillston an area 15km x 18km has been fenced to exclude goats, with over 1,000 goats being removed from this site. Cameras installed at mounds in this site have shown no goats. Two other sites near Mt Hope have also been fenced and goats removed, resulting in around 110, 000 hectares being fenced. A large revegetation project is also being planned around the Yalgogrin site, to reconnect this site with surrounding mallee sites (NMRT 2012, 2013a, 2014).

Besides goat removal, other pest work in central NSW has included pig and fox baiting, with many landholders being involved. Fox baiting has been conducted around the perimeter of sites but not within the sites, which does not seem to have any impact on foxes inside these areas. The Invasive Animal CRC is running experimental trials with the LLS at Mt Hope, looking at different baiting techniques for fox and pig control (NMRT 2013a, 2013b, 2014).

Aerial and ground survey work has been conducted across the area, with 100,000 ha of mallee having been surveyed in the Mt Hope region for signs of Malleefowl populations. A number of significant populations were noted, and over 50 active mounds seen on both national park estate and private lands. Mounds are ground checked and cameras have been installed at many to monitor the activities of Malleefowl and other animals (NMRT 2012, 2013a).

Milton Lewis will be providing two presentations later in this forum on some of the feral animal control work undertaken by the Central West LLS in the rangelands of NSW.

Captive Breeding

Taronga Western Plains Zoo in Dubbo currently has 17 adult Malleefowl in aviaries. Two of the birds are very old (20 years) and are still breeding successfully, demonstrating the longevity of the species and their reproductive capacity. There is currently no release programs planned for offspring and the zoo is investigating various options for the continued management of the captive population (Kleinig, S. 2014 pers. comm.). **Paul Andrew** from Taronga Zoo will be leading a discussion regarding the options during this forum.

Acknowledgements

I would like to thank Ray Dayman, Ranger, Lower Darling Area, NPWS, Laura Douglas, Ranger, Mid West Area, NPWS, Marc Irvin, Senior Threatened Species Officer, North West Region, OEH, Marybeth Baker, Acting Manager Strategic Land Services, Western LLS and Steve Kleinig, Senior Malleefowl Keeper, Taronga Western Plains Zoo for their valuable input into this presentation.

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8. Malleefowl conservation in South Australia - Activities from 2012–14

Sharon Gillam, Department of Environment, Water and Natural Resources South Australia; Chair, National Malleefowl Recovery Team

Abstract

Malleefowl conservation in South Australia (SA) from 2012–14 has been largely dominated by the now well-established national monitoring system, which has been in operation in some form since 1989, and now consists of thirty regularly monitored sites in four Natural Resources Management (NRM) regions. The SA Department of Environment, Water and Natural Resources (DEWNR), contract staff and a growing body of volunteers conduct the monitoring.

Volunteers remain a critical part of the monitoring process, collecting important data, including trends in breeding activity, which underpins Malleefowl management strategies. Breeding activity was consistently higher over the regions in 2012, with overall state-wide activity picking up slightly from 6% in 2005 to 8% in 2013.

Other activities to promote Malleefowl conservation conducted by DEWNR include predator and herbivore control; prescribed burning and tracking in the arid far-west of SA. Private landholders and community members also participate in these activities.

The recently appointed position of National Malleefowl Coordinator has given added impetus to staff and volunteers participating in monitoring and other recovery initiatives, as the challenge to maintain activities is ever present, with limited resources and uncertainties in continued funding for staff and contractor positions. This position, together with the Adaptive Management Project currently in progress, will provide further opportunities to drive recovery actions for Malleefowl in South Australia.

Introduction

Malleefowl *Leipoa ocellata* occur sporadically throughout the arid and semi-arid mallee scrub regions of SA, in both public reserves and on private land (Figure 1). Public reserves are managed by the Department of Environment, Water and Natural Resources (DEWNR), and on ground works such as prescribed burns and predator/competitor control are undertaken to benefit threatened species, including the Malleefowl. Several patches of mallee on private land are protected under Heritage Agreement covenants, which also contribute to conservation of Malleefowl.

Malleefowl conservation in SA from 2012–14 has been largely dominated by the now well-established national monitoring system, an event which occurs annually in the mallee regions below Goyder's Line. The monitoring system has been in operation in some form since 1989, and now consists of thirty regularly monitored sites in four regions, using the latest software and hand-held electronic devices to capture data, which go into the National Malleefowl Monitoring Database. The monitoring process is coordinated by DEWNR and contract staff, with sites monitored by both volunteers and staff.

Other activities to promote Malleefowl conservation conducted by DEWNR include predator and herbivore control; prescribed burning and tracking in the arid far-west of SA. Private landholders and community members also participate in these activities.

The last three years have seen significant changes to funding resources and organisational structures within DEWNR, which in some cases have led to reduced capacity or loss of staff who were familiar with the monitoring system and regional volunteers. This has been challenging in terms of keeping the established national monitoring system rolling along, and maintaining and supporting good working relationships with already known and new volunteers.

The recently appointed position of National Malleefowl Coordinator has given added impetus to staff and volunteers participating in monitoring and other recovery initiatives, and has been particularly useful in light of limited resources and uncertainties in continued funding for staff and contractor positions.

This position, together with the Adaptive Management Project currently in progress, can provide further opportunities to drive recovery actions for Malleefowl in South Australia.

Malleefowl conservation activities in SA from 2011–12 to 2013–14 are outlined in this paper.

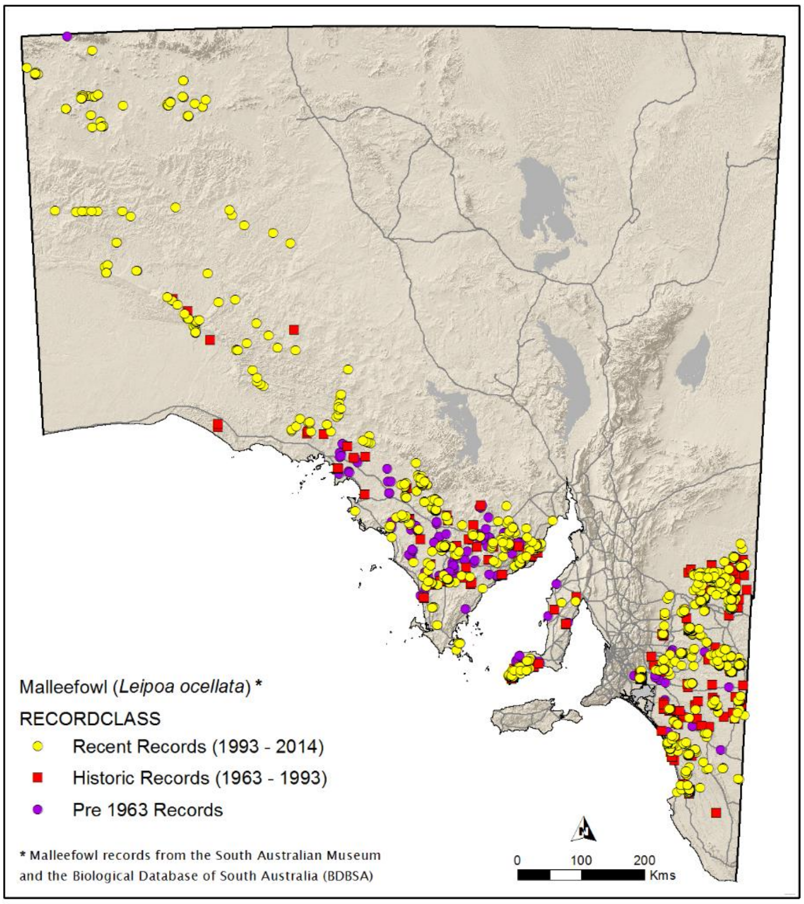

Figure 1. Distribution of Malleefowl in SA, with records shown in three age classes. (Source: Biological Databases of SA, DEWNR, 2014).

Activities over the past three years: 2011–12 to 2013–2014

Monitoring

By 2007, forty monitoring sites, or grids, were established in SA, however only thirty of these sites are now regularly monitored each season (Table 1). The sites range in size, however, most measure around 4 $km^{2,}$ which is the standard sampling size recommended in the National Monitoring Manual (Victorian Malleefowl Recovery Group 2007). The monitoring sites are located in the southern third of SA (Figure 2), and have been selected to represent the general mallee habitat in which the birds persist, while being close enough to human settlement to visit. In 2009 ten sites that were regularly monitored by Community Land Management (CLM) volunteers in the Murraylands were no longer surveyed, leaving the total number of grids in this region at twenty, all coordinated by DEWNR contract staff. There are five grids on Eyre Peninsula, however, one site in the Gawler Ranges (Pinkawillinie) was severely burnt by wildfire in 2006, and has only been revisited once since then, in 2011. A number of sites in the Murraylands were also burnt in 2006 (Pooginook, Gluepot 3, Gluepot 5), however, these sites have continued to be monitored. Funding has been sourced in a number of regions, specifically to upgrade the electronic monitoring devices, with all regions no longer using the original Palm Pilots.

Table 1. Number of grids regularly monitored in each region in South Australia.

Region	Regularly monitored grids
Murraylands	20
Eyre Peninsula	4
Yorke Peninsula	1
South East	5
Total	**30**

Table 2 shows the number of active and inactive mounds recorded within the monitored grids, across each of the four regions in SA, over the last three breeding seasons from 2011–13, including the percentage of active mounds. The total number of mounds monitored in each region has been reasonably consistent over the last three years, with a small number of new mounds found in the South East each season. Breeding activity in the Murraylands was slightly higher in 2012, with 55 active mounds found, up from 38 in 2011, and down again to 31 active mounds in 2013. Breeding activity was lower in 2013 for Eyre Peninsula, and remained relatively stable across the three seasons for Yorke Peninsula and the South East. Yorke Peninsula, which is represented by one grid in Innes National Park (see Figure 2), showed the highest breeding activity over the regions, followed by the South East. Both of these regions experience higher rainfall than the more arid sites located in the Murraylands and Eyre Peninsula, which may be a contributing factor to higher breeding activity. The percentage of active mounds recorded in each region over the last ten years is shown in Figure 3. Breeding activity was higher across most regions in 2012. Overall, activity picked up slightly from 6% in 2005 to 8% in 2013.

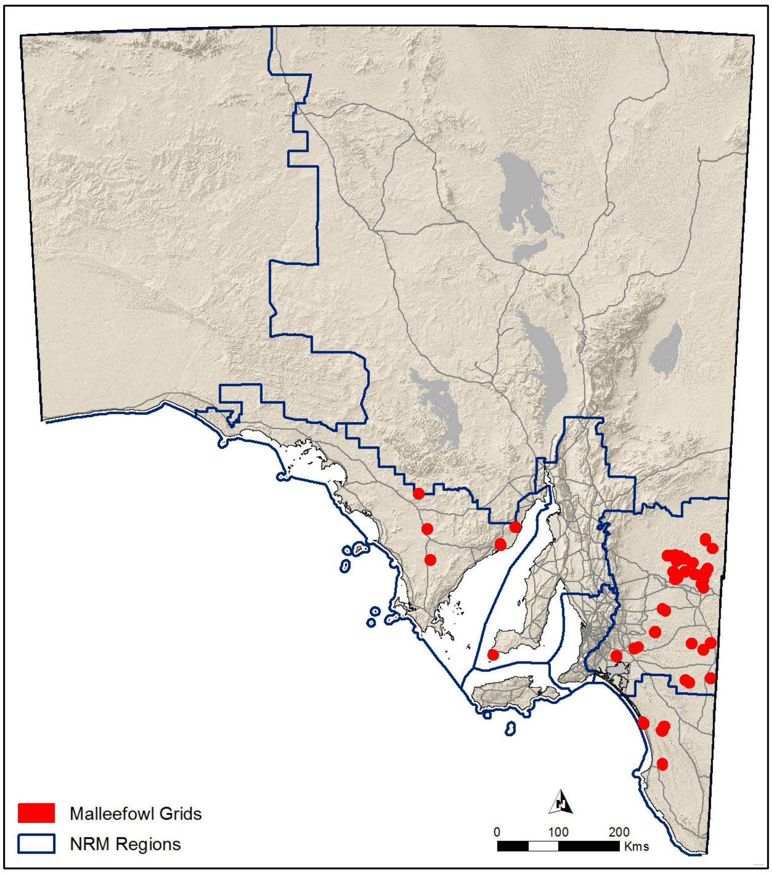

Figure 2. Monitoring site locations within four of the eight Natural Resources Management Regions in SA.

Table 2. Number of active and inactive mounds recorded per region in South Australia, across three Malleefowl breeding seasons.

	2011			2012			2013		
Region	Inactive	Active	Total	Inactive	Active	Total	Inactive	Active	Total
Murraylands	548	38 (6%)	586	533	55 (9%)	588	559	31 (5%)	586
Eyre Peninsula	201	16 (7%)	217	178	17 (9%)	195	188	11 (6%)	199
Yorke Peninsula	36	11 (23%)	47	38	9 (19%)	47	37	10 (21%)	47
South East	160	29 (15%)	189	164	32 (16%)	196	169	29 (15%)	198
Total	**945**	**94 (9%)**	**1039**	**913**	**113 (11%)**	**1026**	**953**	**81 (8%)**	**1034**

A report by Benshemesh (2006) suggests a significant decline of 2–3% per year in Malleefowl breeding activity at least over the last decade, in sites that are regularly monitored across southern Australia, with a definite downward trend shown in South Australia. On examining which environmental variables may be responsible for the decline, winter rainfall appeared as a major factor affecting Malleefowl breeding densities, which agrees with other studies on the ecology of Malleefowl (Benshemesh 2006). The effects of patch size and fire were found to be insignificant, and similarly, there was no evidence that foxes or fox control influenced Malleefowl breeding numbers (Benshemesh 2006). A study by Gillam (2008) found rainfall in 2006 across the lower half of SA to be well below average, which could partly explain the dip in breeding activity from 2006 to 2007 that can be seen in Figure 3.

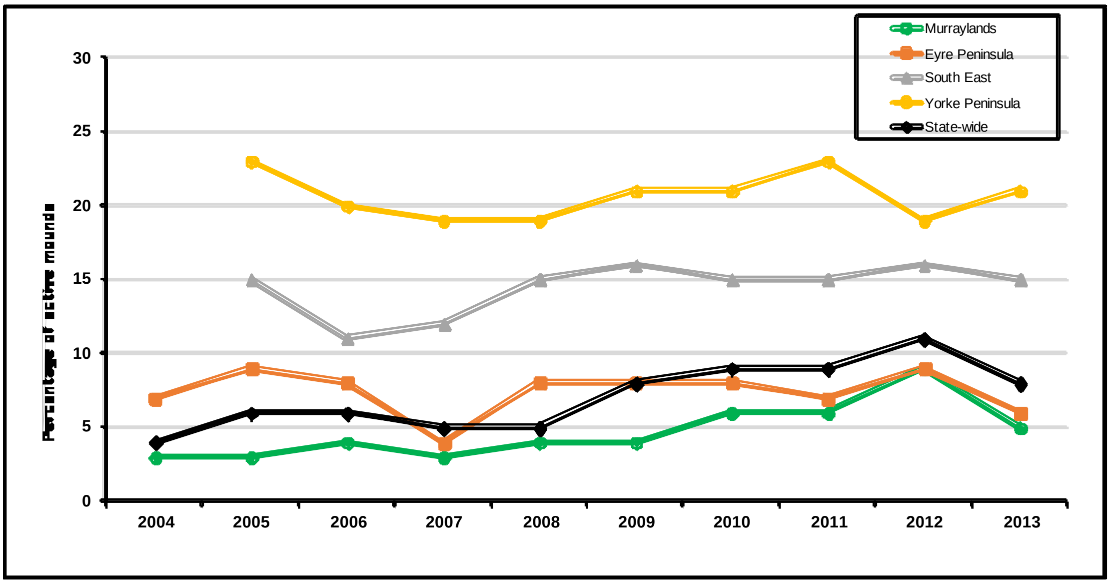

Figure 3. Percentage of active mounds across four regions in SA, plus a total for the state, from 2004 to 2013. No grids were monitored for the South East and Yorke Peninsula in 2004.

Looking at the grids individually during the last three seasons, the Innes NP grid has shown the highest breeding activity in 2011 with 4.2 active mounds/km^2, and in 2013 with 3.8 active mounds/km^2. Peebinga CP grid in the Murraylands had the highest activity in 2012, also showing 3.8 active mounds/km^2. This was followed closely by the Murray Bridge Army Range and Ettrick grids, also in the Murraylands, with 2.9 and 2.6 active mounds/km^2, respectively. Mt Boothby grid in the south east showed the highest breeding activity in that region, with 2.6 active mounds/km^2 in 2012.

Any further interpretation of grid activity would require knowledge of a range of other variables at play, such as regional rainfall, competitors (e.g. rabbits, goats, sheep), predators (e.g. feral cats), fire history, etc.

Monitoring of the grids in SA, along with other activities such as grid re-searches, would almost certainly not be possible without the dedication, energy and time put in by volunteers across the regions, each season. Regular volunteers have continued to monitor sites, and new volunteers have come on board. There is still room for more people to take part in the monitoring process. The number of volunteer hours recorded for the annual Malleefowl monitoring for each region in SA is shown in Table 3, with over 850 hours contributed across the state each year. This is outstanding, and does not include time spent on other activities such as grid re-searches, checking camera traps, predator control, etc.

The challenge to maintain coordination of the monitoring process at both regional and state levels remains, particularly given departmental changes in staff, priorities and resources. Unlike the Victorian Malleefowl Recovery Group or the North Central Malleefowl Preservation Group (WA), which conduct an annual training weekend pre-monitoring season, to train and refresh volunteers in the use of equipment, safety measures, the monitoring process and general networking, training in SA is undertaken within regions, is somewhat more informal, and relies on paid personnel with knowledge of the whole monitoring process. The transfer of data, photos and equipment has also provided challenges in some regions.

Despite these challenges, both staff and volunteers have maintained an enthusiasm which has so far prevailed, and we continue to strive to improve communications and support with staff and volunteers across regions.

Table 3. Number of volunteer hours per region in SA over the last three years, for Malleefowl monitoring (Source: National Malleefowl Monitoring Database, DEWNR internal regional reports).

	Murraylands	Eyre Peninsula	Yorke Peninsula	South East	Total
2011	632.5	119.2	32.0	193.5	1023.2
2012	510.0	133.7	54.0	175.0	885.7
2013	657.8	n/a	76.4	131.2	865.4

Yorke Peninsula Region

There is one Malleefowl monitoring grid on Yorke Peninsula, located in Innes National Park (NP) on the southern tip, and established in 1992. This grid represents the remnant coastal mallee woodland communities on southern Yorke Peninsula, where scattered populations of the birds continue to exist. Establishing a second grid in the region has long been on the DEWNR agenda, and several attempts have been made at locating a suitable site, however, this has not yet been successful.

An intensive fox control program commenced within Innes NP in 2004, prior to the reintroduction of Mainland Tammar Wallabies to the park. Baits were laid throughout the park on a fortnightly basis for the next seven years, which changed in 2012 to every three weeks. Fox control activities on southern Yorke Peninsula were further improved in 2008 with a community-based “Baiting for Biodiversity” program commencing. This program was instigated by Natural Resources Northern and Yorke, primarily to protect endangered species, including Malleefowl. As at 2014, there are 690 permanent bait sites across 80,000 hectares. Thirty-nine sites are located on private property and four on reserves. Two baiting rounds are conducted over a ten-week period in February/March and September/October each year, with a total of 2,800 baits laid each round. Average bait-take for the program is 35% per round. Testing of fox scats was carried out in 2013 and 2014, with feathers (from all birds) representing a very low percentage of the fox diet (5% 2013; 2% 2014). The overall scat analysis indicated that house mice, rabbits, sheep, kangaroos and insect material formed the major part of the fox diet. Whilst it is has been recognised that fox baiting has not necessarily increased Malleefowl breeding activity (Walsh *et al.*. 2012), it is notable that of all the grids monitored across southern SA, breeding density remains the highest on the Innes NP grid.

South East Region

Over the last three years, significant changes have taken place within DEWNR's Natural Resources South East (SE) Sustainable Landscapes Project Team (former Threatened Species and Habitat Recovery Team), in terms of structure, staffing and resources, in turn impacting on various recovery initiatives previously identified in the Regional Action Plan for Malleefowl. Despite this, five sites in the SE continue to be monitored annually, coordinated by part-time Project Officer Vicki Natt, who also coordinates grid searches when required. Funding for this position is currently provided by the Coorong Tatiara Local Action Planning Association, for a five-year period.

A re-search of the Mount Scott grid commenced in July 2012. After numerous attempts were made to complete the search process by various staff and volunteer groups, it was almost completed in September of that year. The search unveiled a further four mounds which were added to the list of known mounds.

Interpretive signs were installed in late 2011 at the entrance to a number of parks with important Malleefowl populations (Figure 4). This was made possible through a grant from Nature Foundation SA.

Predator control continues to occur in a number of the reserves in the Upper South East containing Malleefowl, including fox baiting and feral deer control.

The Sustainable Landscapes Project Team is currently working on reviewing and updating the SE Regional Action Plan for Malleefowl.

Figure 4. Interpretive signage at the entrance of Gum Lagoon CP, which contains significant Malleefowl habitat.

Murraylands Region

In DEWNR's SA Murray-Darling Basin NRM Region (SA MDB or Murraylands), funding has so far continued to be sourced for Mallee Eco Services (Dave and Heidi Setchell) to be contracted to coordinate the seasonal monitoring of twenty grids. Other Malleefowl recovery initiatives have started or continued, with great support from Chris Hedger, Fire and Threatened Mallee Bird Ecologist for the SA MDB.

A number of groups continue to be actively involved in the Murraylands Malleefowl monitoring program including: Friends of Gluepot Reserve, Friends of Riverland Parks, Scientific Expedition Group (SEG), Community Land Management, BirdLife Australia, Sporting Shooters SA and individual volunteers.

In the winter of 2013, DEWNR's Natural Resources SA MDB staff conducted an aerial survey over parts of Gluepot Reserve to determine the number of mounds located outside of the regular grids that are surveyed. This was undertaken so the region could then decide how best to manage the Malleefowl population in this area. Gluepot, and the wider Bookmark Biosphere area, represent the arid to semi-arid environment that Malleefowl inhabit – much of which is inaccessible by foot. A helicopter was deployed to survey 6,000 ha of the 54,000 ha Gluepot Reserve. Eighteen unused mounds were found, one active mound and one bird was seen. The area surveyed showed the mounds to be at a much lower density than the area currently monitored with seven grids. This could be an accurate reflection of mound density in this area, or perhaps the method did not pick up all possible mounds. The accuracy of this method of survey needs to be tested by flying over an existing grid, to help determine its usefulness. Whilst the aerial survey covered an area much quicker than could have been achieved on foot, it was expensive.

Another project currently in progress is reviewing and recommending future directions for a SA MDB predator control program for ground dwelling birds, including Malleefowl. This project commenced in 2009, and involved working with private landholders so that baiting foxes occurred twice a year: in autumn during the lambing season, and spring during the ground-dwelling bird nesting-season. A requirement was for participating landholders to fill out and send back report forms stating the number of baits laid and the uptake. Unfortunately, over the five-year project term, the return of reports was poor with numerous inconsistencies in data gathered. As such, no analysis of these data has been undertaken. Future project options include a pilot study aimed specifically at identifying impacts of fox baiting on known ground dwelling bird populations. The Bookmark Biosphere area has been suggested as a potentially suitable study site.

For information on further Malleefowl recovery activities in the SA MDB, see paper by Chris Hedger on ***Reproductive outputs of two comparable regions of the SA Murray–Darling Basin – Results and learnings for recovery*** and poster by Chris Hedger and Jarrod Pippos on ***Mallee Fires in the SAMDB – Losses, learnings and linings***.

Eyre Peninsula Region

The past three years have also seen major changes to staffing and structure within the Eyre Peninsula (EP) NRM Region. Long-time Malleefowl monitoring coordinator Andrew Freeman moved on to a new role in late 2011, although he still ran the monitoring program that season, and extra training and support was provided to EP volunteers by Graeme Tonkin and myself, in the 2012 season. During this time the once centrally operated office in Port Lincoln was split into sub-regions, with the four regularly monitored grids spread over three regions. This required training new staff in the monitoring process for the 2013 season. These challenges have been resolved, with staff and volunteers ready to tackle the 2014 season with renewed enthusiasm!

A re-search of the Munyaroo and Lock Grids is currently in progress. Both of these sites have not been searched for around ten years.

See report by John Read and Katherine Moseby on ***Comparison of three survey techniques for locating Malleefowl mounds***, whose study was undertaken on northern Eyre Peninsula.

Aboriginal Lands

See report from Adam Pennington on ***Malleefowl as a flagship species for indigenous land management in the Great Victoria Desert of Western Australia***, and report by Joe Benshemesh on the ***Progress towards a method of monitoring Malleefowl in the Maralinga Tjarutja Lands, South Australia***.

Statewide

In April 2013 Tim Burnard was appointed by the National Malleefowl Recovery Team (NMRT) as the National Malleefowl Recovery Program Coordinator. This position was funded by agencies Australia-wide, including five South Australian NRM Boards with Malleefowl in their regions. The position is part-time, for an initial period of three years. It is a very exciting period for the NMRT, as it provides for the first time an opportunity to drive and support Malleefowl recovery initiatives in a way not possible by a volunteer-based recovery team. One of the major components of Tim's role is to assist in facilitating community groups in the National Monitoring Program to ensure a coherent national approach, as well as work closely with the Adaptive Management Project Team to collate relevant nationwide information. Tim has worked very hard in his first year to meet and network with relevant agency staff, volunteer groups and individuals; to learn the monitoring system, become familiar with the national database, and visit the sites to assist volunteers. In South Australia Tim managed to inspect all regions, particularly during the 2013 season, and gained an understanding of the many facets of the monitoring system. Support from Tim will continue to be provided to all regions.

As the Adaptive Management Project continues to progress, a number of experimental sites will be set up in South Australia, most likely in the SA MDB. This also provides an opportunity for a number of stakeholders (land managers, agency staff, volunteers), to become involved in a recovery activity that makes use of the monitoring data with the potential to better inform management of this unique species.

Conclusion

The National Malleefowl Monitoring System continues to play a large and important role in the overall Malleefowl recovery program for SA. While there have been changes to staffing and funding arrangements in all regions, staff and volunteers have shown an extraordinary resilience and dogged determination to overcome the challenges that have presented, with the National Coordinator position providing further support. All regular grids continue to be monitored, and funding has been sourced through numerous avenues to upgrade monitoring equipment and fund contract staff.

The monitoring data from SA contributes to a program operating at a national scale at over 120 sites, which is in turn underpinning an Adaptive Management Project that aims to make the best use of these data. We look forward to continuing our contribution to improving Malleefowl conservation.

Acknowledgements

Many thanks to everyone involved in Malleefowl conservation in SA. Thanks to the following for providing information for this paper: Ken Rudd, Team Leader Sustainable Landscapes, Yorke Peninsula; Vicki Natt, Malleefowl Program Coordinator, South East; Dave Setchell, Mallee Eco Services, SA MDB; Melissa Herpich, Team Leader Sustainable Landscapes, South East; Greg Kerr, Landscape Ecologist, Eyre Peninsula. I am grateful for the expertise, advice and support given freely by Graeme Tonkin, who plays a crucial role, not only in SA but nationally, with setting up and testing hand-held devices and software; retrieving and analysing data; and trouble-shooting – among many other things – sincere thanks. Thanks also to Tim Burnard, for providing immeasurable support across the board in all Malleefowl-related activities in SA. Many thanks to DEWNR staff Angela Duffy and Nigel Willoughby for providing valuable comments on an earlier version of this paper, and to Colin Cichon for final editing.

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9. Malleefowl conservation action in Victoria 2011–14

Peter Stokie, President Victorian Malleefowl Recovery Group; Member National Malleefowl Recovery Team

Abstract

In Victoria Malleefowl almost exclusively live in large public national parks and reserves and are managed by Parks Victoria and the Department of Environment and Primary Industries through policy development and on ground actions including fire regimes and predator/competitor control.

Since 2000 the Victorian Malleefowl Recovery Group (VMRG) manage and carry out all monitoring of Malleefowl at 41 sites across all areas in Victoria where Malleefowl exist and, since 2004, have also re-searched or established the majority of these sites. Community groups and individuals have been actively involved in these searches. There remain a few unrepresented areas in the monitoring program especially in the Little Desert and the Western Big Desert, but the VMRG have added some additional sites to the monitoring area in this period.

The Wedderburn Conservation Management Network has organised extensive rehabilitation programs to protect Malleefowl in Victoria's most isolated remnant in the Wychitella NCR.

The VMRG organise annual training of monitors to carry out the monitoring and re-searching activities. The group has supported the PhD Genetics Research Project through participation in field activities. The VMRG has supported the ARC Adaptive Management Research project through the National Database and recent forums. Several additional research projects using the National Database have been commenced.

Planning and cooperative activities between Parks Victoria and local government shires has resulted in an expansion of the educational role of the VMRG through installing many large interpretive signs in key locations in northwest Victoria. School education kits are still being distributed.

Actions to protect Malleefowl habitat from inappropriate development have been pursued.

There are challenges for this forum and for Victoria to devise ways to maintain volunteer effort, address inappropriate fire regimes, to refine and improve the National Monitoring Manual, and to effectively use the National Malleefowl Monitoring Database.

Report

Malleefowl conservation in Victoria is undertaken by Parks Victoria, The Department of Environment and Primary Industries (DEPI) and two volunteer organisations, The Victorian Malleefowl Recovery Group and the Wedderburn Conservation Management Network.

Each group has specific roles, with Parks Victoria and DEPI working at a management level. Parks Victoria continues to support Malleefowl through on-ground weed, competitor and predator control and are actively involved in research projects through fox scat analysis, the Adaptive Management Project at the University of Melbourne and the Malleefowl Management Committee, which administers the Iluka Malleefowl Offset Fund.

Parks Victoria has funded the volunteer work of the VMRG on an annual basis. DEPI is less involved with Malleefowl as most Malleefowl in Victoria inhabit public lands managed by Parks Victoria. DEPI has a major role in fire management and fire research through the Hawkeye project.

The VMRG has a major role in monitoring the breeding success rate of Malleefowl through annual visitation to more than 1,200 mounds in 41 monitoring sites across the Malleefowl range in Victoria. VMRG membership is in excess of 100 volunteers and approximately eighty collect data in the field. The group also maintains more than thirty remote sensor cameras in two monitoring sites and also conducts systematic site searches of old and new sites on a periodic basis.

Data collection and analysis are proceeding along the usual lines, but three significant events have been noted in the years since the Renmark Forum.

2011 was a remarkably wet summer with some record rainfall events. It was difficult to gain access to some of our monitoring sites in January and February. Malleefowl did not seem to mind as there was an above average number of active mounds recorded (158). What was significant was the breeding numbers the following year in 2012 with a close to 20% increase in active mounds (218). Nothing like this number has ever been recorded to date.

The second remarkable event was the multiple sightings of Malleefowl on a ten kilometre stretch of road close to the isolated town of Patchewollock in spring and summer of 2012. It appears that cartage of canola along this road resulted in continual spillage and the word got around the Malleefowl community that free feed was available. It was not uncommon to see between 50 and 80 Malleefowl on the road verges in early morning and late evening for a period of three months. The Patchewollock pub ran a Malleefowl sighting competition and the pub blackboard highest count was eighty-eight.

The third event does not have a happy outcome. In the middle of January 2014 the Victorian mallee experienced catastrophic wildfires in Wyperfeld NP and surrounds. One of the reserves of more than 9,000 hectares, known as Bronzewing, was totally destroyed. This reserve was one of the best breeding areas for Malleefowl in Victoria. The monitoring site in this area consistently recorded 15 or more breeding pairs annually and 30 in the exceptional year of 2012. Up to 100 Malleefowl were counted fleeing the fire in one corner of the reserve. The fate of these birds is unknown, and it may be twenty or more years before Malleefowl breed in this reserve again.

In Victoria since 1996 volunteers have been collecting data from the same sites and the same mounds. All this data is now entered on to the National Malleefowl Monitoring Database. The database now contains twenty years of consistently high standard scientifically valid data and volunteers have collected it all. I stress this because I want to highlight the value of the work of VMRG members and the significant contribution they have made to recent scientific studies. All of the data is now able to be used for valid scientific research.

Victorian data stretches over a long period of time, covering different climatic conditions of drought, significantly different rainfall events, fires and heatwaves. There are no gaps in the data as VMRG monitors have visited more than 99% of mounds every year during the Malleefowl breeding period.

The most obvious use of the data is to record the annual breeding density of Malleefowl, and the data is used to produce an annual report based on the data. The reports are on the VMRG website. The long term data, particularly the location of active mounds in the Wandown and Menzies sites, has been used extensively in the genetics PhD studies undertaken by Taneal Cope and will be reported on in this forum. The complete dataset has been invaluable in the development of the ARC funded Adaptive Management in Arid and Semi-Arid Ecosystems research project.

Since 1996, volunteer monitors have collected fox scats at all mounds, and Parks Victoria has had these scats analysed to determine fox diet. The results indicate that Malleefowl are only a very small component of fox prey with small mammals predominant. Recently the fox scat analysis has been part of a major study in fox and wild dog prey undertaken by DEPI.

Another recent study using VMRG data is exploring vegetation types around active and non-active mounds in an attempt to determine how vegetation may impact on breeding success.

I guess some of us might wonder from time to time why were are visiting the same mounds year after year, and the significant research projects I have referred to provide the answer.

Since the Renmark Forum there have been a number of successes for the VMRG and a number of challenges.

Successes since the Remark Forum

Monitors continue to collect valid data from every mound visited, totalling 1,200 mounds at a 99% visiting rate.

The VMRG has established a Malleefowl kids group, who meet at the training weekend every year for loads of fun educational activities. The VMRG continues to work with schools and other youth groups who have been involved in searches and monitoring.

The VMRG has expanded its monitoring sites in the Little Desert and surrounds, and has increased the sites from two to six.

The group has continued to conduct track searches for Malleefowl prints and have driven more than 650 kilometres of tracks in the Northern Big Desert in 2012 in association with the Victorian Mobile Landcare Group.

Many projects have arisen through the use of Iluka mining Malleefowl offset funds, another item on the 2014 forum agenda. The most significant projects have been the installation of ten large interpretive signs in key locations in the Mallee Region and another six planned for the Wimmera Region. The fund has been used to produce a new information brochure. The fund has also enabled the purchase of several remote sensor cameras and their use will be outlined later in the forum.

Challenges

There are a number of recent government policies that will need to be addressed in the next three years. It is becoming increasingly difficult to attract government funding for a volunteer group such as the VMRG to continue its work and other funding avenues will need to be found.

The VMRG needs to liaise closely with Parks Victoria during the monitoring period. There is considerable restructuring within Parks Victoria, and the outcomes of the restructuring are not clear yet, but the VMRG may need to find ways to fit into the new structure to maintain the level of support currently provided by Parks Victoria.

Fire is a huge issue for Malleefowl, and on two levels, the VMRG needs to voice our concerns. The frequency and intensity of bushfires is increasing but there is no credible government policy to address climate change at a national level. The Victorian Government response to major bushfires arising out of the 2009 Royal Commission was to set up a regime of 5% targeted burns on public land in Victoria. To achieve this target large sections of prime Malleefowl habitat is subject to a burning regime that over time will destroy all long unburnt habitat bringing Malleefowl to the brink of extinction. We sometimes feel that we are a voice crying out in the wilderness, but it is important not to become disillusioned that our voices appear not to be heard.

The VMRG is committed to continuing our emphasis on annual data collection and supporting the conservation initiatives arising out of the National Malleefowl Recovery Plan. We appreciate the opportunity to outline what is happening in Victoria, and look forward to the discussions arising throughout this forum that may help us resolve some of the challenges we need to address.

10. Saving Our Species – Malleefowl Iconic Species Project

Marc Irvin, NSW Office of Environment and Heritage

Abstract

The NSW Government's Saving our Species program is a new conservation initiative. Unlike previous programs, threatened species have been allocated to one of six management streams depending on their distribution, ecology, security, and what is known about them. The six management streams are: site managed species, data deficient species, landscape species, partnership species, keep watch species and iconic species. The Malleefowl has been identified as one of only five iconic species, along with the Koala, Brush-tailed Rock-wallaby, Southern Corroboree Frog and the Wollemi Pine.

$1.2 million has been allocated for iconic species up to 2016 and, to date, the program has assisted Malleefowl conservation through the provision of canid pest ejectors or M44's (bait delivery device for fox control), funding the cost of baits for fox control, aerial survey and mound monitoring and some pilot monitoring work using motion-triggered camera traps. Over the coming year the program is planning to coordinate and support community engagement in monitoring Malleefowl in the Goonoo forest region and expand camera monitoring on mounds in suitable habitat in the central mallee of NSW. We are also investigating the potential for using LiDAR (Light Detection and Ranging) technology to locate mounds in areas where other methods are impractical.

Saving Our Species Program

In NSW threatened species are listed under the *Threatened Species Conservation Act* (TSC Act) 1995. The Act contains schedules for species, populations, communities and key threatening processes, and also has provisions for various threat categories - vulnerable, endangered, critically endangered and presumed extinct. Up until 2007, recovery and management of listed entities was implemented via recovery plans. However, the rate of recovery plan preparation was not keeping pace with the rate at which new species were being listed. The amount of government investment in preparing plans was disproportionately high compared to investment in recovery actions.

The NSW Threatened Species Priorities Action Statement (PAS) was introduced in 2007 to streamline the recovery process from recovery plans to detailed and targeted actions. The PAS aimed to identify strategies to help recover threatened plants and animals, establish priorities to implement these strategies, identify actions for all listed species, populations and ecological communities, and identify actions to manage key threatening processes.

A review of the PAS in 2011 found that while significant worthwhile conservation work was being undertaken, it was unclear to what extent this work benefited threatened species, and so recommended improvements.

Through the PAS review, eight recommendations were made:
1. Establish six new management streams to better target the management of each threatened species.
2. Enhance uptake of the PAS and raise community awareness.
3. Make PAS actions, and their timing, more specific.
4. Provide a framework for local actions to contribute to state-wide outcomes for species.
5. Target investment at the minimum set of actions that are crucial for securing a species.
6. Develop a sound, repeatable and transparent process for prioritising effort between species state wide.
7. Develop a process for monitoring and reporting on the outcomes of projects and actions for threatened species.
8. Develop a simple, user-friendly database to support program delivery.

Saving Our Species

Saving Our Species (SOS) is a new conservation program in NSW developed to deliver on the recommendations of the PAS review.

The SOS program aims to maximise the number of threatened species that can be secured in the wild in NSW for 100 years. Unlike previous programs, Saving Our Species:

- aligns everyone's efforts under a single banner, so investment in threatened species conservation can be accounted for;
- assigns threatened species to different management streams; and
- invites the NSW community and businesses to participate in threatened species recovery.

Through the SOS program, threatened species listed under the TSC Act are allocated to one of six management streams depending on their distribution, ecology, security, and what is known about them.

The six management streams are:

Site- managed species (406 species)
- Require site-based management.
- Projects that identify management sites and costed management and monitoring actions at sites.

Landscape-managed species (132 species)
- Distributed over large areas and subject to landscape level threats – habitat loss and degradation.
- Managed through existing broad scale habitat programs and management of NPWS reserves.

Data Deficient species (103 species)
- Insufficient knowledge to develop management response.
- Prioritised based on feasibility of filling gaps and conservation status (TSC and *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999*).

Partnership species (151 species)
- Less than 10% of their populations in NSW.
- Projects will be developed for EPBC Act listed species that have key populations in NSW and prioritised.

Keep watch species (97 species)
- Rare but not threatened or more recent data indicates that more abundant/less threatened than when listed.

Iconic species (5 species)
- Highly valued by the community.
- Currently 5 species – Koala, Brush-tailed Rock-wallaby, Southern Corroboree Frog, Wollemi Pine and Malleefowl.
- Projects based on recovery plans.

Priorities for action under the SOS program are species in the site-managed, iconic, data-deficient and landscape-managed streams. Direct action will be considered for nationally listed partnership species but is not expected for keep watch species unless threats substantially increase. Revised strategies for landscape-managed species, endangered populations, threatened ecological communities and key threatening processes will be developed next.

Malleefowl Iconic Species Project – to 2014

Malleefowl in NSW are listed as Endangered under the TSC Act 1995 and have been allocated to the Iconic Species management stream of the SOS. The Malleefowl Iconic Species Project was first funded two years ago to assist and enhance existing Malleefowl projects. Over the past two years this assistance has been provided to several projects across NSW.

In NSW predation by the European Red Fox has been listed as a key threatening process under the TSC Act (1995) and a Fox Threat Abatement Plan (TAP) has been approved under the legislation to reduce this threat. The Fox TAP prioritised threat reduction at 53 sites to benefit a range of threatened species, including four sites which target fox control towards Malleefowl recovery. The SOS has assisted at all of these Fox TAP sites.

Goonoo National Park & State Conservation Area

The SOS has funded the purchase of 1080 baits for landholders surrounding the Goonoo National Park (NP) and State Conservation Area (SCA). The landholders undertake coordinated fox baiting assisted by the Central West Local Land Services. The program has been recognised nationally and has been running for more than 20 years. The SOS is pleased to have been able to assist with crucial funding to assist this program to continue.

Also, working with the National Parks and Wildlife Service in Dubbo the SOS contributed to Goonoo NP and SCA through:

- *Mound excavation* - During the 2012/13 breading season only one mound was active. This mound was excavated several times and found that six eggs in total were laid. Of the six eggs, four appeared to have hatched while two remained intact without hatching more than 100 days after being laid.
- *Monitoring* - Mound monitoring using the National Malleefowl Monitoring System was undertaken in the 2009/10 breeding season, with opportunistic monitoring of active mounds since then. Despite visits to mounds known to be active in recent years, there have been no active mounds identified in either the 2013/14 or 2014/15 seasons. Two records, including one set of tracks and one observation of an adult Malleefowl, from August 2014 are the most recent Malleefowl sightings in the Goonoo.
- *Camera traps* - camera monitoring of the only active mound known in 2009/10 identified fox, deer, echidna, emu, goat, kangaroo, wallaby and Malleefowl visited. Apart from Malleefowl, goanna, swamp wallaby and goat were the most common visitors.
- *Image processing* - assistance was provided to help tag images from camera traps used to monitor foxes in the 2014 Fox TAP program in the Goonoo NP and SCA.

Western NSW – Nymagee

The Western Local Land Services (LLS) initiate a high conservation value program to provide incentives for landholders to undertake conservation management on their properties. Two properties in the Nymagee region of central NSW were assisted to install fencing to prevent goat access and to implement a fox baiting program. The SOS program assisted during the development of the project and continued to be involved in monitoring for the first three years. Since the beginning of the project:

- Aerial survey of approximately 6,000 hectares of mallee habitat in the Nymagee region has located 20 new mound locations (observer provided by SOS).
- Goat and fox control across 3,000 hectares of known Malleefowl habitat.
- Landholder management agreements of 15 years duration.
- Greater than two years of camera trap data from two active mounds (SOS - to be reported in the coming year).

Yathong, Round Hill (Central Mallee), Tarawi and Nombinnie Nature Reserves and Nombinnie State Conservation Area

At several locations in NSW, canid pest ejectors or CPEs (also called M44 ejectors) have been supplied to supplement fox control efforts for the benefit of Malleefowl. CPEs are a bait delivery device targeted at foxes and wild dogs. This spring loaded device only triggers when enough force is applied in a specific direction, which only foxes and dogs can do.

Camera traps have also been deployed as part of a pilot program to assess their potential as a monitoring tool to assess threats to Malleefowl at the mound, and quantify chick emergence:

- 150 CPE devices have been provided to NPWS for deployment throughout the Central Mallee, and 210 have been provided to Tarawi NR and Mallee Cliffs National Park (NP).
- Three camera traps have been operating across Tarawi NR and Mallee Cliffs NP, and two have also been deployed in the Central Mallee.

Each CPE activation is almost a certain fox kill. Therefore data in the example from Tarawi NR (Figure 1 below) potentially represents a significant further reduction in foxes that are not being taken out by other ground baiting techniques. There are 90 CPE devices deployed on Tarawi NR, they are all checked once a month. There is also ongoing baiting via buried ground baits at this site.

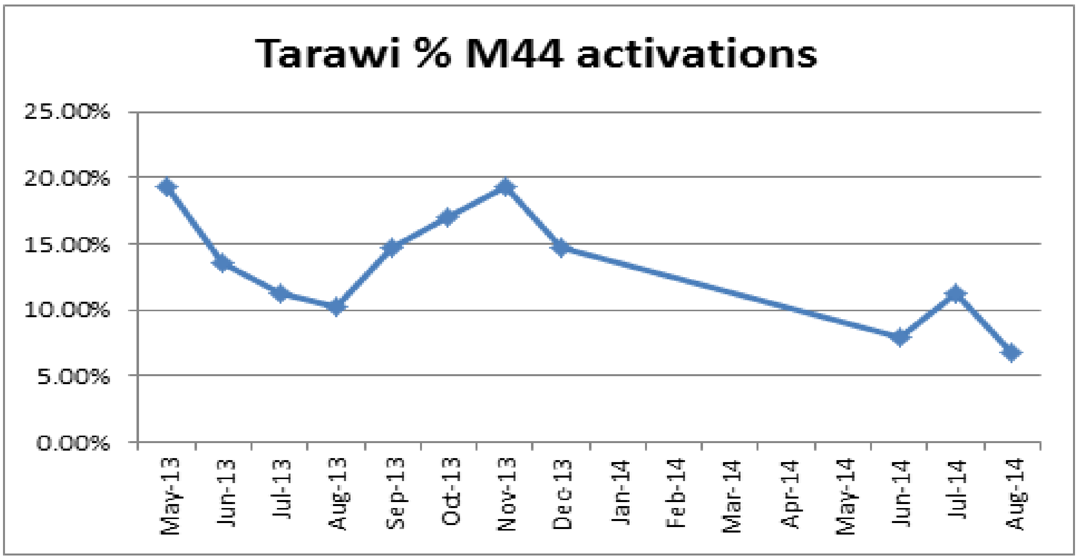


Figure 1. Percentage of CPE activations at Tarawi NR (Source: NPWS Lower Darling Area). NOTE: The devices were not set from December 2013 to May 2014 due to high ambient temperatures melting the seal of capsules containing the 1080 poison (no longer an issue).

Malleefowl Iconic Species Project – beyond 2014

Goonoo Malleefowl Group

Malleefowl data available for Goonoo region has been built up over many years of Forestry, National Parks, field naturalists, researchers, local residents and other individuals visiting the region reporting their observations. Since a wildfire in the forest in 2007, that burned approximately 33% of the park including 35% of known mound locations, spatial knowledge of Malleefowl in Goonoo is lacking and needs to be rebuilt. Only three mounds are known to have been actively worked by Malleefowl since the fire. The last active mound was from the 2012/13 breeding season and, no mounds are known to have been prepared for the 2014/15 season. No coordinated ongoing monitoring of the population has been undertaken to date. Figures 2 and 3 below show the distribution of Malleefowl records in the Goonoo region.

The SOS is assisting the formation of a stakeholder group representing community interest, management and specialist expertise to contribute to Malleefowl recovery in the Goonoo NP and SCA to rebuild the knowledge base and use that to focus recovery efforts. The Goonoo Malleefowl Group (GMG) will represent a range of relevant knowledge and aims to:

1. meet to identify and engage in local Malleefowl activities;
2. contribute to identifying and development of management options;
3. engage the community in on–ground activities that benefit Malleefowl.

The establishment of the Goonoo Malleefowl Group (GMG) is about engaging the community and other stakeholders in the development of management options aimed at long-term sustainability of Malleefowl in the Goonoo NP and SCA. The stakeholder group will work closely with land managers to develop practical actions that prevent Australia's eastern most population of Malleefowl from declining. Potential projects to which the group can contribute are a knowledge audit, Malleefowl mound searches, establishing an easy process for park visitors to report Malleefowl sightings, exploring the potential of remote sensing methods to locate mounds, determining habitat requirements, and assessing needs for population supplementation. This project will raise the profile of the species in the local community and aims to foster collaboration and ownership between the Office of Environment Heritage and those interested in Malleefowl in the region.

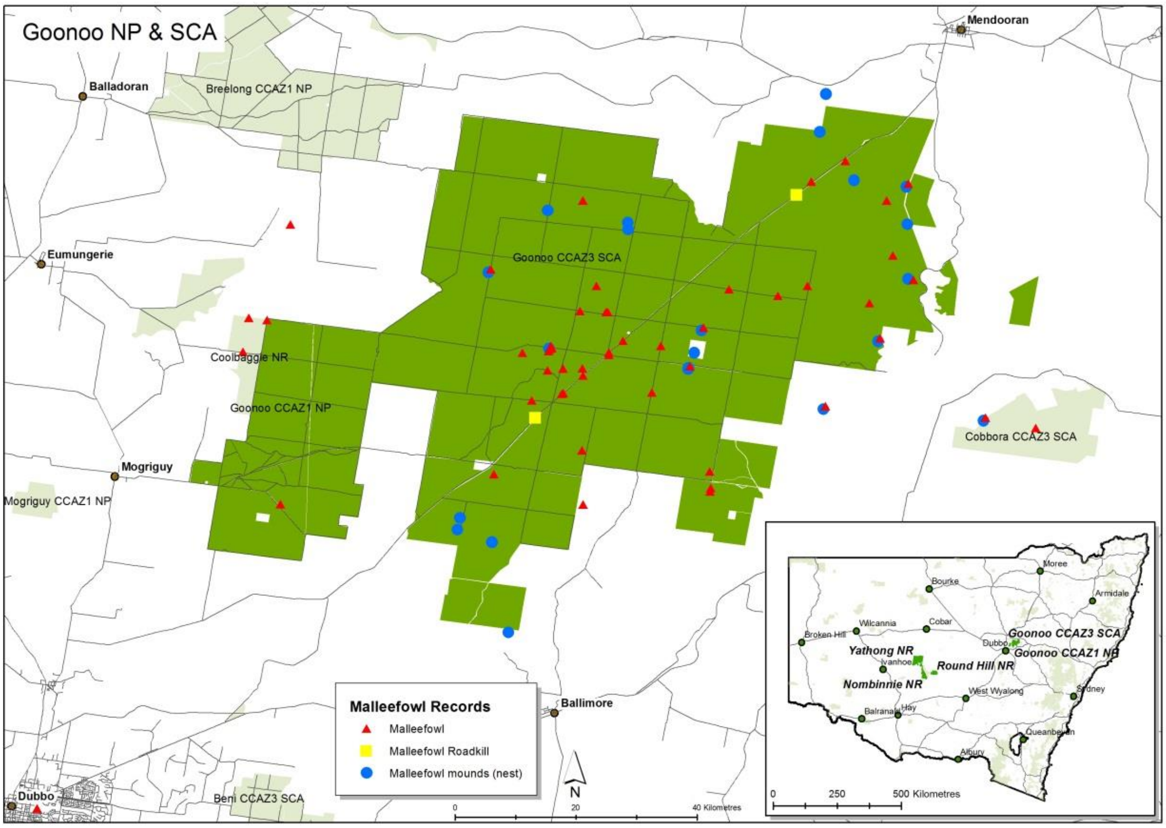


Figure 2. All Malleefowl records from the Goonoo NP and SCA (Source: Atlas of NSW Wildlife).

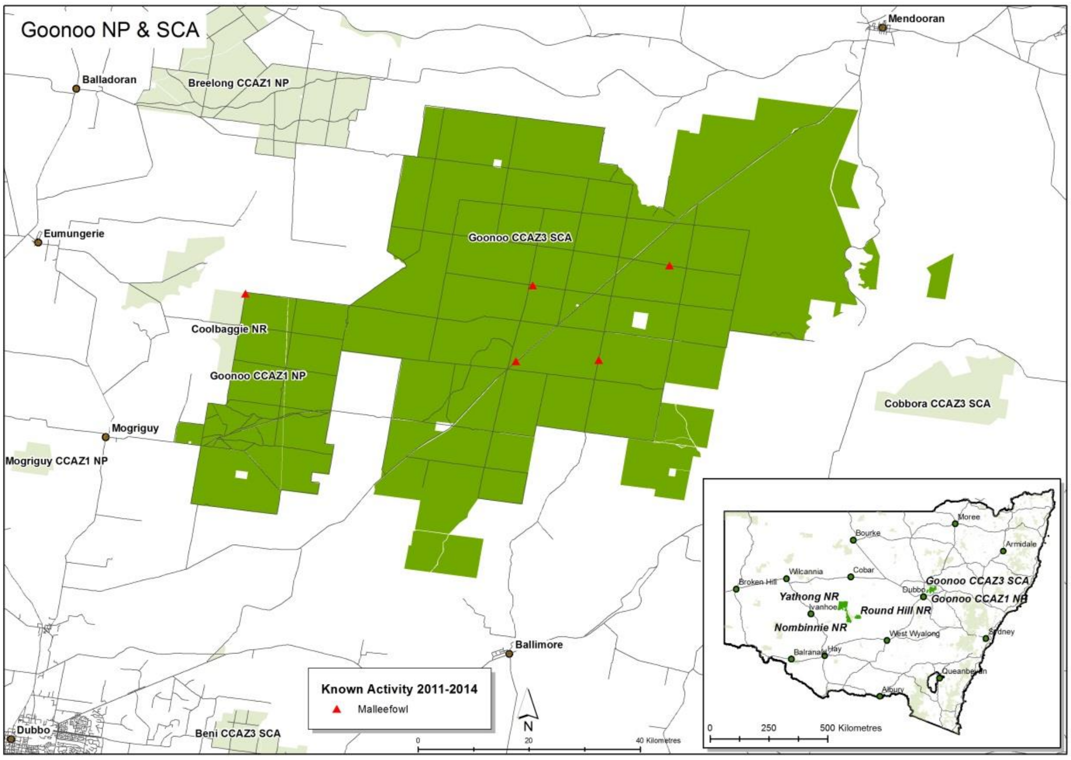


Figure 3. Malleefowl records from the Goonoo NP and SCA from 2011 to 2014 (Source: Atlas of NSW Wildlife).

Aerial Survey in the Central Mallee

In the Central Mallee (Yathong NR, Nombinnie NR & SCA and Round Hill NR) there has been long-term investment in research and threat control to benefit the Malleefowl as well as other species. Additional investment by the Western Local Land Services (LLS) and the Invasive Animals Cooperative Research Centre (IA CRC) in the areas surrounding the NPWS estate, have provided collaborative work opportunities. The new Fox Threat Abatement Plan (FoxTAP2) Site Plan also formalises management actions to control fox predation. The SOS project builds on the FoxTAP2 Site Plan by providing resources to conduct aerial survey in areas of Malleefowl habitat and capture information on the current spatial distribution and breeding population size, which is vital for management for the species.

Figure 4 shows Malleefowl sightings in the Central Mallee region and known mounds from previous aerial surveys. The last survey on park (a mound to mound survey) was in 2012 which was focused on a portion of Yathong NR. The objective of aerial survey this year is to search habitat to locate new mounds which has not been done since around 2003.

The opportunity for SOS to partner with the FoxTAP2 Site Plan to fill knowledge gaps in the spatial distribution of active Malleefowl mounds and breeding population size is a timely one as the new site plan contains revised and new fox control techniques. Gaining this knowledge now provides baseline data from the point of change in management and can be used to measure success of the new FoxTAP2.

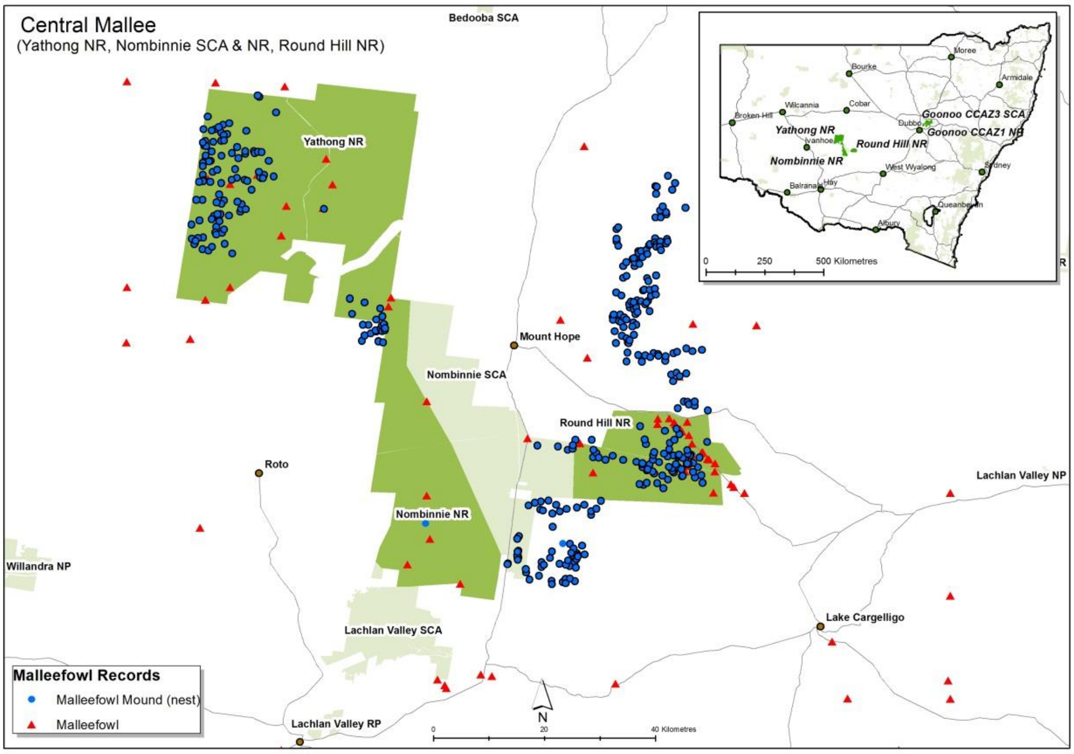


Figure 4. All known Malleefowl records from the Central Mallee (Source: Atlas of NSW Wildlife; NPWS Mid West Area; IA CRC).

Malleefowl mound monitoring – Camera traps

Motion triggered camera traps will help to monitor active Malleefowl mounds to measure threats to Malleefowl, mounds, eggs and mound maintenance by visiting fauna.

Yathong NR, Nombinnie NR and SCA and Round Hill NR

In the Central Mallee, the SOS Malleefowl Iconic Species Project is aiming to contribute to Malleefowl monitoring through the use of motion triggered camera traps. The camera trap monitoring on active Malleefowl mounds aims to measure threats posed by fauna species visiting the mounds. Quantifying threats through 24/7 monitoring has previously been constrained by logistical and resource constrains. A volunteer base to assist in the field and in image analysis will be established, thus providing an opportunity for interested community members to be directly involved in Malleefowl recovery. Data will be correlated with results from broader monitoring associated with the FoxTAP2 program. There is potential for camera trapping to be a valuable part of a monitoring strategy and provide quantified evidence of threats directly from the Malleefowl breeding population. The project also aims to develop tools and recommendations that can be used to guide Malleefowl recovery elsewhere in NSW, both on and off-park.

The current opportunity coincides with the start of the new FoxTAP2 Site Plan which incorporates a fox control strategy with changed baiting frequency as well as deployment of CPE devices. Also, pilot data from cameras deployed elsewhere indicate foxes may be a threat at mounds despite baiting. Other fauna species potentially posing a threat at the mound can also be measured through camera trap techniques. The camera trap program aims to identify predation or disturbance threats posed by other species at the mound from which appropriate management responses can be developed and refined.

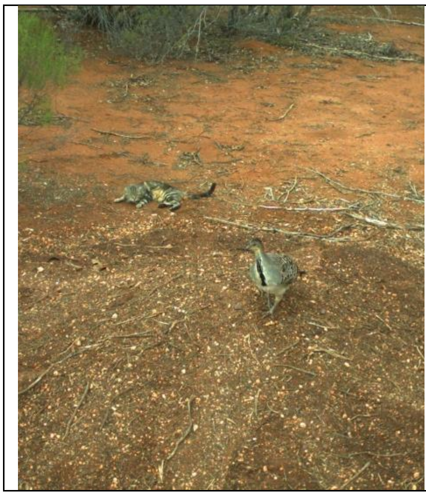
Observations from data so far

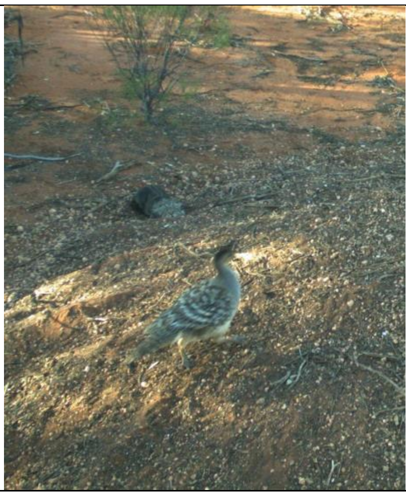
The camera trap project aims to capture image data from a representative sample of the Malleefowl population on Yathong NR; from past knowledge there may be up to 12 or 15 mounds active during a good breeding season. The SOS Iconic Species Project has the potential to monitor up to 15 mounds (i.e. up to 100% of the active population). Currently the project aims to capture data from an entire breeding season, with data analysis expected to provide guidance on the longer term value of continuing monitoring beyond the first year period (including recommendations for cost efficiency measures). Within current resources the project will focus on sampling mounds within Yathong NR, although Malleefowl also occur in Nombinnie and Round Hill NRs and surrounding areas. The Invasive Animals CRC is undertaking Malleefowl recovery work on nearby properties including camera trap monitoring and the potential to combine information and data for analysis and reporting purposes is being discussed.

Guided by the National Recovery Plan the SOS program hopes to gradually build knowledge and incorporate all Malleefowl recovery projects and action into the SOS system. This will allow more coordinated and strategic approach to Malleefowl recovery in the future.

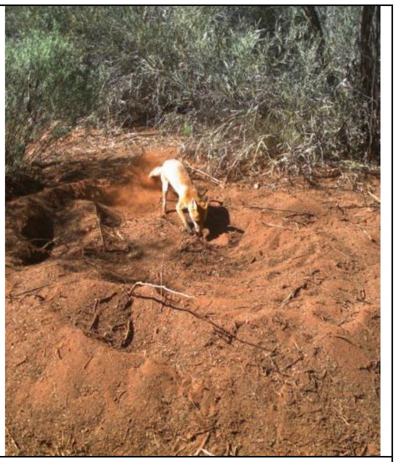
Interesting Camera Trap Observations

Below are some interesting observations from our Malleefowl mound camera traps. Over the coming year we will be working to provide quantitative image analysis that can inform threat management at our sites.





Feral Cats
Though not a regular occurrence we have observed on several occasions feral cats sitting by the mound watching Malleefowl. On one occasion the cat appears to attack the Malleefowl but all that is captured on the camera is a heap of feathers spread across the mound; both Malleefowl returned to continue working the mound.



Fox disturbance and egg predation is a regular occurrence at our unbaited mound locations.

Lace monitors appear to be occasional visitors to Malleefowl mounds, however at Goonoo we have one mound that was regularly visited by at least 10 different lace monitors during one season. This included several large monitors digging deep into the mound. The images above show the Malleefowl defending the nest from a lace monitor attack.

Acknowledgements and Stakeholders

Thanks to the all the individuals and groups who provided advice, information and comment for this paper, the Forum presentation and the SOS program in NSW, including Ray Dayman (NPWS Buronga), Melanie Bannerman (NPWS Dubbo), Rob Wheeler (OEH Science Division), Jason Wishart (IA CRC), Milton Lewis (CT LLS), Amanda Jowett (OEH Dubbo).

Thanks also to the Office of Environment and Heritage Supplementary Pest Control Team, the NSW Fox TAP Program, the Saving Our Species Team and the OEH North West Region Ecosystems and Threatened Species Team.

Further information

http://www.environment.nsw.gov.au/SavingOurSpecies/iconic.htm

http://www.invasiveanimals.com/research/phase2/commercialisation/mallee-recovery/

http://dubbofieldnats.org.au/

11. WA Malleefowl Network: a progress update

Dr Blair Parsons, MWH Australia; Member National Malleefowl Recovery Team

Abstract

The WA Malleefowl Network, a once functional means of facilitating information-sharing and coordination of activities, became largely inactive in 2009 subsequent to the withdrawal of funding support for threatened species. Despite the impressive scope and magnitude of activities conducted for Malleefowl management and conservation across Western Australia the approach tended to be somewhat disjointed, with community groups, industry, non-government organisations (NGOs) and government agencies conducting activities often with a lack of knowledge of other activities being undertaken. Recently, the Network has been reinvigorated thanks largely to the cooperative efforts of the WA Department of Parks and Wildlife (DPaW). To this end, a meeting was held in January 2014, attracting a number of attendees from a range of different environmental sectors. The meeting sought to summarise the priorities of the Network in terms of Malleefowl conservation and management, and also sought to determine what the Network's role should be into the future and the types of tasks it should tackle.

Key themes to come out of the meeting included:
1. Funding a coordinator to maintain/facilitate the Network;
2. Data sharing and collaboration (e.g. between community groups, mining companies, government and NGOs);
3. Linking with the National Recovery Team;
4. Better definition of the species' distribution;
5. Focus on specific recovery actions.

It is hoped, with the support of a diverse and skilled group of stakeholders, the Network will represent an effective forum for coordinating and facilitating effective action for Malleefowl conservation and management into the future.

Introduction

This paper, and the accompanying presentation, summarise the key developments and activities associated with the WA Malleefowl Network in Western Australia. Additionally, the paper describes current activities undertaken by selected people working with Malleefowl in Western Australia.

A Brief History

- The WA Malleefowl Network was "conceived" in 2004 as part of the Threatened Species Network, administered by World Wildlife Fund (WWF) Australia.
- The Network was driven by a WA Malleefowl Facilitator, hosted by WWF Australia.
- Between 2005 and 2009, positive communication amongst interested parties was actively maintained and the Network was involved in or supported a number of active projects across Western Australia including the following:
    - research (in collaboration with CSIRO Sustainable Ecosystems and the Malleefowl Preservation Group (MPG));
    - monitoring and training (in collaboration with the MPG, North Central Malleefowl Preservation Group, Merredin Malleefowlers and other community groups); and
    - support for funding applications (in collaboration with community groups and not-for profit agencies).
- After this time, the Network entered a hiatus as Threatened Species Network funding ceased. Community groups working with Malleefowl continued with their excellent on-ground work. However, communication between groups and coordination of activities largely ceased.
- In January 2014, DPaW hosted a meeting to gauge interest in the Network and determine a way forward.

Who is involved?

- Community Groups and Traditional Owners: The key community groups in the WA wheat belt include the Malleefowl Preservation Group, North Central Malleefowl Preservation Group and several other smaller entities. Traditional Owner Groups actively involved in Malleefowl conservation and management include Ngadju Conservation Group and Pila Nguru (Spinifex Land Management).
- Mining companies: typically, Malleefowl is intersected by mining activity associated with iron ore and gold projects, particularly in the Goldfields and mid-west WA.
- Agencies: WA Department of Parks and Wildlife (DPaW).
- Non-profit organisations: Bush Heritage Australia (Malleefowl occur on Eurardy, Chereninup Creek, Monjebup, Beringa and Charles Darwin Reserves, all managed by Bush Heritage Australia), Australian Wildlife Conservancy (Malleefowl occur on Mt Gibson Sanctuary), Birdlife Australia.
- Environmental Consultants: a substantial number of consultants are actively involved in the survey, monitoring and management of Malleefowl, primarily on behalf of industry.
- Natural Resource Management groups: Wheatbelt NRM, South Coast NRM, Rangelands NRM, Northern Agricultural Catchments Council.
- Universities: at present there are several researchers working on projects that are of specific relevance to Malleefowl conservation and management, including Tim Doherty (Edith Cowan University) and Keren Raiter (University of Western Australia).

A meeting in January 2014

In January 2014, a meeting of the WA Malleefowl Network was facilitated and hosted by DPaW to discuss the top issues or priorities in relation to the conservation and/or management of Malleefowl in WA (Figure 1). The following represents the key priorities for the Network (and the National Recovery Team) to contribute to, as decided at this meeting:

- defining WA specific recovery actions and priorities, and also a list of research questions;
- feedback: report on information specific to Western Australia;
- threat abatement as a priority:
  - research into the impacts of fire to allow the consideration of Malleefowl in fire management guidelines;
  - feral predators;
- reassessment of the listing status;
- coordination and collaboration:
  - establishment of an effective working relationship between DPaW, community groups and others with the National Recovery Team;
  - guidance on monitoring site selection, collation of existing survey data;
  - data sharing and data collection and management protocols;
  - better utilisation of monitoring data to complement key recovery actions;
  - capture the potential of mining companies - many operate within known distribution, and are required to mitigate for impacts on Malleefowl - it would be preferable for them to contribute to existing programs rather than establishing new programs;
- establish a better understanding of the species distribution:
  - retain and collate “absence” data to complement presence data;
  - understand the species’ distribution in relation to habitat - presence of mounds doesn’t necessarily indicate the presence of birds.

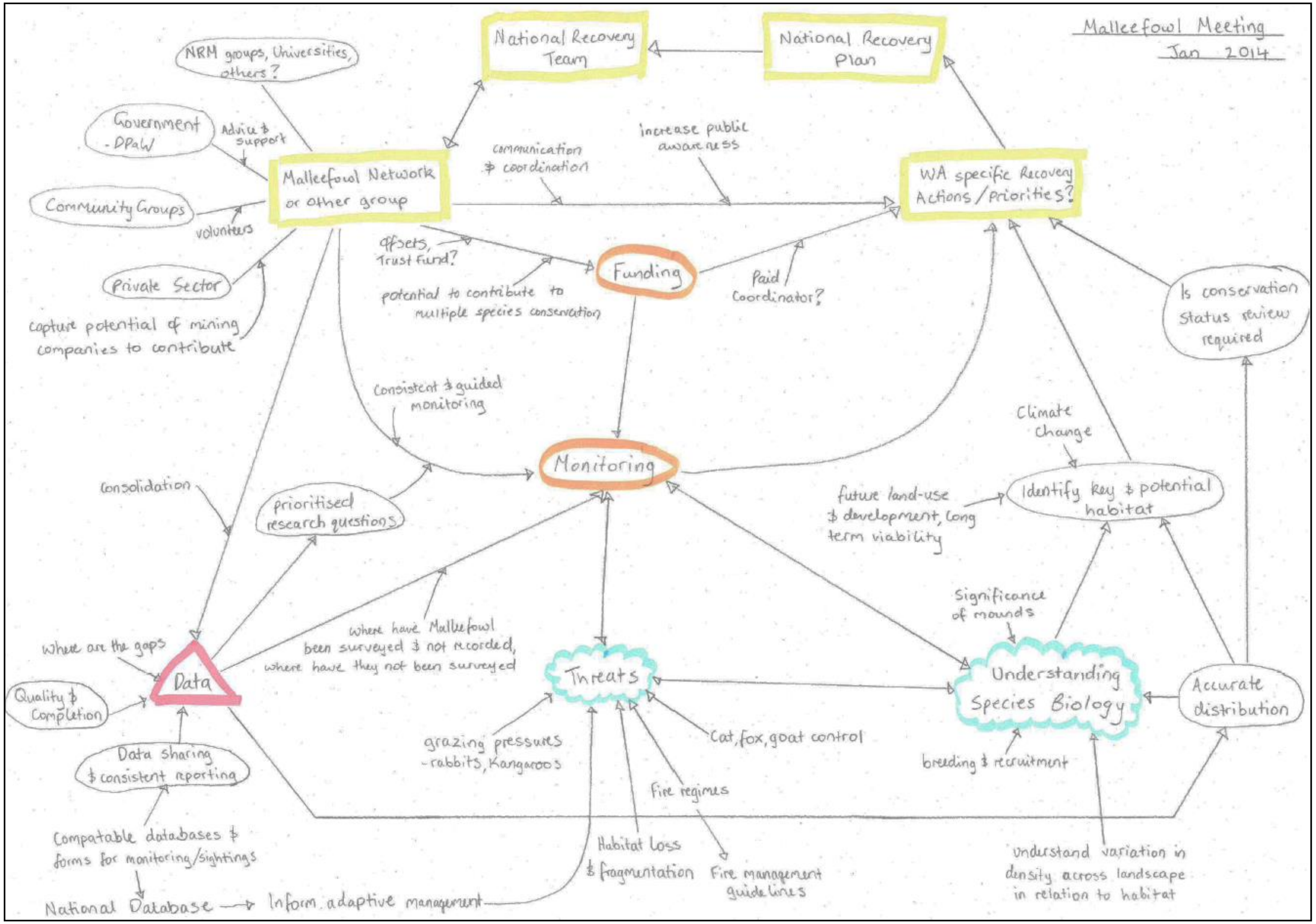


Figure 1. A diagrammatic representation of issues associated with Malleefowl conservation and management in Western Australia.

Current Activities

Edith Cowan University / Bush Heritage Australia

- Ecologists are building a predictive model of habitat suitability for Charles Darwin Reserve, Mt Gibson and neighbouring properties.
- Modelling will be based on mound surveys, camera trapping and opportunistic sightings 2004 – 2014.
- The model will aim to identify optimal areas of Malleefowl habitat with regard to vegetation types and fire history.
- It is intended for this model to be shared with landholders and land managers in the region.
- Researchers are interested to hear from anyone else working on Malleefowl and fire in Australia; please contact t.doherty@ecu.edu.au for more information.

Australian Wildlife Conservancy

- A large survey was conducted for Malleefowl at Mt Gibson Sanctuary. This survey, undertaken by the Malleefowl Preservation Group, encompassed two 1,000 hectare areas.
- The initial baseline survey was conducted in April-May 2010, and subsequently in October-November 2010.
- Volunteers have monitored known mounds since that time in 2012, 2013 and were scheduled to return in 2014.
- All data from the survey areas is entered into the National Database.
- One of the survey areas now lies on the inside of a newly-built predator-proof fence (feral control works inside have now commenced); the other area is on the outside of this fence.
- This fortuitous experimental design of the two areas presents opportunities for research, which may be pursued in short- to medium-term.

Keren Raiter – University of Western Australia

- Project Title: 'Mitigating Mining's Enigmatic Ecological Impacts in Australia's Great Western Woodlands'.
- PhD: School of Plant Biology, UWA.
- Supervisors: Prof. Richard Hobbs, Dr Suzanne Prober (CSIRO), Prof. Hugh Possingham (University of Queensland), Dr Leonie Valentine (University of Western Australia).
- Study Area: the Great Western Woodlands, which is the largest remaining temperate woodland in the world. This area is home to extensive mineral exploration and extraction, mainly for gold, nickel and iron ore.
- Focus: Improving our understanding of ecological impacts of mining and exploration that tend to 'slip under the radar' of formal impact assessments, including, cumulative impacts, offsite impacts, cryptic impacts and secondary impacts.
- Areas of interest:
    - spatial analysis – mapping exploration gridlines and access tracks and assessing the extent of their impacts on ecological values (e.g. mapped vegetation communities and intactness).
    - a year-long investigation of how roads and tracks in relatively undisturbed landscapes affect the activity of cats, foxes and dingoes using motion-sensor cameras and surveys of scats and prints.
    - an investigation into the effects of roads and tracks on the movement of water across landscapes: an important issue in a water-limited system.
- Relevance to Malleefowl: the project targets two of their threats – changes in predator dynamics, as well as habitat destruction or degradation in an important, intact, poorly studied and extensive portion of the species range.

Ngadju Conservation Group and GondwanaLink

- Norseman's Ngadju community are protecting and conserving the Vulnerable Malleefowl and caring for key sites in the Great Western Woodlands of WA.
- Funding: Rangelands NRM's Caring for our Country Sustainable Environment Program, managed by Gondwana Link.
- Aim: To build capacity of the Ngadju community to manage their traditional lands, threatened species, with an initial focus on Malleefowl.
- Increased knowledge of critical Malleefowl habitat is needed across the Great Western Woodlands.
- Initiatives to date:
  - An initial fire management program; a project mapping water trees; two significant knowledge documentation programs with CSIRO; and development of a Conservation Action Plan.
  - Ngadju will also be trained in Malleefowl surveying techniques, undertake surveying of Malleefowl presence and habitat within the Great Western Woodlands.
  - The Malleefowl is a useful flagship species which will help Ngadju develop initial skills before doing similar work with more cryptic threatened species.

Cliffs Asia Pacific Iron Ore Pty Ltd

- Cliffs have been surveying for and monitoring Malleefowl since 2003, and as of 2013 a total of 299 mounds have been recorded in 4,000 hectares of survey area.
- Monitoring is undertaken as per the Manual for National Malleefowl Mound Monitoring with results uploaded to the National Database.
- During mining exploration, staff have discovered Malleefowl using sumps created for exploration work for establishment of new mounds. This may have the potential to manipulate birds near roads; however, if reintroducing the species into an area where all the old mounds are hard and degraded, fresh, loose earth might facilitate successful reproduction.

Table 1. Number of active Malleefowl mounds recorded during monitoring at Mt Jackson Iron Ore Project

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
No. total mounds	36	70	91	120	92	111	52	231	101	117	151
No. active mounds	4	2	9	9	1	3	8	15	9	13	31
% Active mounds	11.1	2.9	9.9	7.5	1.1	2.7	15.4	6.5	8.9	11.1	20.5

Karara Mining Ltd

- Recent annual monitoring identified 11 active mounds. One of these mounds was observed within 600 metres of mining activity and was subsequently monitored using motion cameras, during which a hatching event was observed.
- Birds tending this mound were identified as suitable to track using a GPS/UHF tracking device.
- The bird was caught successfully by Bold Park Bird Banding group using a specifically designed trap. A tracking device was attached and a band was applied to one of the individual's legs.
- This bird was released successfully, unfortunately the tracker detached after 20 minutes.
- The bird was thought to have abandoned the mound. However it returned after ten days and subsequent to its return it tended the mound every second day in preparation for breeding.
- A second attempt at fixing a transmitter (on a different bird tending a different mound) is expected to produce better results due to refined attachment methods.

Where to from here?

- Funding a coordinator to maintain / facilitate the WA Malleefowl Network.
- Data sharing and collaboration (e.g. between community groups, mining companies, government and non-government organisations).
- Establishing stronger and more active links with the National Recovery Team.
- Better defining the species' distribution within Western Australia.
- Focusing on WA-specific recovery actions to achieve on-ground outcomes.

Acknowledgements

- Dr Manda Page, Rebecca Kay, Abby Thomas, Jennifer Jackson – DPaW
- Those who responded to requests for information:
  - Tim Doherty - Edith Cowan University
  - Keren Raiter – The University of Western Australia
  - Laura Ruykys - Australian Wildlife Conservancy
  - Jeremy Shepherdson, Kylie Wilkinson – Cliffs Asia Pacific Iron Ore Pty Ltd
  - James Sansom – Karara Mining Ltd
  - Mike Bamford – Bamford Consulting Ecologists.

12. Reproductive outputs of two comparable regions of the South Australian Murray–Darling Basin – Results and learnings for recovery

Chris Hedger, Department of Environment, Water and Natural Resources South Australia; Member National Malleefowl Recovery Team

Abstract

What started as a project to determine if plague locust spays had any obvious effects on Malleefowl reproductive output (no detectable impacts), soon developed into a much more versatile project. Regular nest excavations were utilised to monitor the reproductive output across the breeding season at a number of nest sites south of the River Murray in the 2010-2011 breeding season. Subsequent surveys the following year were carried out across a similar number of sites north of the river where grid monitoring indicated greatest regional concern. The results from both these surveys will be explored and results will be stacked up against one another. Comparisons will also be made between historic and national results elsewhere to provide perspective. Further discussion will then demonstrate how these results have improved regional understanding of Malleefowl productivity and helped to refine regional recovery prioritisation foci.

Background

The Malleefowl is a prominent threatened species within the mallee landscapes of the South Australian Murray-Darling Basin Natural Resources Management Region. Its size and widespread conspicuous use of dirt mounds as a breeding tool has cemented its place as a flagship species for the wider community of threatened mallee birds within this region. This degree of general community fascination has led to the successful rollout of annual mound monitoring across 20 grids within the region over the last 15 years. Direct comparisons of these surveys results highlight a distinct difference between populations north and south of the River Murray (see Figure 1) (Packer *et al.*. 2014). The northern landscape (hereafter Bookmark), has consistently registered lower active mound densities than the southern (hereafter Murray) landscape, indicating Bookmark is traditionally less productive than the Murray landscape.

Trajectories of the two landscapes have largely followed similar trends, with peaks and troughs of both landscapes replicated similarly across the timeline. However since the end of the millennium drought in the late 2000's and the onset of the significant La Nina event in 2010-2011 the two landscapes have demonstrated greater disparity in response indicating that the Bookmark landscape is less capable of responding to highly productive periods.

During this La Nina event in 2011, widespread locust plagues across the region resulted in an extensive spraying program by Primary Industries and Resources South Australia (PIRSA). As an attempt to assess potential impacts on native fauna, PIRSA approached regional staff from the Department of Environment, Water and Natural Resources (herein DEWNR) to assess for pesticide uptakes and potential impact on nesting success at numerous sites across the Murray Mallee. Whilst the results of this study revealed no observable impacts (Ryan-Colton *et al.*. 2011), the data collected proved useful in highlighting reproductive outputs of Malleefowl across this landscape during periods of high resource availability and rainfall. In light observed differences between these two landscapes at the grid level it was decided that a similar study the year after (still pulsing from La Nina event) in the Bookmark landscape might help to draw out rationales behind landscape differences.

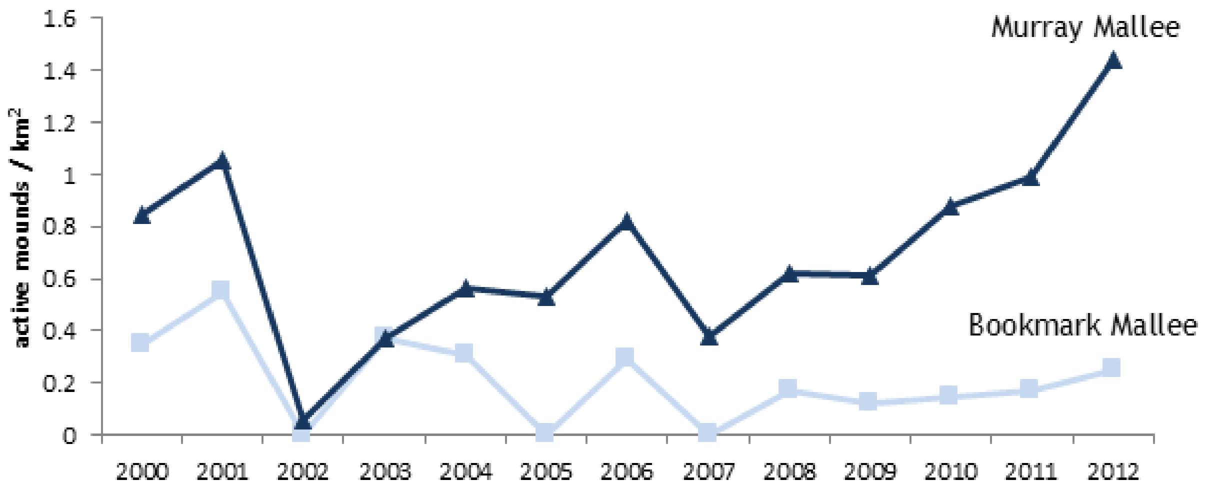


Figure 1. Comparison of active nest densities within Bookmark (northern) and Murray (southern) mallee landscapes between 2000 and 2012 (National Malleefowl Recovery Team 2015, Packer *et al.*. 2014).

Methodology

Study site

Within each landscape, a spread of grids were selected to attempt to capture variation and reduce bias. Within these individual nests were chosen based on availability of active nests at the time, these locations can be seen in Figure 2. Despite considerable effort to attain more sample sites, the existing nest density variation between the two landscapes meant that an unequal number of mounds was surveyed in each; Bookmark (8 mounds), Murray (17 mounds).

Sampling and data collection

The methodology utilised was adopted from extensive mound excavation surveys conducted by Joe Benshemesh and Jessica van der Waag (unpublished). To minimise risk to the Malleefowl initial surveys were supervised by Joe, to ensure appropriate and least risk methodologies were adhered to.

Surveys began in early spring with the first mound opening and continued every three weeks to monitor egg progression and fate. The surveys were only terminated at a site when it was clear that the mound had been abandoned and that all remaining egg fates were accounted for. During each survey session, each mound was carefully opened to the egg chamber and eggs were counted, weighed and measured, before being returned to the nest with a unique identifying number pencilled lightly onto to the egg. Each numbered egg returned to the mound was mapped in the chamber respective to north. On subsequent trips any hatched eggs could be identified based on the presence of remaining shell and membranes, observation of identifying number or relevant location based on previous mapping. Additional to this, any new eggs were completely sampled, but old eggs were only reweighed to determine egg development. Standardly eggs in normal development should gradually lose weight as they grow through chorionic respiration processes (Benshemesh 1992, Vleck *et al.*. 1984), therefore any eggs that failed to lose small amounts of weight over two consecutive visits, were deemed suspect and candled for signs of development equivalent to known age). Nests were not revisited when the mound ceased to be maintained by Malleefowl and all remaining eggs were clearly unviable.

Analysis of egg volume was converted from measurements taken using a conversion formula widely used by previous survey methodologies (Benshemesh 1992, Brickhill 1987, Priddel and Wheeler 2005).

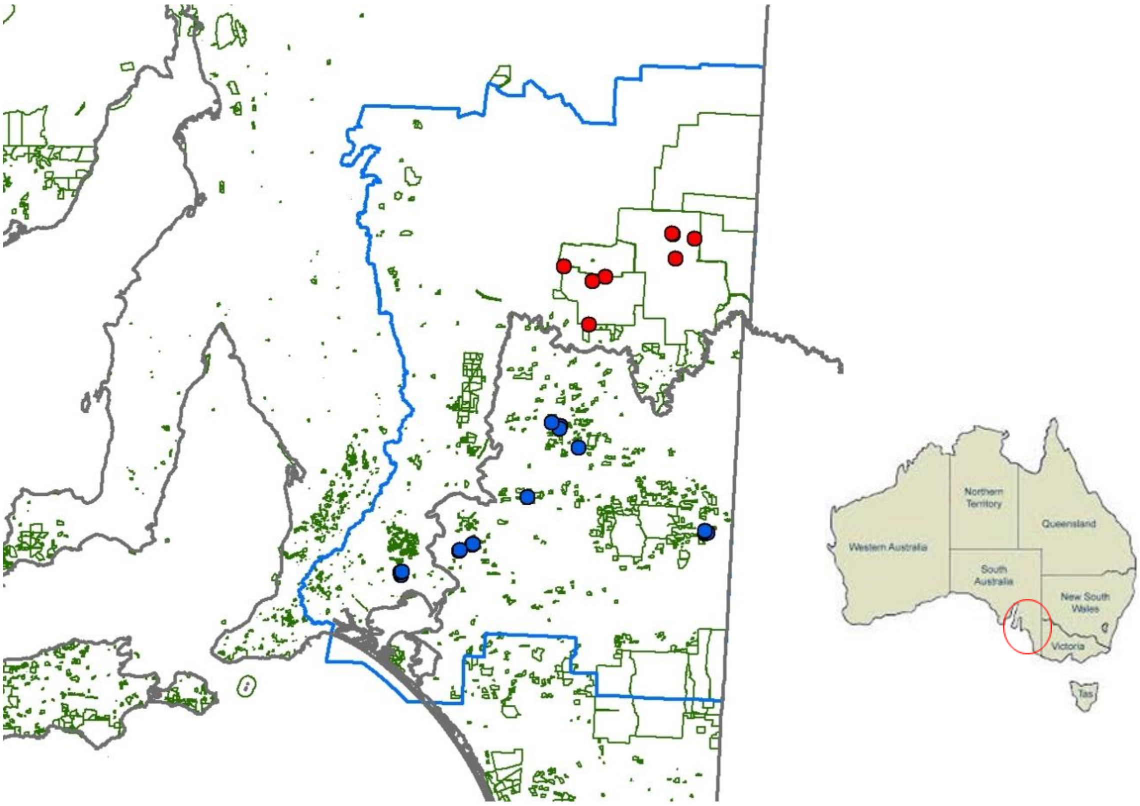


Figure 2. Nest sites sampled during combined surveys 2012-13. Blue dots indicate nest sites in Murray, whilst red dots indicate nest sites in Bookmark. Solid blue line indicates SAMDB regional boundary.

Results

Clutch size

In the Murray landscape a total of 463 eggs were laid across the 17 sites, giving an average of 27.2 eggs per mound. A number of mounds exceeded 40 eggs, whilst only a few were less than ten. The highest number of eggs laid for one mound was 47, with the lowest being four. Figure 3 highlights the spread of results across the mounds.

In contrast the Bookmark landscape demonstrated lower figures, with 160 eggs laid across the eight mounds surveyed. The average mound yield was 20, with five of the eight mounds exceeding this average. The highest number of eggs laid in one mound was 26, with the lowest being ten. Figure 4 highlights the results from across the surveyed mounds.

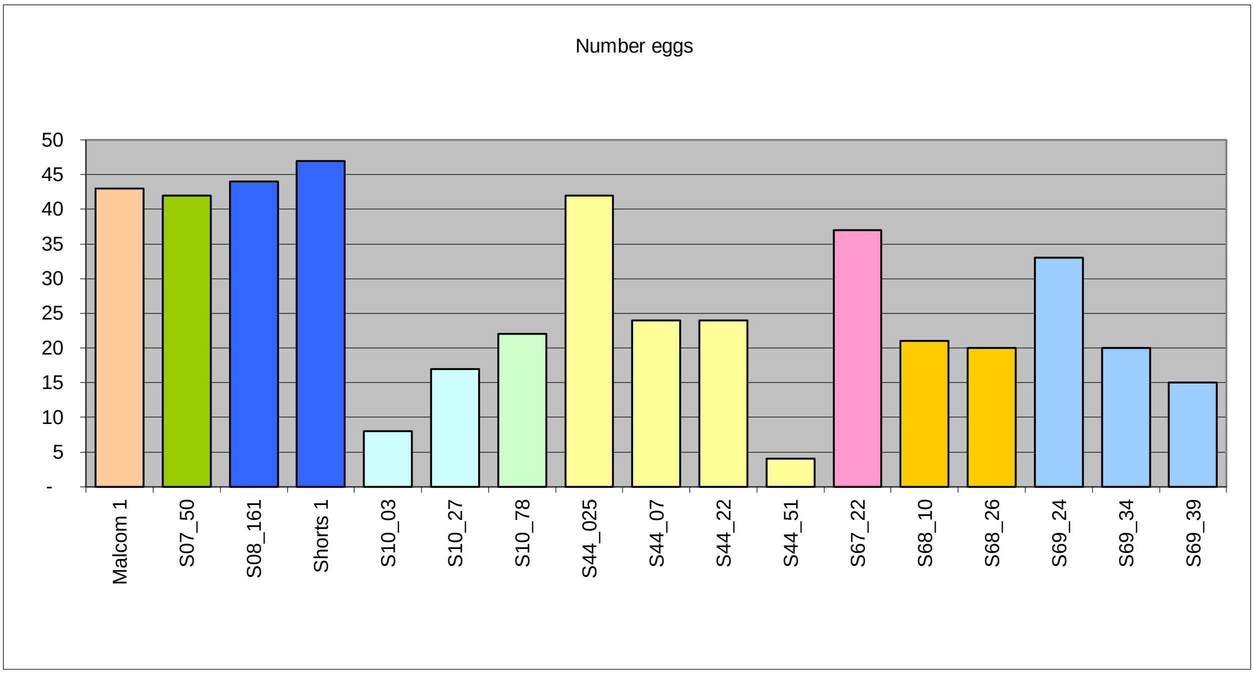


Figure 3. Murray landscape clutch size results per mound, colours indicate mounds in the same grid.

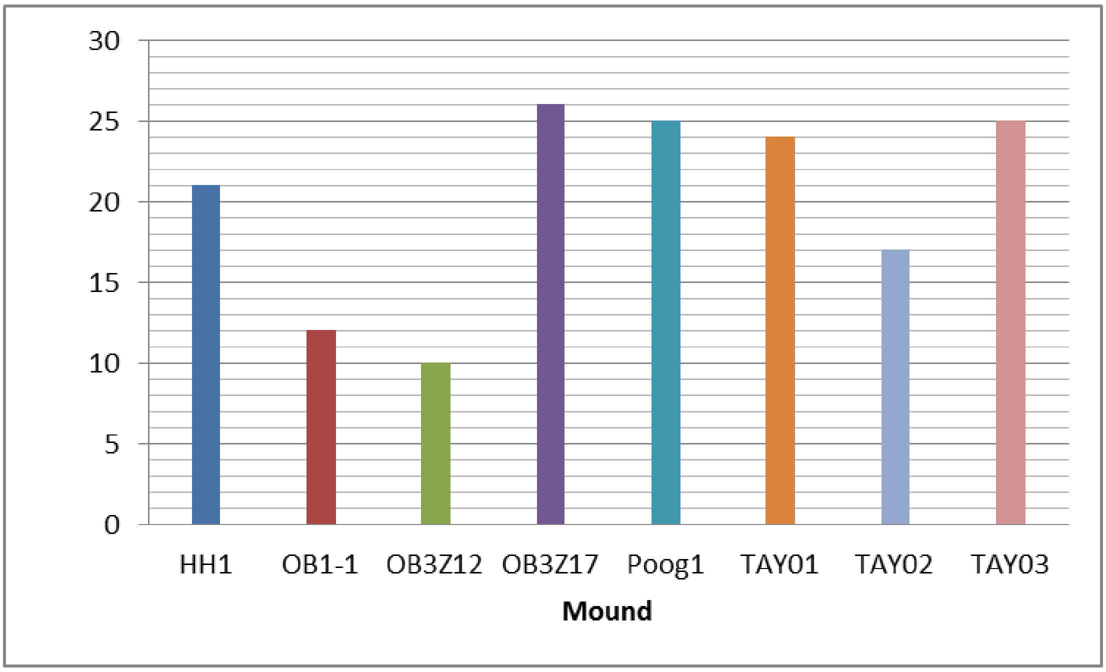


Figure 4. Bookmark landscape clutch size results per mound.

Hatching Success

In the Murray Mallee landscape a variety of hatching success ratios were noted throughout the mounds surveyed. The majority of mounds demonstrated hatching success ratios between 50% and 90% (as seen in Figure 5), with an average of 58% across all sites. Figure 6 shows the fates of eggs for the mounds in the Murray Mallee. Predation inside the mound accounted for very little of the fate, with only one mound having eggs raided by a fox during visits. Predation outside the mound was difficult to survey but was noted as being lightly scatted across the sites.

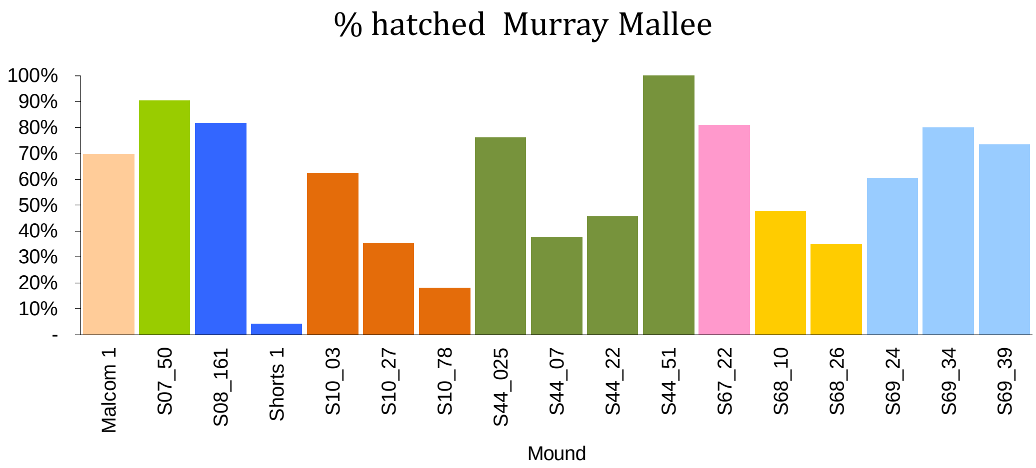


Figure 5. Spread of hatching success at all mound sites in Murray Mallee landscape, colours indicate mounds in the same grid.

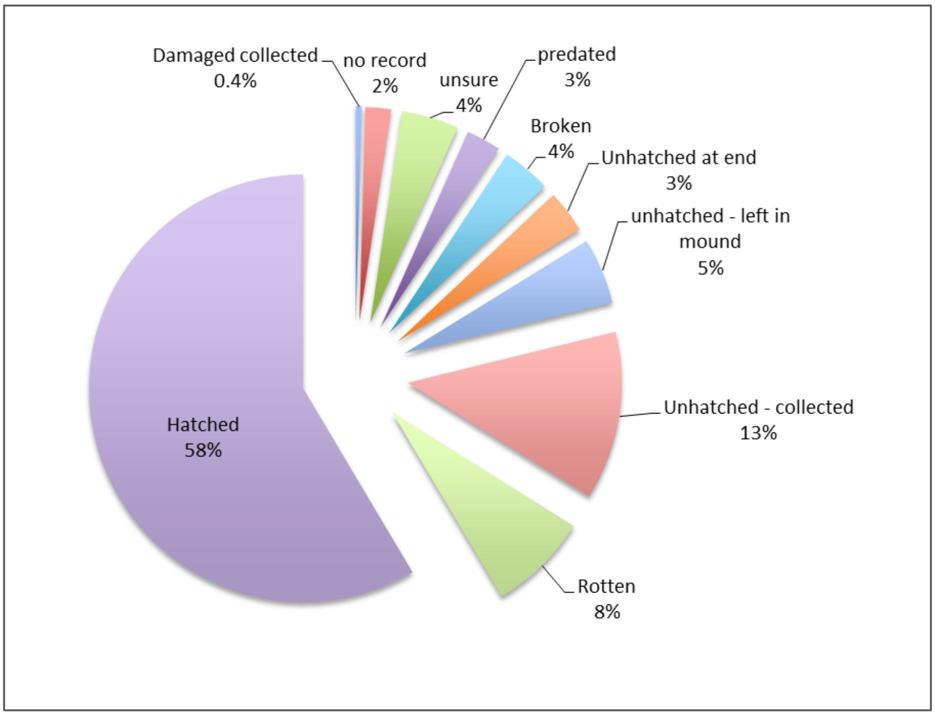


Figure 6. Fate percentages for the collective Murray Mallee mounds.

In the Bookmark landscape hatching percentages were fairly uniform across all the sites, ranging between 60% and 100% (as seen in Figure 7). Only one site (OB3Z17) demonstrated poor hatching success ratios, with less than 20% of eggs successfully hatching. The average successful hatching percentage across the sites was 68%, ten percent higher than the Murray Mallee landscape. Nineteen percent of eggs were unaccounted for in these surveys, due largely to sudden emptying of the nest by adults between visits. This final clearing of the nest at the end of the season, was not noted in the Murray Mallee landscape, however it is likely that the majority of these unaccounted eggs failed to hatch due to cooling chambers or premature ejection. No predation within the mound was noted, although several attempts were noted on large mounds during surveys. It was noted that at OB3Z12 (where hatching success was very low), nest abandonment coincided with evidence of adult bird attack (extensive gatherings of adult feathers around the mound). Although not quantified, predation outside the immediate nesting area, appeared to be significantly more regular across this landscape, compared to the Murray Mallee.

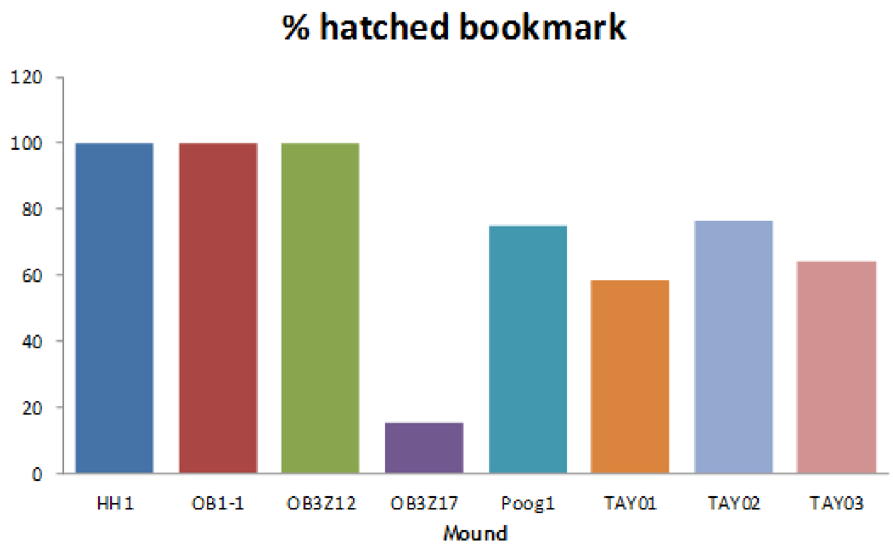


Figure 7. Spread of hatching success across all sites in the Bookmark mallee.

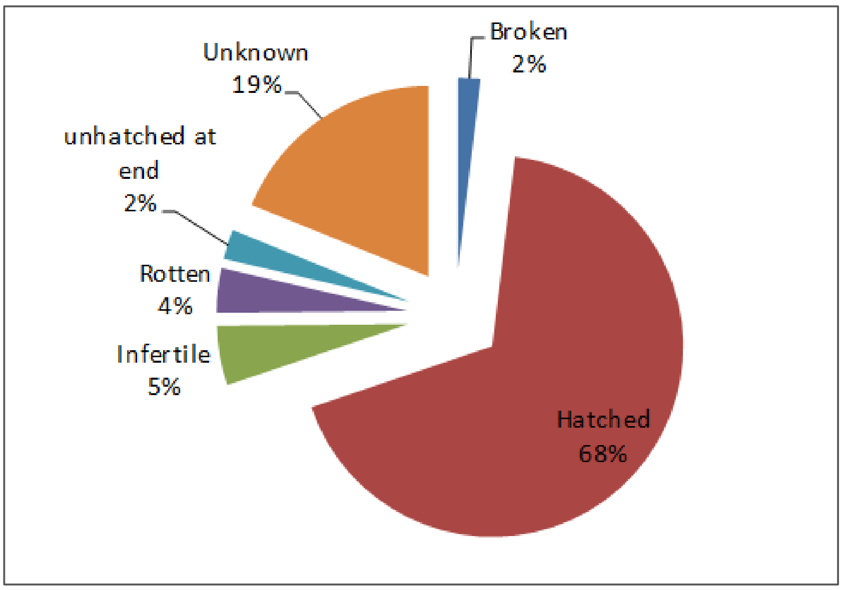


Figure 8: Fate percentages for the collective Bookmark landscape.

Egg size and Volume

Egg volume in the Murray Mallee landscape was uniformly variable across the board (see Figure 9). The average egg volume across the landscape was 168ml. The largest average egg volume per mound was 183ml at Murray Bridge army range, with the lowest being 155ml at Peebinga. The only specific trend at sites with more than one nest sampled was seen at Murray Bridge army range, where volumes were consistently amongst the highest.

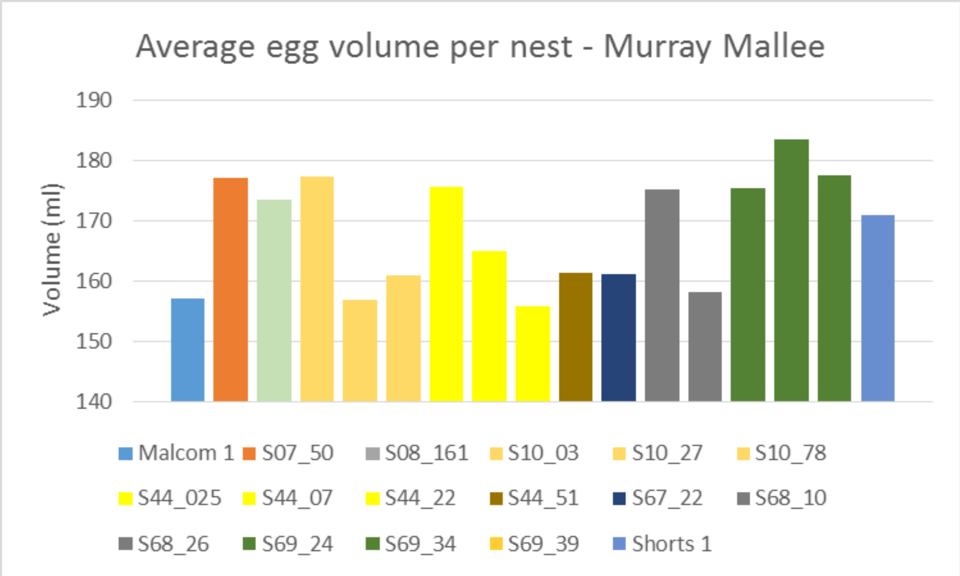


Figure 9. Average egg volumes per nest across the Murray Mallee landscape.

Egg volume in the Bookmark mallee landscape was highly variable (see Figure 10). The average egg volume across the landscape was 160ml. The largest average egg volume per mound was 182ml, with the lowest being 134ml. As sites were spread across the landscape with little foci areas, no general trends across specific areas can be determined.

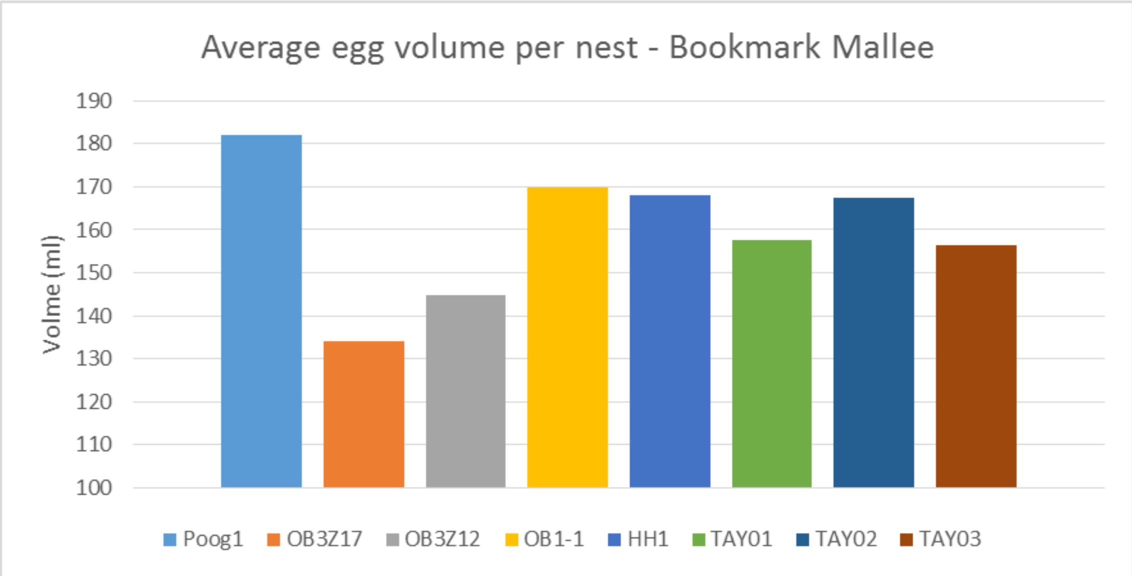


Figure 10. Average egg volumes per nest in the Bookmark mallee landscape.

Overall productivity

Overall productivity represents the total number of chicks hatched from each mound, and is a direct culmination of both clutch size and hatching success. The number of chicks varied considerably across the Murray Mallee, with an average of 15.3 chicks per mound successfully hatched. The highest number of chicks successfully hatched was 37, with the lowest being two. Looking into specific sites, Ferries Macdonald sites (highlighted below in light blue – s10) demonstrate a consistently low output, with six or fewer eggs hatched per mound.

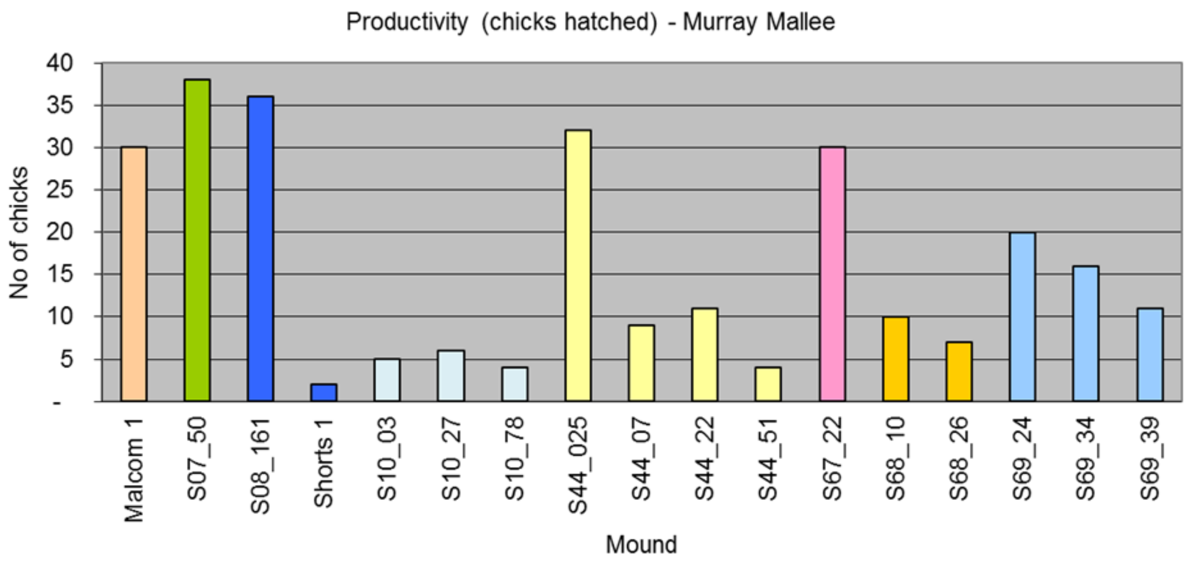


Figure 11. Productivity in Murray Mallee, colours indicate mounds in the same grid.

Productivity numbers across the Bookmark mallee were considerably less variable, with average outputs per mound between 10 and 20 chicks. The average was number was 13, with OB3Z17 having the lowest output at three chicks, and HH1 having the highest at 21.

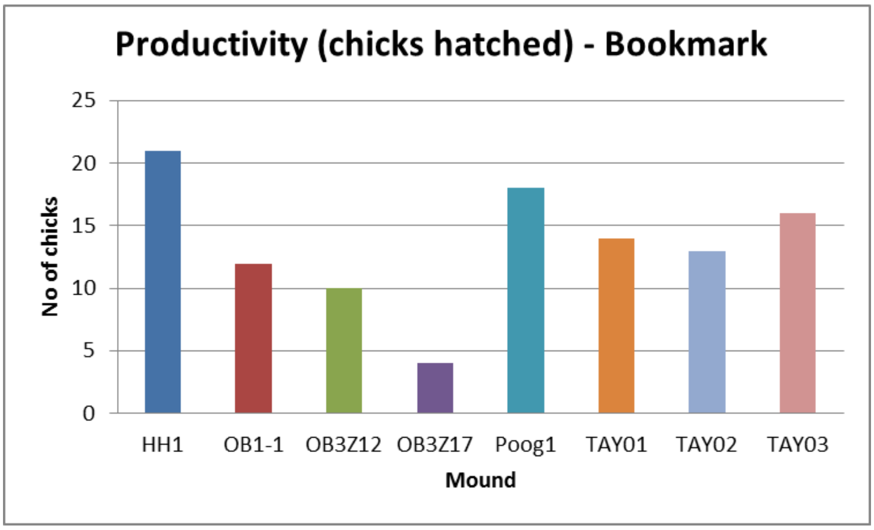


Figure 12. Productivity in the Bookmark mallee.

Comparisons between historic national data

Comparisons of historic productivity surveys both at a landscape (where available) and a national level reveal some interesting findings. Table 1 below highlights the basic figures for all of these.

Table 1. Average survey statistics for project surveys results compared to historic survey effort. Brackets in fields indicate number of separate studies sourced (Priddel *et al.*. 2007, Booth 1987, Burton 2000, Frith 1959, Brickhill 1987, Gillam 2008, Benshemesh 1992, Benshemesh *et al.*. 1997).

Average variables	Murray Mallee 2010-11	Bookmark 2012-13	Murray Mallee historic (0)	Bookmark historic (2)	National (7)
Clutch size (n)	27.2 (4-47)	20 (10-26)	-	9(2-15) & 14(2-34)	14-19.8 (1-34)
Hatching success	58%	68%	-	56% & 79%	50-85%
Egg volume (mean)	170.8ml	162ml	-	-	160-168ml

Murray Mallee landscape figures have no prior reference surveys to compare against, but when compared to the averages highlighted at the national level, it demonstrates a significant positive deviation from the norm. This is especially true for maximum clutch size in any one nest (47 versus 34) and average clutch sizes across all mounds (27 vs max 19.8). Mean egg volumes were also up against previous landscape averages (170.8ml vs max 168ml).

Figures from the Bookmark landscape fit within national averages more generally, but when compared against historical surveys within this landscape, it shows mixed results. Paul Burton recorded much lower averages in clutch size and hatching success in 2000 (Burton 2000), however David Booth recorded higher average clutch sizes and greater hatching success in the early 80's (Booth 1987).

Conclusion and discussion

The period during which the surveys were conducted was within or immediately after a significant La Nina period for most of the country. No previous historic survey effort used as reference for national standards refers to specifically to such events such as these, and thus likely explains the significant differences between both landscape and national comparisons. Results from these surveys strongly suggest that Malleefowl in general are capable of increasing productivity outputs in response to increases in resource availability. Historic survey efforts elsewhere confirm the impact of significant rainfall events as key to increases in laying season and interval period (Priddel and Wheeler 2005, Benshemesh 1992). This response is likely to play an important role in all Malleefowl populations, especially in more arid parts of their range where standard climatic conditions are likely to produce poor productivity outputs. Chick survivorship is largely contributed to availability of food and water, along with levels of predation (Priddel and Wheeler 1990, Priddel and Wheeler 1994, Priddel and Wheeler 1997). In a moisture and resource rich environment such as those seen during the period of these surveys, these pressures are likely significantly relieved, and an increase in potential fledging recruitment rates into the wider functional population are speculated to occur (Priddel and Wheeler 1990, Priddel and Wheeler 1994, Priddel and Wheeler 1997, Benshemesh *et al.*. 1997). As aridity levels increase across the species range, responses to such events at the mound level are likely to be even more critical to replacement and long term persistence of the species within a given area.

The differences between the two landscapes studied in the project, begin to shed some light into reasons why national grid data also shows a clear distinction between these two landscapes (Figure 1). When compared to the Murray Mallee the Bookmark mallee landscape demonstrated lower average clutch sizes, lower egg volumes and decreased productivity outputs. The differences between these landscapes are largely unsurprising. It is plausible this is primarily caused by climatic differences between the two landscapes, and its flow on effect on palatable resource availability or resource response rates. Mean rainfall differences between these two landscapes can be up to 120mm in places. Studies as early and Henry Frith's in the 1950's confirm these correlations between local climate and productivity (Frith 1959). However, the disparity between this study and the one of Brickhill in the 1980's (Brickhill 1987), even given the boom in resources, suggests that some of the results seen in the Bookmark may not be purely geographic variation in climate, but rather that this landscape may have at least temporarily lost some of its capacity for this species. Climate change is the most obvious potential contributor to this and widespread reductions in winter and annual rainfall across this landscape (Setchell 2011) go some way to confirming this.

Several historic examples across the country highlight the positive correlation between initial egg volume scores and chick survivorship, indicating that the greater the egg volume the stronger and more resilient a successfully hatch chick will be (Benshemesh 1992, Priddel and Wheeler 1994). In the case of the Bookmark mallee, where a reduced rainfall more generally increases the odds of predation or starvation related deaths, improvements in early stage fitness are likely critical. In this particular season the low volume scores in eggs noted in this study may be offset by increased food availability and a reduction in predation pressures.

Although poorly documented in this study, the observed increase in predation around the mound in the Bookmark mallee despite likely increases in alternate prey sources, suggests that predators may inherently sustain learned hunting behaviours more readily within this landscape. The presence of apparent adult attack, also heavily noted in Brickhill's study is rare amongst other study results and supports increases in learned behaviours across this landscape (Brickhill 1987). Benshemesh and Sandell, noted sustained increases in mound predation following a dramatic reduction in alternate prey sources, and postulate that desperation invokes prey switching to more difficult food sources may initially drive increases in learned hunting behaviours, which are then sustained until population turnover (Benshemesh *et al.*. 1997). If true, this could potentially explain the increases in predation at multiple life stages across the Bookmark, as the increased aridity of this landscape likely influences increases in prey switching.

Throwing all of this together, one can begin to understand the long term differences in grid survey results between these two landscapes and furthermore the apparent lack of response to La Nina events. All suggestions point towards a loss of resilience in Malleefowl across the Bookmark mallee. Something perhaps masked by augmented food sources in more fragmented southern systems. The key for managers looking to protect this species, is to determine how best to react to this information. Are limited resources best focused on creating more resilience in this incredibly large and relatively intact landscape, or are they best focused on those populations currently most resilient and adaptable. Fox baiting for example is rolled out across both landscapes, principally for the benefit of Malleefowl, however recent publications hint that perhaps the scale and intensity is not appropriate for reducing risk to this species (Priddel and Wheeler 1997, Thomson *et al.*. 2000, Walsh *et al.*. 2012). Perhaps in this case these resources are better pooled to more effectively target foxes in the most deserving landscape? Based on previously discussed logic around increases in aridity and added predation pressures through loss of alternate prey, one could fundamentally argue its added benefit compared to more mesic systems.

The results from this project however should not be treated as the gospel and the justification for all future management considerations. It should be treated as additional data to guide and inform, or more simply a discussion to illicit more conversation or research around what we do for this species. It is critical that moving forward any attempts to address key recovery outcomes are done so in an adaptive fashion using smart, evidence based recovery tools to test and revise all actions. Often this is difficult under current funding arrangements, so extensive community engagement throughout these processes will be critical. These two landscapes and Malleefowl more generally are well placed to become pioneers in adoption of such processes as they already engage heavily with community through annual grid surveys.

Acknowledgements

These surveys would not have been possible without the help of the following key people; Joe Benshemesh, Ellen Ryan-Colton, Luke Ireland, Dave Setchell, Matt Humphrey, David Wells, Ryan Hamood, Zac Moore and Taneal Cope.

Further acknowledgement to several other key volunteers that helped throughout the surveys includes: Kevin Smith, Graham Frahn, Benita Dillon, Glenn Drogemuller, Graeme Tonkin, Malcolm Johns, Henry Short and numerous other staff and community members.

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13. An investigation of potential landscape links to enhance Malleefowl conservation in northwest Victoria

Geoffrey G. Allen, Ogyris Ecological Research

Authors: Allen, G.G. and Sluiter, I.R.K., Ogyris Ecological Research, Birdwoodton, Victoria

Abstract

The northwest Victorian natural landscape is dominated by a series of large national parks and other reserves which provide habitat for Malleefowl. Surrounding these parks and reserves exist small to medium sized outlying remnants of both crown and freehold land that contain suitable Malleefowl habitat. Some of these remnants are known to be populated with isolated Malleefowl and some are monitored for mound activity by the Victorian Malleefowl Recovery Group.

The National Recovery Plan (2007) calls for outlying remnants to be reconnected to core areas via revegetation in order to facilitate the ongoing use by Malleefowl of those remnants. Reconnection is to be preceded by a novel ranking process so that revegetation resources are efficiently targeted. The present study describes a new ranking process and by its use, ranks 38 outlying remnants on size, proximity to core area, existence of surrounding vegetation, degree of disturbance and habitat quality. Produced is a hierarchy of sites proposed for reconnection via revegetation. Outlying remnants that are larger, nearer to core areas, in better condition and with more surrounding vegetation ranked higher than smaller, more distant, poorer and more isolated remnants. The prioritised ranking of small to medium sized remnants across northwest Victoria is considered to be a guiding tool for the future planning of revegetation schemes aimed at enhancing Malleefowl habitat connectivity. The table of 38 ranked sites is considered to fulfil the suggested methodology for Action 5.1 of the National Recovery Plan for Malleefowl in Victoria.

Presentation

In northwest Victoria, we are fortunate that state governments have reserved large tracts of mallee vegetation which are present as large national parks and medium-sized reserves (LCC 1989). These include Murray-Sunset National Park, Hattah-Kulkyne National Park, the Big Desert complex including Wyperfeld National Park, Little Desert National Park and a number of medium sized flora and fauna reserves. These all contain suitable habitat for Malleefowl. Surrounding these parks and reserves are numerous small-sized remnants of both freehold and crown land that exist in an otherwise fragmented landscape dominated by dryland agricultural land use. Some of these smaller remnants contain Malleefowl habitat and indeed some also contain small populations of Malleefowl themselves (Benshemesh, J. pers. comm.). Corridors linking these smaller remnants back to the core areas are largely narrow and heavily disturbed road reserves, or in many instances simply non-existent.

It is desirable that these smaller remnants be considered for re-connection, using vegetation, back to the larger core areas in a way that facilitates Malleefowl movement. The present study is a precursor to any such re-vegetation program for connectivity. In order that future re-vegetation for Malleefowl conservation is targeted to priority areas, it is critical that potential sites be ranked on appropriate criteria.

The present study is supported by the 2007 National Recovery Plan for Malleefowl (Benshemesh 2007). Specific Objective 5 of the Recovery Plan calls on us collectively to "*Reduce isolation of fragmented populations.*" The associated Action 5.1 states "*Develop strategic corridors of native vegetation to connect patches of habitat that are suitable for Malleefowl*" and the Plan suggests achieving this Action through the following methodology: "*Identifying priorities for new links, to be established through planting or natural regeneration.*" It is this latter suggested methodology that the present study specifically addresses.

In the present study, recent orthophotography of the Victorian Mallee and Wimmera Regions was visually analysed revealing 38 small-sized remnants surrounding the core areas mentioned earlier. For the study, land tenure was ignored. These 38 remnants occurred across the central, eastern and southern Mallee Region as well as within the Wimmera Region and served as the focus for the study. Each of these 38 remnants was assessed and scored using a component of the Victorian state government's "Habitat Hectares Scoring Method" (DSE 2004).

The Victorian state government introduced and uses the "Habitat Hectares Scoring Method" for assessing the quantity and quality of remnant vegetation. A part of this method, the Landscape Context Component, was slightly modified and used for the present study. The Landscape Context Component is used to score remnants for 'Patch Size', 'Neighbourhood' and 'Distance to Core Area'. Patch Size is simply the size of the remnant being investigated. Neighbourhood is a measure of the amount of native vegetation surrounding the remnant within given radii. Distance to Core Area is the shortest straight line distance to the nearest core area. For Patch Size, remnants score from 1 to 10 points, with larger remnants scoring higher. Neighbourhood scores are a calculation based on the percentage of remnant vegetation surrounding the patch in question, with increasing vegetation in the neighbourhood scoring higher between 0 and 10 points. Distance to Core Area (with Core Areas being the large and medium sized blocks of public land identified above) scores from 0 to 4, with remnants closer to large vegetation blocks generally scoring higher.

Figure 1 below shows the Patchewollock West State Forest site. The site is relatively large, measuring approximately 4.5km x 3.5km or 1,500 hectares. There is some fragmented vegetation surrounding the site and it is relatively close to the core area of Wyperfeld National Park.

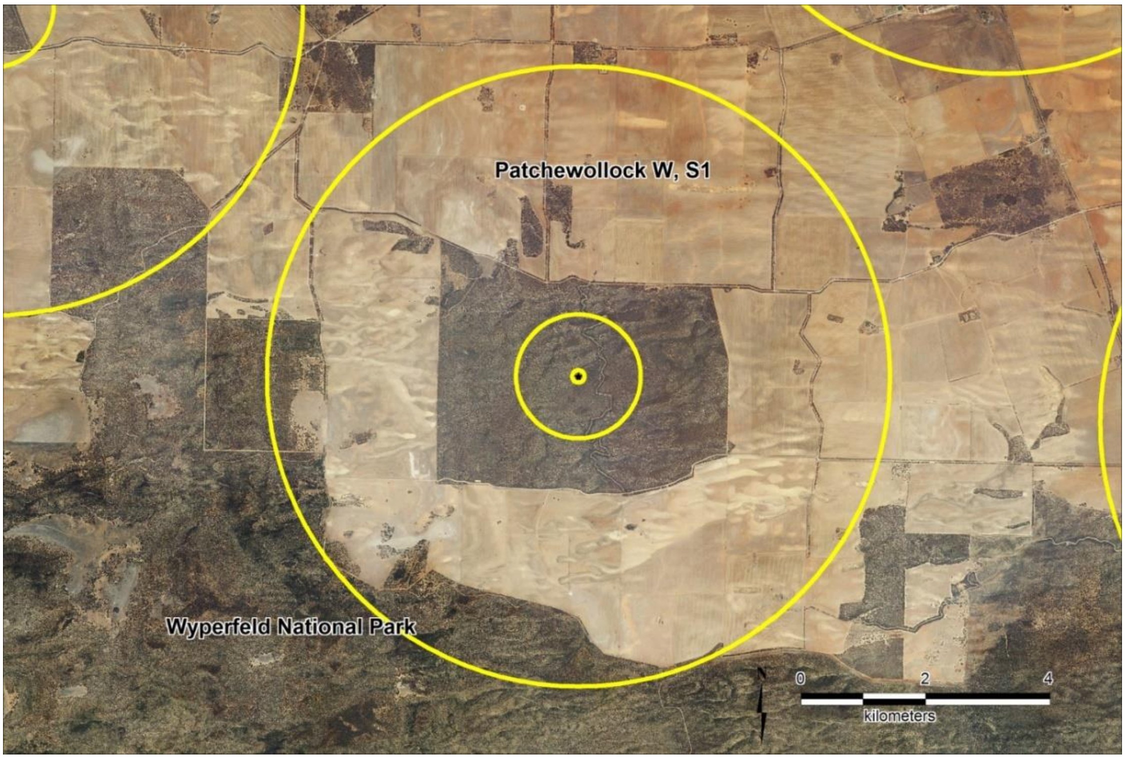

Figure 1. Patchewollock West State Forest site of approximately 1,500 hectares isolated by dryland farmland from Wyperfeld National Park.

The Landscape Context Component also has an embedded assessment of level of disturbance of the remnant, with all fragmented remnants in the study being deemed by the Habitat Hectares Scoring Method to be “disturbed”. Further, each remnant was assessed for its immediate suitability for Malleefowl colonisation. Remnants with an open overstorey or lacking a suitable understorey were scored lower on a scale of 1 to 6. Thus the remnant at each site was scored for 1) its size, 2) the distance to the nearest core area, (being national park or major flora and fauna reserve), 3) the amount of surrounding vegetation, i.e. ‘neighbourhood’, 4) the degree of disturbance, and 5) the immediate habitat suitability for Malleefowl. The ‘scorecard’ for the above site is shown in Table 1 below.

Table 1. ‘Score Card’ for the Patchewollock West State Forest Malleefowl remnant site.

Area 16 Site 28 Patchewollock W, S1				
	Radius	Actual	Score	Maximum score possible
Patch Size		1,543ha	8	10
Distance to Core Area		0.9	4	4
Neighbourhood	0.1km	100%	3	3
	1km	100%	4	4
	5km	40%	1.2	3
Disturbance		Y	-2	0
Habitat suitability		High	6	6
Rounded Total			**24**	**30**

The Patchewollock West State Forest Site scores highly for Patch Size and for its short Distance to Core Area. It also scores the maximum for surrounding vegetation at 100m radius and 1km radius and scores moderately for surrounding vegetation at 5km radius. It is deemed “disturbed” and so 2 points are subtracted, but it is very suitable (even holding a small Malleefowl population (Allen *et al.* 2014)) and so scores the maximum 6/6 for Habitat Suitability.

All 38 sites were scored in such a manner, with total scores ranging from a low of 16 to a high of 24 out of a maximum of 30. Thus it was possible to rank all sites into a preliminary list based on these scores.

The top 12 ranked sites were then ground-truthed to verify results obtained from the orthophotography. This step proved to be useful, giving both confidence in the desk-top analysis as well as an opportunity to fine-tune three of the results. In the case of two sites, the Habitat Suitability was down-graded from 6/6 to 5/6 due to the understorey being both sparse and lacking in food plants. In the case of a third site, the vegetation community was deemed to be inappropriate for Malleefowl colonisation and so its Habitat Suitability was down-graded further. Following ground-truthing, a final list of the top nine sites ranked on suitability for connectivity was produced. That list is reproduced in Table 2 overpage.

Table 2. Final list of the highest scoring Malleefowl remnant vegetation sites in northwest Victoria as scored in the Landscape Links Project.

Site number	Site name	Score
7	Cramenton	24
25	Berrook, Homestead	24
26	Berrook, I228	24
28	Patchewollock W, S1	24
11	Bronzewing NW	23
6	Annuello, Corridor S	22
17	Wandown E, Wandown	22
22	Paradise FFR	22
31	Wagon Flat	22

In conclusion, it is believed that the suggested methodology for Action 5.1 of the National Recovery Plan for Malleefowl has been fulfilled in Victoria. Revegetation and covenanting recommendations have been provided in the present study's report (Allen & Sluiter 2014) and, importantly, future on-ground projects may now proceed with some direction.

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14. How mining offsets can make a contribution towards meeting National Recovery Plan objectives

Stephanie Mitchell, ILUKA Resources Ltd

Abstract

The Malleefowl Management Fund is a $700,000 financial offset which funds activities to address actions identified in the National Recovery Plan for Malleefowl. The offset is one of the approval commitments under the *Environment Protection and Biodiversity Conservation Act* 1999 for the Iluka Murray Basin Stage 2 Mineral Sands Mine Sites in Ouyen, Victoria. Now in its fourth year, the fund has helped to support a range of activities which have contributed towards meeting the recovery plan objectives. This talk gives an overview of how the offset came to be, the projects funded to date, and details of how to apply to the fund.

Presentation

Iluka Resources Ltd is a mineral sands mining company. The Murray Basin Stage 2 (MBS2) project consists of the Kulwin and WRP mine sites, located in close proximity to Ouyen, Victoria. As part of the EES approval process the Biodiversity and Habitat Assessment for the project determined that the WRP site would impact upon Malleefowl habitat.

As a result, the Federal government set approval conditions under the *Environmental Protection and Biodiversity Conservation* (EPBC) *Act* 1999 to provide $700,000 for the implementation of measures to address actions identified in the National Recovery Plan for Malleefowl. The priority actions were to be identified by representatives from the Victorian Malleefowl Recovery Group, the National Malleefowl Recovery Team, the Department of Environment, the Department of Environment and Primary Industries and Iluka Resources. As a result the Malleefowl Management Committee was convened with representatives from these five organisations plus Parks Victoria, and today consists of the following people:

Iluka Resources Ltd	MBS2 Rehabilitation Superintendent
Victorian Malleefowl Recovery Group	President of VMRG
National Malleefowl Recovery Team	Chairperson of NMRT
Department of Environment	Terrestrial Species Conservation Section
Department of Environment and Primary Industries	Biodiversity Officer - Threatened Species
Parks Victoria	District Program Manager - Mallee District

The Fund is now into its fourth year. A number of projects have been supported - the major projects are outlined in the table below. Many of the projects funded have complimented one another or met more than one objective. As an example the National Malleefowl Monitoring Database has played a crucial role in providing data to the Adaptive Management Team, whilst the National Malleefowl Recovery Program Coordinator has made a huge contribution towards facilitating communication between groups as well as meeting criteria 9.4.

Table 1: Major projects (listed by National Recovery Plan objective) funded by the Malleefowl Management Fund.

Objective 5: Reduce isolation of fragmented populations		
5.1	Landscape Linkages Project	
Objective 9: Monitor Malleefowl and develop an adaptive management framework		
9.1	Adaptive management of arid and semi-arid ecosystems	3 year funding
9.1	National Malleefowl Monitoring Database	Four phases
9.1	Fox Scat Analysis	Two phases
9.1	Camera Trap Monitoring Program	Two phases
9.1	Malleefowl Data Analysis	
9.4	National Malleefowl Recovery Plan Coordinator	4 year funding
Objective 16: Facilitate communication between groups		
16.1	2011 Renmark National Malleefowl Forum	
16.1	2014 Dubbo National Malleefowl Forum	
16.1	Around the Mounds Newsletter	5 year funding
9.4	National Malleefowl Recovery Plan Coordinator	
Objective 17: Raise public awareness through education and publicity		
17.1	Interpretive Malleefowl Signage	Two phases
17.1	VMRG Information Brochures	
Objective 4: Reduce predation		
16.1	Adaptive management of arid and semi-arid ecosystems	

The offset fund has been well managed, and this is due to a number of reasons:

- The development of a Memorandum of Understanding by Iluka and the VMRG – the VMRG worked closely with Iluka to produce a sound Memorandum of Understanding which outlined how the fund was going to be managed.
- A shared vision between the VMRG and Iluka on how the offset should be managed – both organisations wanted the best value for money from the fund and as a result the VMRG administer the funds on Iluka's behalf and no admin costs are incurred.
- Charter and funding guidelines were agreed upon by the whole committee – including the decision not to fund landscape restoration projects which could use up large sums of money and therefore ensured that the fund stretched further.
- Good representation on the grants decision panel – a range of people with knowledge of good project management and Malleefowl conservation experience sit on the committee.
- Good continuity of committee members and Iluka staff – which has enabled the committee and Iluka to communicate well.

Other EPBC Act Malleefowl offsets - before commencing researching for the talk I had anticipated that there were more mining offsets of this nature. However it became apparent that there are very few mining offsets that are linked to meeting recovery plan objectives. The Department of Environment were able to provide details on some other mining companies whose EPBC Act commitments include actions for Malleefowl, these included Mount Gibson Iron, who have a Malleefowl Management Plan and have undertaken extensive aerial searches for mounds, and the Great Victorian Desert Biodiversity Trust Fund, which has recently been formed to manage the financial offset for the Tropicana project, and will facilitate priority research and on-ground conservation management which meets recovery plan objectives for Malleefowl, the Sandhill Dunnart and Marsupial Mole.

As demonstrated by the Malleefowl Management Fund, mining offsets can provide real benefits to meeting recovery plan objectives and it will be exciting to see what benefits present and future mining offsets can bring to support recovery plan objectives.

Three years funding remain of the Malleefowl Management Fund with approximately $230,000 available. For all funding enquiries, or copies of the guidelines and an application form please contact Stephanie Mitchell on 0408051635.

15. A discussion on a proposed release of Malleefowl at Taronga Western Plains Zoo

Paul Andrew, Taronga Zoo, Sydney

Abstract

Taronga Western Plains Zoo has managed a population of Malleefowl as part of a breed for release program for nearly two decades. The release program has now ended but management has been competent and the population of 16 birds remains genetically healthy. An experimental release into the zoo grounds is proposed. Taronga Western Plains Zoo is a mosaic of suitable habitat and capacity, survivorship, and dispersal, could be monitored in a well-studied and managed landscape. Predators are controlled within the zoo perimeter and naturally occurring populations are nearby, and the release is proposed as a translocation.

Introduction

Taronga Western Plains Zoo (TWPZ) in Dubbo, NSW, has managed a population of Malleefowl as part of a breed for release program for over two decades. The population is of NSW origin with founders from Goonoo National Park and Yalgogrin district, and in the period 1993 to 2006, 458 captive bred birds were released at Yathong and Nombinnie NR (central NSW).

The release element ended in 2006 but population management continued and the population remains genetically healthy. In the absence of a formal captive component to recovery initiatives, an experimental release into the zoo grounds was proposed at the 5th Malleefowl Forum held at TWPZ (2014). This proposal was subsequently endorsed by the Recovery Team and a translocation proposal is now being prepared. It is envisaged that birds might be released in early 2016.

TWPZ is a mosaic of suitable habitat and capacity. Survivorship and dispersal could be monitored in a well-studied and managed landscape. Predators are controlled within the zoo perimeter and naturally occurring populations are nearby (19km to Goonoo NP), and the release is proposed as a translocation. The release would be directly into the environment (the 'Sanctuary') and as close to hatching as possible (usually within a couple of hours but never more than 24 hours). Monitoring is not proposed except as an additional research component: the rationale behind this proposal is that a maximum number of chicks are released directly in to the wild at minimum cost and maximum efficiency.

There would continue to be some predator control in the Sanctuary but the perimeter is not predator proof, and it is acknowledged that attrition in young would be high though perhaps slightly less high than attrition in the wild. It is envisioned that over time Malleefowl will establish themselves within the zoo grounds and that this free living population will be a precursor to the next wave of adaptations which will see chicks dispersing out of the zoo grounds. Birds could eventually make their way to surrounding habitat such as Goonoo, while quite possibly adapting to local semi-rural areas around Dubbo much the same way as Australian Brush-turkeys have adapted to the Sydney suburbs and, over a period of 10 years or so, have moved as far as the Mosman suburbs surrounding Taronga Zoo.

Rationale

Recent history has shown that megapodes can be extremely adaptable: the recent invasion of Darwin by Orange-footed Scrubfowl and the invasion of Sydney by Australian Brush-turkey are two examples of this adaptability. Whether this adaptability is behavioural plasticity in the individual megapode or rapid selection for traits improving fitness in newly exploited environments is a question that the release of captive bred birds in to a novel environment at TWPZ could answer. The only certainty is that there can be no adaptive transmission from parents to offspring in such an aggressively precocial species and that this life history lends itself to a low resource release program.

The analogy for behavioural plasticity might be seen in tramp-colonising Rallidae in the Pacific, where large numbers disperse and the few that arrive on a previously uninhabited island are able to exploit any resource, whether tidal, mangrove or forest. Indeed the same species might exploit quite different habitats on different islands.

Previous attempts to release birds given a 'head start' has probably been counterproductive because whichever of the two scenarios (plasticity or selection) accounts for behavioural adaptability a 'head start' in a captive environment is likely to lead to the release of birds that do very well in a captive environment. Wild Malleefowl hatch and leave their mound without any parental assistance, being fit and fully equipped to immediately fend for themselves. This includes avoidance of foxes (or at least those birds that can avoid foxes are selected through their survival). It can be argued that the released birds that were "grown on" at the zoo were in fact selected for life at the zoo and that by the time they were released after several months on an easily procured captive diet they lacked much of the initial fitness that they hatched with.

Release strategy

This proposal suggests that birds can be captive bred at Western Plains Zoo and be released immediately into the zoo grounds on the day of their hatch. They will be at least as physically fit as their wild-hatched counterparts and be equally adaptive as a wild hatched chick. It is acknowledged that, as with wild hatched chicks, there will be a high mortality, but those chicks surviving will be adapted for living in the zoo grounds including the ability to cope with a moderate fox population, rather than being adapted for life in captivity through being reared in an aviary until several months of age.

Pairs will be set up in aviaries at TWPZ in the same manner as during previous breed for release attempts. Mounds will be monitored and after chicks hatch they will be released into the zoo grounds. Chicks will not be individually identified (applying leg bands will not be possible as they would out-grow these, and micro-chipping would require the involvement of veterinary staff, a cost and inefficiency that would compromise the program).

The current Malleefowl round takes about an hour per day with basic cleaning and feeding. Managing the birds for successful breeding will require a higher degree of attention to the aviaries and the environment, daily provision of leaf-litter for them to build their mounds, closer monitoring of aviaries for the presence of hatched chicks etc. It is estimated that this will increase the round by at least an hour per day.

The project has the potential for Aboriginal cultural engagement with assistance in tasks such as collection of leaf litter through Taronga based social programs.

16. Conservation genetics of Malleefowl

Taneal Cope, University of Melbourne

Authors: Cope, T.M.[1], Mulder, R.M.[1], Dunn, P.O.[2] and Donnellan, S.C.[3]

[1.] The University of Melbourne, Australia, [2.] University of Wisconsin–Milwaukee, USA, [3.] South Australian Museum, Adelaide, Australia

Abstract

PART 1: Phylogeography and Population Genetics
Malleefowl present an interesting case in terms of their genetic variation and distribution across Australia. We investigated mitochondrial and microsatellite population structure across Australia and found relatively deep divergence between eastern and western Australia (split by the Flinders Ranges). However, further analysis suggests that both historical and contemporary factors are still influencing Malleefowl phylogeography and population structure. The full results of our study will be presented here with implications for national genetic management of this species.

PART 2: Landscape Genetics of Malleefowl
If analysis of this study is complete (due in September), I will present the findings of the effects of various land changes and land forms on gene flow and differentiation between fragmented blocks of mallee in north-western Victoria. This study is particularly relevant to management of Malleefowl on a local as well as national scale, as the factors affecting isolation of mallee populations are likely to be similar across Australia.

PART 3: Mating Systems and Relatedness of mound siblings
We present evidence to show that Malleefowl are not monogamous as previously suspected. Our study involved using new methods of sampling Megapode DNA for paternity analysis, which could be used in future studies of individual Malleefowl.

Introduction

Malleefowl have suffered from massive habitat clearance. In parts of Australia large tracts of mallee have been cleared, leading to small isolated patches. The populations of Malleefowl that inhabit these areas could be facing a large range of threats, including the effects of inbreeding and limited genetic variation. The aim of this research is to understand how genetic variation is distributed among populations of Malleefowl across Australia. In order to achieve this population level structure, gene flow and mating systems in this species were investigated. These components are discussed in the following chapters:

1. Phylogeography and Population Genetics
2. Landscape Genetics
3. Mating Systems and Relatedness between mounds.

PART 1: Phylogeography and Population Genetics

1.1 Methods

Mitochondrial ND2 gene as well as 13 nuclear microsatellite markers were studied in 117 individuals across Australia (shown in Figure 1).

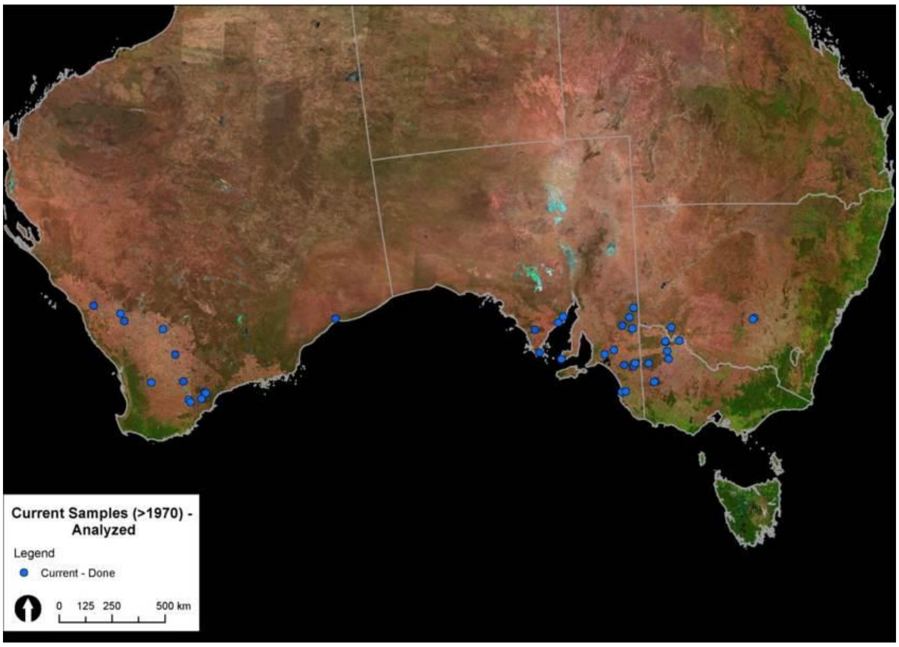

Figure 1. Sample locations of the 117 individuals used in final analysis.

1.2 Results

1.2.1 High diversity, low differentiation between populations

High levels of diversity, but low levels of differentiation between mitochondrial haplotypes were found in Malleefowl. There is no evidence of sub-species in Malleefowl across Australia. However, there is a reasonably strong split between populations of eastern and western Australia, with the Flinders Ranges (Eyrean barrier) acting as a geographical barrier between these sub-populations (as illustrated in Figure 2).

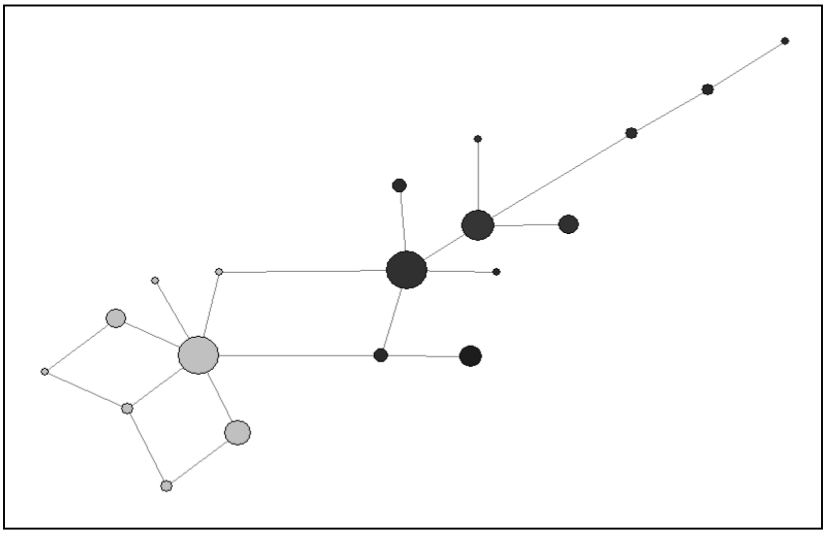

Figure 2. Mitochondrial haplotypes (variations) in Malleefowl populations across Australia. Light grey circles indicate western Australia and black circles indicate eastern Australia (split by the Flinders Ranges). The size of each circle is an indication of the number of individuals with that haplotype. Links indicate a single mutation between haplotypes.

<u>Implications:</u>
1. No sub-species of Malleefowl.
2. Separate populations in eastern and western Australia. Management applications of this species should reflect this.

1.2.2 Past range contractions and expansions

Secondly, Malleefowl appear to have been through population contraction and expansion but in a very ancient context. Looking at their ancestral population size, this was larger than eastern or western populations are today. Results of statistical tests undertaken during analysis are outlined in Table 1; while the results of the population size probability analysis is shown in Figure 3.

Table 1. Results of various statistical tests undertaken during analysis. Ticks indicate significant values as evidence in supporting either the constant population size or the range expansion hypothesis. Crosses indicate no significant result.

Test	Constant Population Size	Range Expansion
Raggedness	x	✓
Fu&Li's D	x	✓
Fu&Li's F	x	✓
Fu's Fstat	x	✓
Tajima's D	x	x

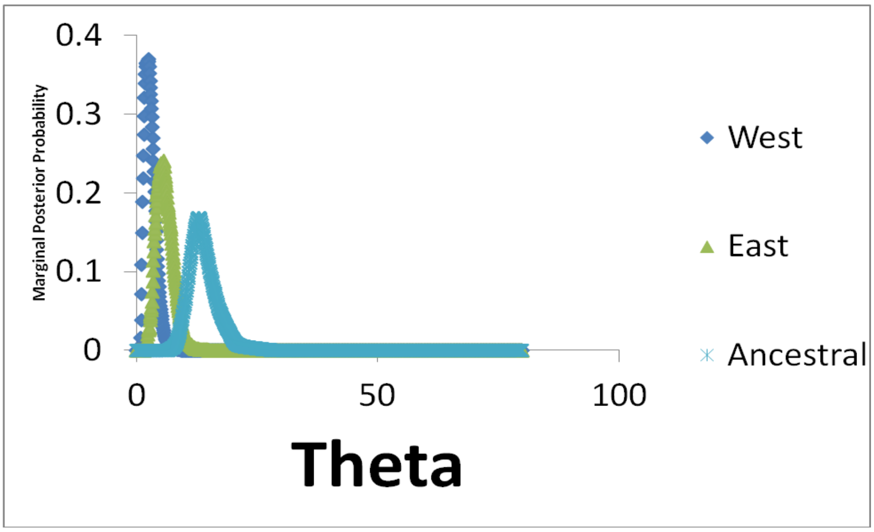

Figure 3. Results of Isolation with Migration analysis (IMa) showing the probability of population sizes for eastern, western and a hypothetical single ancestral population.

All of these tests showed a similar result, and indicated that Malleefowl have gone through gross expansions as well as declines.

The most likely time frame for these changes is during the peak of the last ice age (approximately 20,000 years ago). Instead of being covered in ice, Australia was covered in rolling sand dunes, devoid of vegetation. There were two possible refuges during that time: south-west of Western Australia, and the South Australian-Victorian area.

In attempting to answer the question of which refuge the Malleefowl were confined to, research that has been undertaken on 1080 resistance in Australian birds was investigated. This research looked at a number of our native birds resistant to 1080 and found that Malleefowl have very high tolerance to 1080 (King *et al*. 1996). Furthermore, Gastrolobium, the family of plants that produce the active ingredient (and key toxin) of 1080 (Monofluoroacetate), has high endemism in south-west Western Australia, with all but two of the 62 known plants in this family confined to south-west Western Australia (Twigg *et al.* 1996).

If Malleefowl were primarily restricted to the South Australian-Victorian area and then spread west, once the sand dunes retreated you'd expect high mortality of the birds from the east when they come in contact with the plant as they had not yet developed a resistance. However what was found was that all birds across Australia have the same resistance to 1080, indicating that Malleefowl were once confined south-west Western Australia refuge for a significant period of time, enough to develop a resistance to the toxins produced by these plant species, and spread east.

1.2.3 Isolation by distance

Another key result was that Malleefowl populations have an isolation-by-distance structure. Meaning that individuals that are geographically closer end up being genetically more similar, as neighbouring populations are more likely to interbreed.

Implications:
1. Management of current populations should concentrate on corridors between habitat fragments.
2. Translocations should be undertaken on a local scale with neighbouring populations.

1.2.4 Mitochondrial vs. Microsatellite (nuclear) markers

Different patterns in mitochondrial and nuclear DNA of Malleefowl were observed. The mitochondrial data indicates a deep split between eastern and western Australia. However, the microsatellite markers show no evidence of population structure.

There could be several reasons for this difference, including a) male biased gene flow; b) differences in introgression rates between nuclear and mitochondrial markers; or c) insufficient time since isolation between eastern and western populations to show evidence in the microsatellites.

Our analysis of isolation-with-migration suggests that there is no migration from eastern Australian to western Australia. However, there is evidence of some very low, but significant, amounts of migration from western Australia to eastern Australia. Unfortunately the software doesn't tell us at what point this migration happened, so it is not clear whether migration occurred two generations ago or 20,000 years ago.

The majority of Australian species that are separated or impacted by the Eyrean barrier show an eastern expansion (moved from west) (Schodde 1982). As discussed in Section 1.2.2, there is additional support for this in the resistance of many Australian species to 1080 (King *et al.* 1996, Twigg *et al.* 2003).

1.3 Conclusions

The isolation by distance analysis indicated that translocations should ideally be undertaken between geographically close populations, i.e. from NSW to NSW populations rather than from WA to NSW. Maintaining corridors between habitat fragments are also very important, as this allows birds to come in contact with their closest relatives.

With evidence of past population collapse (on a massive scale) and low corridor movement, Malleefowl populations have changed significantly over time (from 100s to 1,000s back to 100s). Ensuring Malleefowl have the habitat to allow them to spatially expand will therefore be important to ensure the long term persistence of the species.

PART 2: Landscape Genetics of Malleefowl

One of the main objectives of the Malleefowl Recovery Plan was to undertake genetic investigation of populations (Benshemesh 2000) so that management decisions can be made. Populations of Malleefowl have been subjected to extensive land clearance leading to fragmentation and isolation of a once continuous population. The severity of the impact of this fragmentation and isolation has only limited understanding, but Malleefowl are known to be reluctant fliers and do not disperse readily across open country (Frith 1962; Benshemesh 2000). Understanding if and how Malleefowl move between remnant patches of mallee will be important in aiding management decisions, especially relating to the need for habitat corridors between remnants.

2.1 Methods

The landscape genetics component of this study concentrates on the factors that influence gene flow between isolated fragments in south-east South Australia / north-west Victoria. Microsatellite markers were used to determine whether any environmental factors (e.g. patch size, distance between patches, time since last burn, corridor type and quantity) are influencing population structure.

2.2 Results

Preliminary analysis of landscape genetics has been undertaken, however more analysis is needed to provide any degree of certainty in the results. Initially, there has been no evidence of measured environmental factors influencing the genetic structure of Malleefowl. There also appears a pattern of isolation by distance, whereby geographically close reserves are also genetically similar. However the results of this preliminary analysis should be interpreted with caution, as the analysis is not yet complete.

PART 3: Mating Systems and Relatedness of mound siblings

The understanding of genetic variation within a population, as well as the variation in genetic contribution of individuals to future generations, is essential for conservation and management of species (Quader 2005). Biased reproductive success can limit populations by reducing genetic variation (Lacy 1987). Malleefowl have been noted as generally monogamous, although polygamy has been recorded (Weathers *et al.* 1988). In most bird species the social mating system is often a poor reflection of genetic parentage (Birkhead & Moller 1996).

3.1 Methods

The aim of this paper was to analyse paternity in Malleefowl mounds. Mounds at Wandown (Victoria) were sampled, as well as mounds throughout the riverlands in South Australia in collaboration with the Department of Environment and Natural Resources, South Australia (DENR). A permit was required in order to take eggs from mounds, but was restricted to no more than 20% of the eggs from a nest, on average 6 eggs, and a proportion of mounds within each reserve had to be left undisturbed. Each mound is monitored for activity by the national monitoring programme. During excavation, each egg was numbered and a map drawn indicating the location of each numbered egg (shown in Figure 4). All eggs were visually inspected in the field to determine the age of the embryo, using a candling technique adapted from Jessica van der Waag. Eggs were placed into “stubby holders” and incubated in Brinsea incubators at specific temperature and humidity requirements (shown in Figure 5). Once the chick hatched, a blood sample was taken along with the egg membrane for use in genetic analysis. After drying out for a minimum of 6 hours, each chick was released at their natal mound.

Figure 4. Carefully numbering each egg uncovered in a Malleefowl mound.

Figure 5. Left – specially adapted Brinsea incubators. Right – eggs in stubby holders with a chick hatching in the centre.

Attempts to catch adult birds were unsuccessful. Subsequently non-invasive genetic sampling was undertaken. The males spend the majority of their time tending the mound, and fight aggressively with any intruder that comes near their mound. It is therefore highly likely that feathers on the mound belong to that male. All feathers on a mound were collected over two days. The feathers collected on the second day (fresh feathers <1 days old) were primarily used to extract DNA.

Molecular sexing techniques (on large, medium and small sized feathers, as shown in Figure 6) were undertaken to determine which feathers resulted in the best quality DNA, as well as whether the feather was from a male or female from that mound. A large difference was observed in the quality of the DNA extracted from small to medium sized feathers compared to large feathers, as they were shed more frequently, and feathers known to be <1 day old consistently produced the best quality DNA.

Figure 6. Feathers found next to a Malleefowl mound. Left – large sized feather. Right – medium sized feather.

The collected feathers, blood from the chicks hatched in the incubators and the chorioallantoic membrane (as shown in Figure 7) collected from the mounds were analysed. A total of 13 microsatellite markers were used for analysis of paternity and each feather sample analysis was repeated at least three times to ensure accuracy of results.

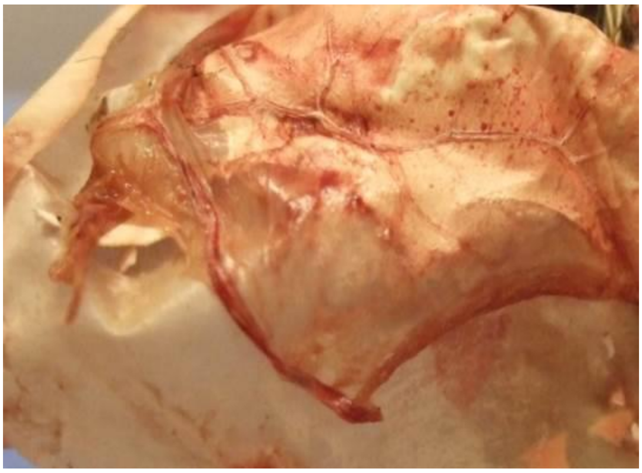

Figure 7. Chorioallantoic membrane (inner membrane) containing fresh DNA from the chick.

3.2 Results

Evidence of monogamy was found in the majority of mounds sampled. In a "monogamous" Malleefowl mound, all sampled eggs belonged to the male and female that regularly tended that mound. There was evidence of extra-pair paternity in a smaller proportion of mounds sampled (ranging from two to four different sires) and evidence of egg dumping (where an offspring failed to match with the female feather collected at the mound) in two mounds. An example of a sampled Malleefowl mound is shown in Figure 8.

These results should be interpreted with caution as not all offspring within a mound were able to be sampled due to permit restrictions. A "monogamous" finding in this case is a conservative label as any of the unsampled chicks could potentially have different parentage.

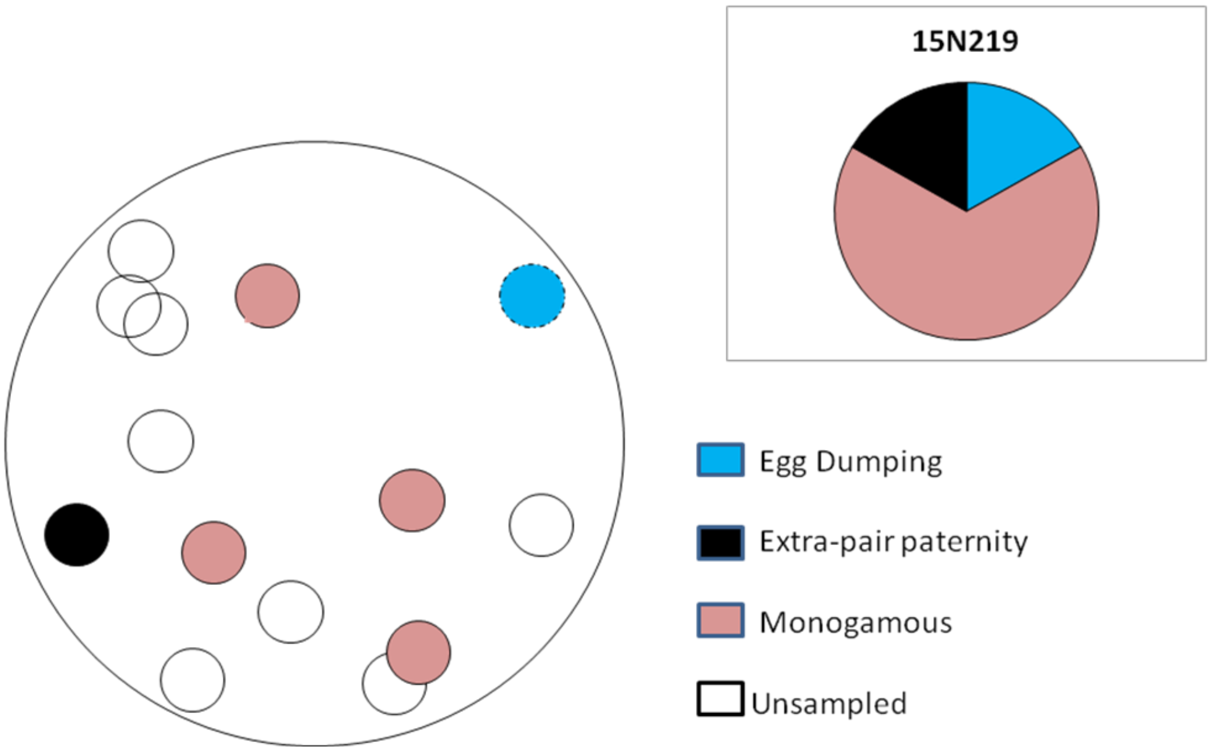

Figure 8. An example of a sampled Malleefowl mound. Each small circle represents an egg as found during excavation. In this particular mound, four of the sampled eggs belonged to both the male and female that tended the mound (eggs shown as pink). One offspring did not match the mound-tending male (egg shown as black) and another offspring did not match the mound-tending female (egg dumping - shown as blue).

The results of this study suggest that Malleefowl are not genetically monogamous, which is the norm in paternity studies of birds (Birkhead & Moller 1996).

<u>Implications:</u>

1. Non-invasive sampling is a successful method of sampling Malleefowl.
2. Small, fresh feathers contribute the most useable DNA out of the feather samples.
3. Offspring can be sampled by digging up freshly hatched membrane from Malleefowl mounds.
4. Our study is the first to undertake paternity analysis in Malleefowl and suggests that captive breeding programmes should consider the need for extra pair parentage to increase the genetic diversity of populations, or at the very least to simulate natural behaviours as found in the wild.

4.0 Future Studies

In the near future it will be possible to analyse the entire genomes of individuals at a reasonably affordable rate. This could open up explorations into adaptations of Malleefowl to local conditions, evidence of any immune system variations, as well as further defining the population structure and interactions between populations.

Tracking individuals (particularly chicks) over a long period of time would help to understand local movements and survival rates / recruitment within various reserves.

Understanding interactions between individuals could help to understand the social and genetic mating systems of this species in more detail. For example, which individuals are coming into contact and for how long? What are the implications of this for reproductive success of individuals?

There are a lot of questions to be investigated if the funding was available.

Acknowledgements

Many thanks to the National Malleefowl Recovery Team for assisting me to present at this conference.

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Thank you to Ann Göth and David Wells from Macquarie University for lending me their Brinsea Octagon incubators.

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17. A brief history of the Megapodes (*Megapodiidae*)

Guest Speaker: Walter E. Boles, Senior Fellow, Ornithology Section, Australian Museum, Sydney

Abstract

The fossil history of megapodes is long but rather sparse. It includes the giant Australian megapode *Progura gallinacea*, which may be the megafaunal form of the living Malleefowl.

Megapodes comprise a family of galliform birds that are notable for their breeding biology, including mode of incubation, absence of parental care and hyperprecociality of hatchlings. They occur mainly in Australo-Papua, where they have their greatest diversity, and the southeastern Pacific. This distribution is possibly constrained by competition with pheasants or predation by certain mammalian groups or both. Megapodes are regarded as the earliest diverging lineage of living galliforms. Their early fossil record is sparse but extends to the Late Oligocene (26-24 million years ago) of central Australia. Most fossil records come from the Pleistocene. Most island species were exterminated soon after the arrival of humans and their mammalian commensals. Species of scrubfowl were the most frequent victims, but there were also very large megapodes strikingly different from modern forms on Fiji and possibly New Caledonia. In Australia at this time, there was a giant megapode *Progura gallinacea*. It was closely related to the living Malleefowl and it has been suggested that Progura was the megafaunal form of that species.

Introduction

The megapodes (Megapodiidae) are a distinctive family in the avian order Galliformes. The common name 'megapode' and the name of the type genus *Megapodius*, from which the family name is also derived, draw attention to the size of the feet (*mega*, large + *podius*, foot). An examination of one of these birds will quickly reveal why this name is appropriate (Figure 1). It is not the feet, however, that have attracted the attention of scientists since the 1800s. Also known collectively as mound-builders or incubator birds, the megapodes are remarkable for their unusual breeding biology. Incubation is through the use of external heat sources (decaying vegetation, sun, geothermal). Other than for temperature regulation of the substrate in which the eggs are laid, there is no parental care of the young. The chicks hatch in a state of hyperprecociality, capable (and obligated) to look after themselves immediately and able to fly within a few hours of emerging from the nest.

While these unusual habits were known for many years, much of the pioneering work was conducted in Australia by Harry J. Frith (CSIRO Division of Wildlife Research) working on the Malleefowl (*Leipoa ocellata*). Like the majority of megapode species, Malleefowl place their eggs in a mound of soil or vegetable matter to be incubated by heat from the sun or decomposing plant matter. Some megapodes, however, lay the eggs in volcanically-warmed soils and others place them in accumulated vegetation among the roots at the bases of trees. A few species nest colonially. Some species exhibit several of these strategies. Recent work has supported mound building as the ancestral incubation behaviour in megapodes, with burrow nesting having arisen independently on at least three occasions (Harris *et al.* 2014). The breeding habits of megapodes, and particularly the Malleefowl, and other aspects of their biology have been well described elsewhere and so will not be repeated here (see Frith 1959, 1962, Elliot 1994, Jones & Göth 2008, and particularly Jones *et al.* 1995, and references therein). This essay presents a brief introduction to the prehistory and history of the Megapodiidae.

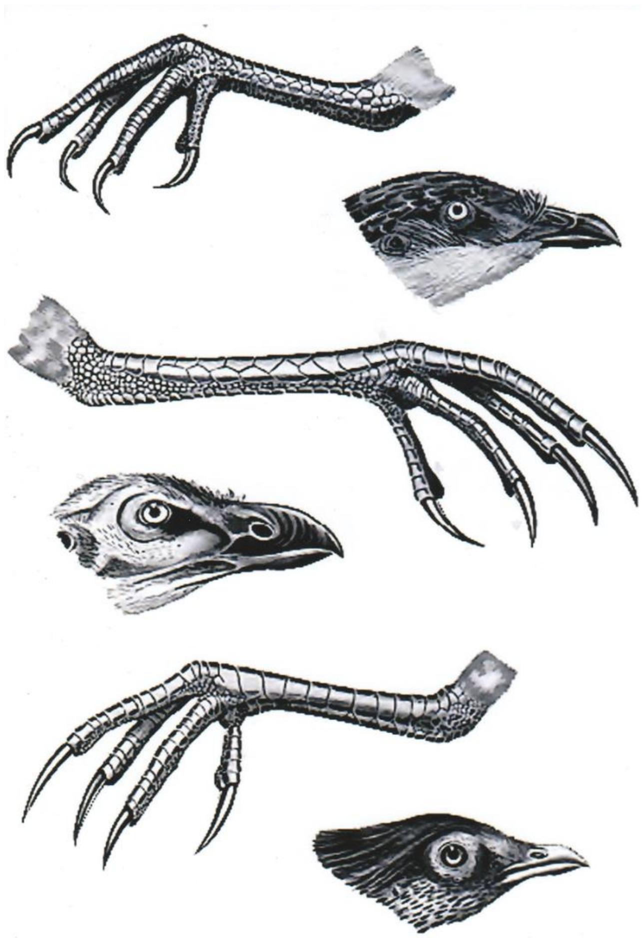

Figure 1. Australian species of megapodes showing the large feet from which the family derives its name. From top to bottom: *Leipoa ocellata, Alectura lathami, Megapodius reinwardt*. Images from Mathews & Iredale (1921).

Classification of the megapodes

The Megapodiidae family belongs to the Order Galliformes (Figure 2a), the fowl-like birds, which also includes the Cracidae (guans, chachalacas, curassows; Central and South America), Odontophoridae (New World quail; North and South America), Numididae (guineafowl; Africa) and the large and diverse Phasianidae (grouse, pheasants, turkeys, Old World quail, partridges, chooks, peafowl; cosmopolitan). Megapodes were once considered the sister-group to the Cracidae but are now thought to be the sister-group to all other living galliforms and the earliest diverging lineage among extant members in the in the Order.

Within the megapode family there are seven genera (Figure 2b) and 22 living species (Jones *et al.* 1995). These are given in Appendix 1, together with dates of description and distributions. Megapodes fall into two major clusters of taxa: the scrubfowls (*Megapodius, Eulipoa, Macrocephalon*) and brush-turkeys (*Alectura, Aepypodius, Leipoa, Talegalla*) (Figures 2b and 3) (Harris *et al.* 2014). Three species occur in Australia, the Malleefowl, the Australian Brush-turkey (*Alectura lathami*) and the Orange-footed Scrubfowl (*Megapodius reinwardt*). The family reaches its greatest diversity in the Australian-New Guinea region, but its distribution extends to the Philippine Islands and eastern Indonesia (Sulawesi, Lombok), east through the southwest Pacific islands currently as far as Tonga and north to Micronesia (Palau, Mariana Islands), with an outlier in the Nicobar Islands in the eastern Indian Ocean (Figure 4).

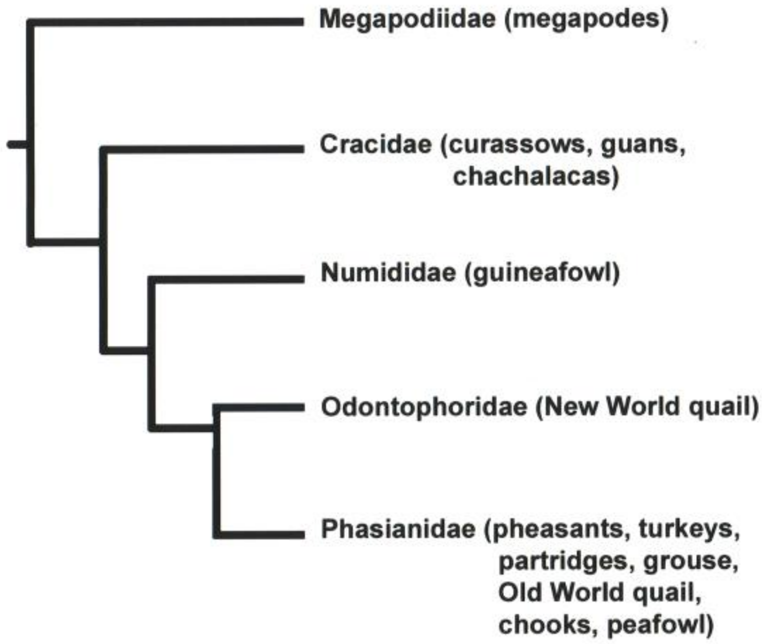

Figure 2a. Classification and relationships of the Families of the Order Galliformes.

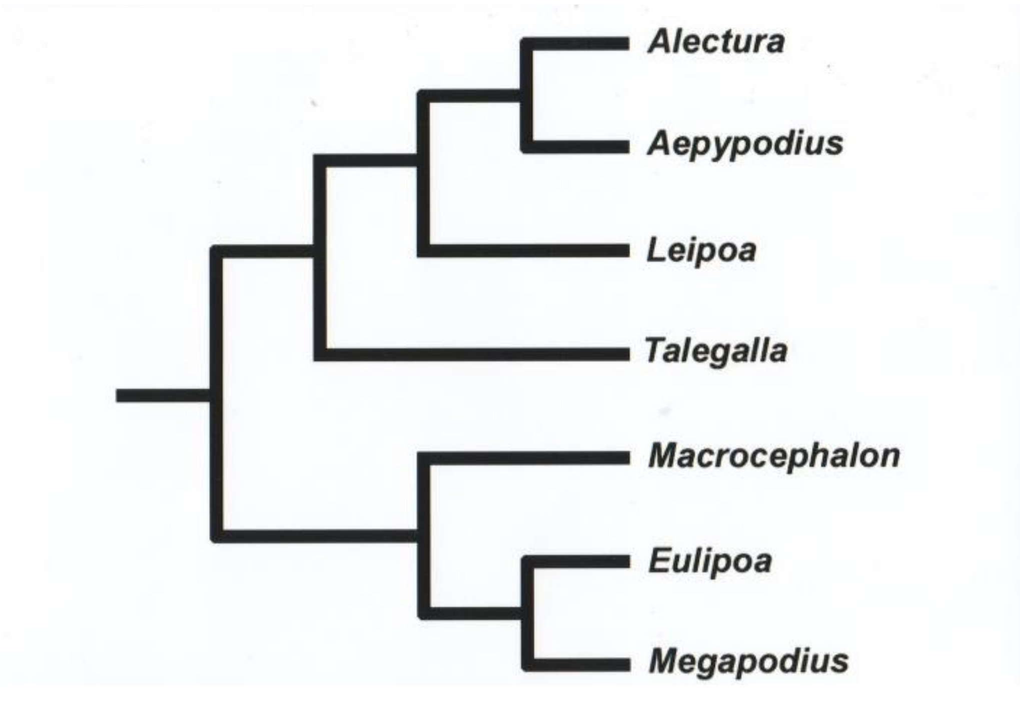

Figure 2b. Classification and relationships of the genera of megapodes following the molecular phylogeny of Harris *et al.* 2014.

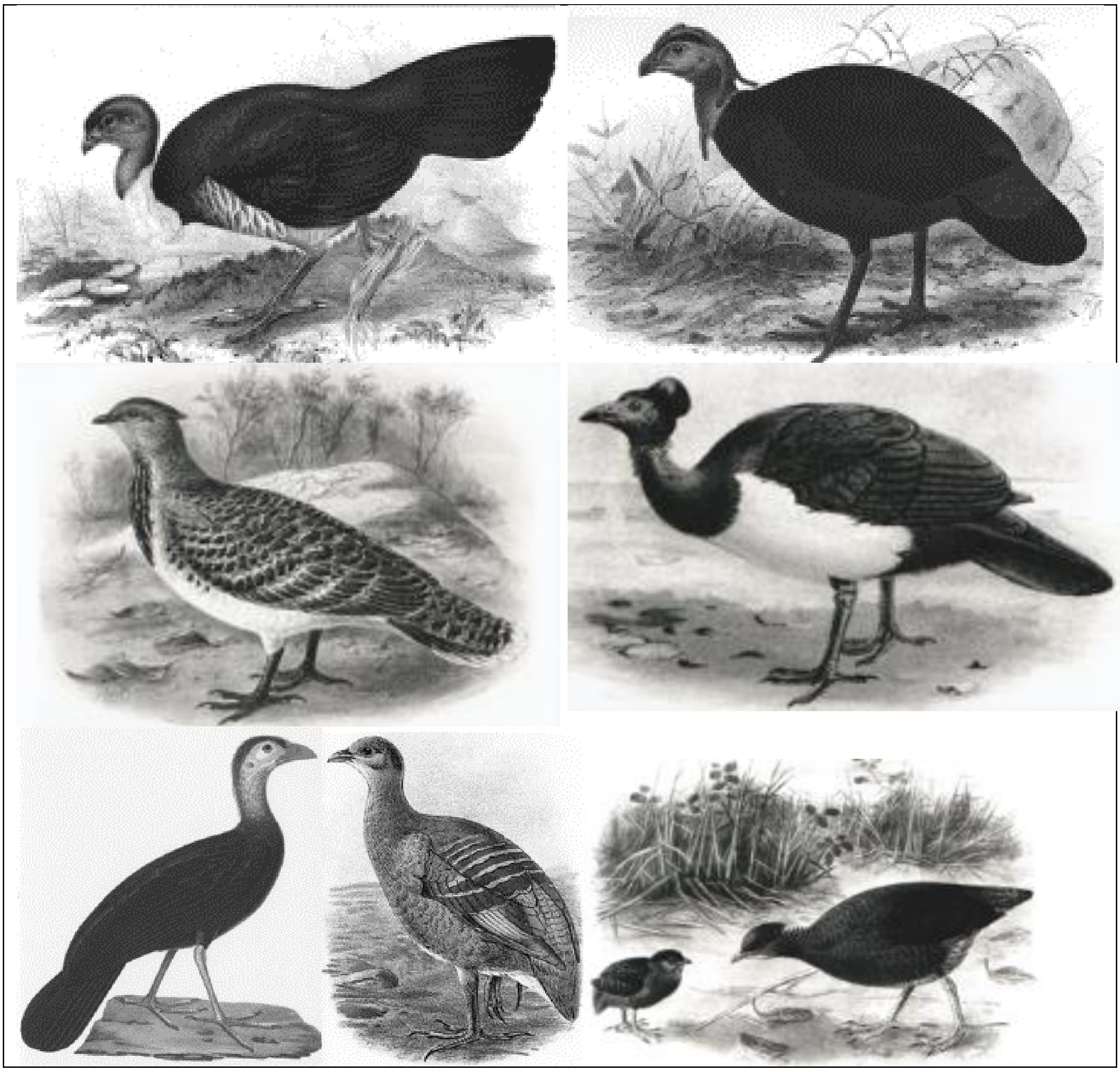

Figure 3. Representatives of the seven living genera of Megapodiidae. Images from references cited. Top row, left*, Alectura lathami* (Gould 1840), right, *Aepypodius bruijni* (Oustalet 1881).

Second row, left, *Leipoa ocellata* (Mathews 1910), right, *Macrocephalon maleo* (Ogilvie-Grant 1897).

Third row, left, *Talegalla cuvieri* (Lesson & Garnot 1828), middle*, Eulipoa wallacii* (Ogilvie-Grant 1897), right, *Megapodius pritchardii* (Buller 1905).

Figure 4. The current distribution of the family Megapodiidae outlined in black, modified from Figure 3.1 of Jones *et al.* 1995.

European discovery of the Megapodiidae

The first western writer to mention megapodes was Antonio Pigafetta (1491-1534), an Italian explorer and scholar who was a member of Ferdinand Magellan's voyage to circumnavigate the world. Magellan was killed in the Philippines in 1521 and Pigafetta was injured in the same incident. Of the approximately 240 men who had accompanied Magellan when he departed in 1519, only 18 men returned to Spain in 1522, of whom Pigafetta was one. In a detailed journal he compiled during the trip, he described scrubfowls observed in the Philippine Islands before the incident and commented on their apparent habit of burying their eggs (Figure 5).

The first megapodes described to science were named in 1823 by the French naval surgeon and naturalist Joseph Paul Gaimard (Gaimard 1823). He collected specimens of two species on the voyage of the *Uranie* commanded by Louis Claude Desaulses de Freycinet (1817-1820). From Tinian, in the Marianas Island, Micronesia, he named *Megapodius laperouse* (Micronesian Megapode), commemorating an earlier French explorer, Jean-François de Galaup, comte de Lapérouse. From Waigeo, off the northwest coast of New Guinea, he acquired and named the original specimens of *M. freycinet* (Dusky Megapode). Gaimard also coined the names megapode and *Megapodius*.

In the same year Charles Henri Frédéric Dumont de Sainte-Croix named *Megapodius reinwardt* after Caspar Georg Carl Reinwardt, a Dutch naturalist and collector who worked in the region (Dumont 1823). The specimen on which the name was based came from Lombok on the extreme western edge of the species' distribution. The range of *M. reinwardt* is the greatest of any species of megapode. It occurs through eastern Indonesia and southern New Guinea and is one of the three species found in Australia, occurring northern Western Australia and Northern Territory and north-eastern and central eastern Queensland.

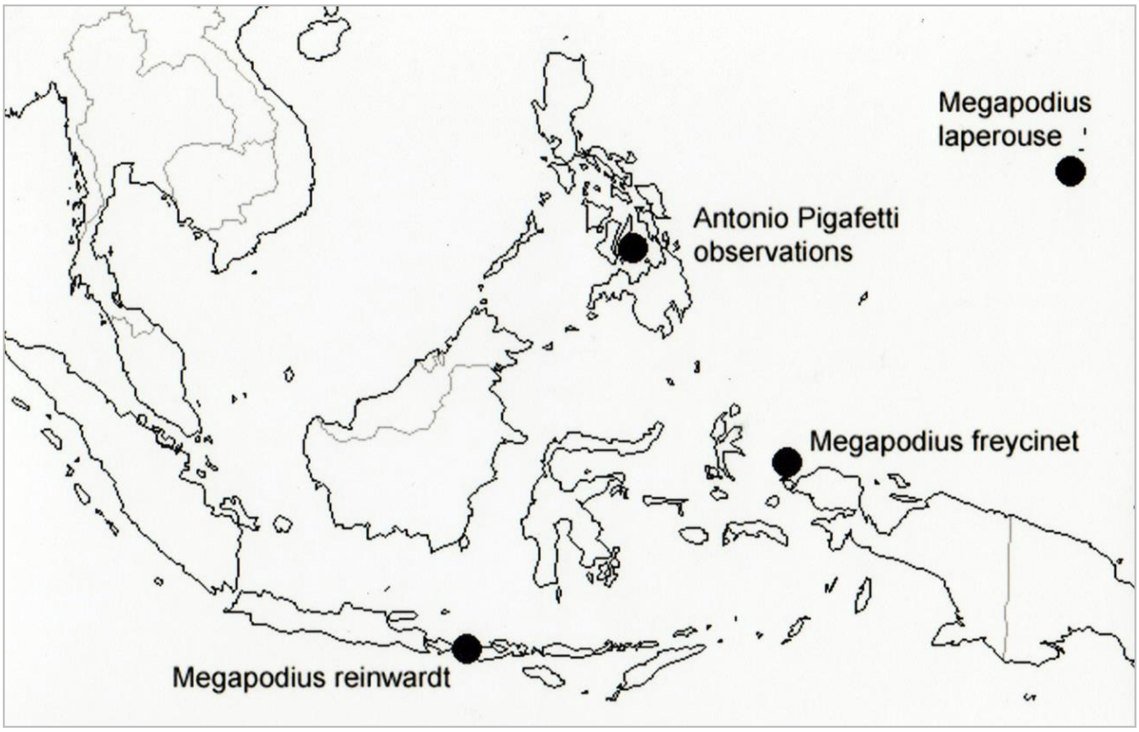

Figure 5. Historical localities in early western discovery of megapodes: site in Philippine Islands from which Antonio Pigafetta observed and described likely megapodes in 1521; islands from which first specimens of *Megapodius laperouse* and *M. freycinet* were collected (Gaimard 1823); and type locality of *M. reinwardt* (Dumont 1823).

Another Australian megapode, the Australian Brush-turkey, was known before these descriptions and had been illustrated earlier by the surgeon-scientist John Latham (Latham 1821). He was working with a dried specimen without the benefit of any knowledge of the live animal and so, impressed by the naked neck and somewhat curved bill, bestowed the name New Holland Vulture (Figure 6). Unfortunately for Latham, the rules of scientific zoological nomenclature dictated that a common name alone was not sufficient to officially describe a new species—a properly formulated scientific name was mandatory. Latham subsequently supplied a new generic name – *Alectura* – but never got around to providing a specific one (Latham 1824). Thus he missed out on being the author of this species' name, beaten by the British zoologist John Edward Gray, who officially named this species in 1831 (Gray 1831). Gray graciously acknowledged Latham's previous work by naming the bird after him: *Alectura lathami.*

The third Australian megapode, the Malleefowl, was described in 1840 by the famous ornithologist, John Gould, in his massive work, *The Birds of Australia* (Gould 1840). The specimen on which the name was based had been obtained by Gould's collector, John Gilbert, in Western Australia the previous year. Gilbert had been informed by locals that these birds left their eggs in large mounds of soil to incubate. Based on this information, Gould gave the Malleefowl the generic name *Leipoa*, meaning 'the bird that leaves its eggs'.

Figure 6. New Holland Vulture (= Australian Brush-turkey) as illustrated by John Latham (1821).

Distribution

Other than the Nicobar Island population, megapodes have a distribution with the revised Wallace's Line as the western limit (Figure 7a). Factors contributing to this pattern have been debated. One suggestion is that the presence of megapodes is constrained through competition with pheasants. The latter group extends from the west from Southeast Asia to Wallace's Line. There is only marginal overlap between megapodes and pheasants in a few islands: Palawan, Lesser Sunda Islands and northern edge of Borneo (Figure 7b) (Dekker 1989). The other idea is that megapodes cannot survive in the presence of predatory mammals, such as cats (Felidae) or civets (Viverridae) (Olson 1980). Both groups have distributions that are largely complementary to that of megapodes, again reaching Wallace's Line but rarely crossing it. It is only in a few localities do the mammalian predators show overlap with megapodes. Whether one or both theories (or neither) explain the present day distribution of megapodes is not certain.

The somewhat anomalous occurrence of a scrubfowl on the Nicobar Islands has been attributed at times to human action. It is easy to transport eggs during oceanic travel and this practice may have contributed to the presence of megapodes on various locations throughout the range of the family. Scrubfowl are particularly vagile, however, and chicks have shown a great ability to disperse, sometimes for considerable distances over water.

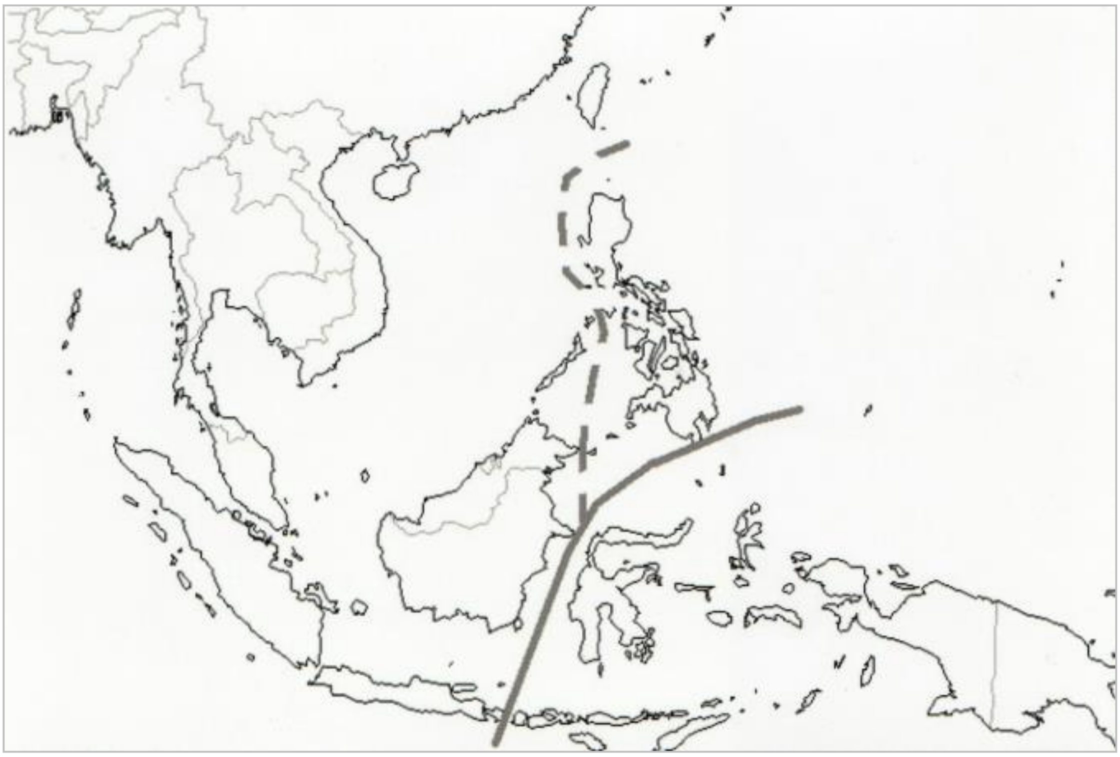

Figure 7a. Wallace's Line, the boundary between the Asian and Australasian faunas. The solid grey line is that originally delimited by Alfred Russel Wallace (Wallace 1860); the dashed line is the modification of the northern section by Thomas H. Huxley (1868). The latter is a better fit for the western boundary of the megapodes.

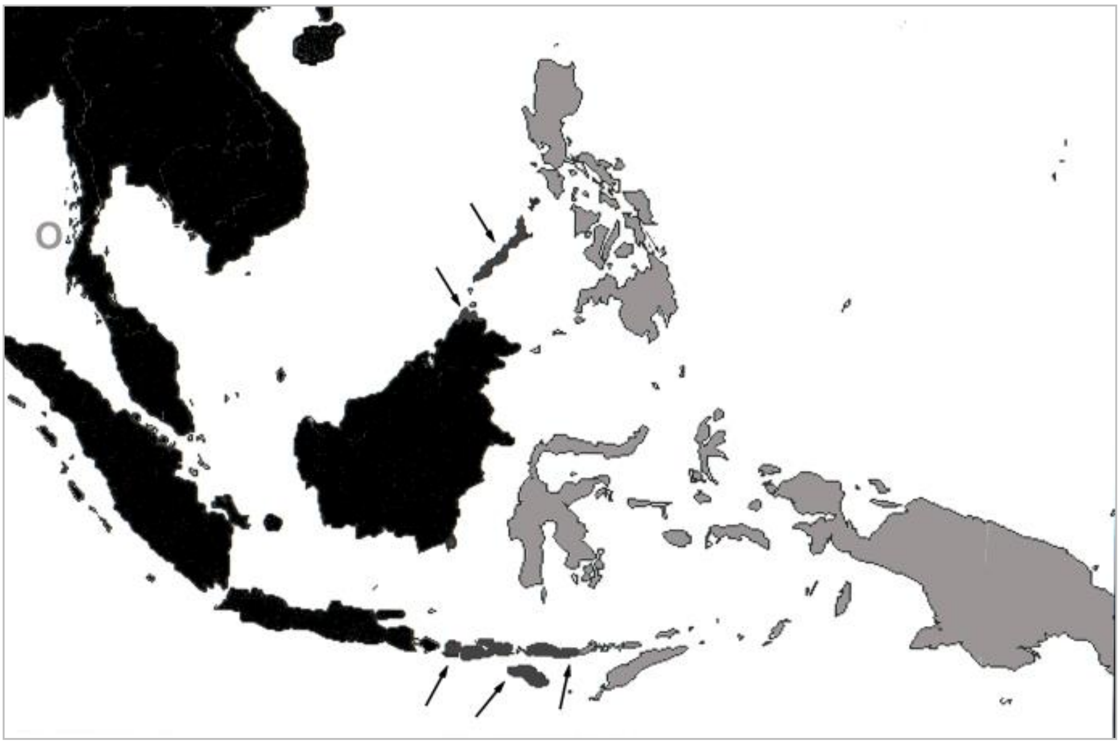

Figure 7b. Comparative distributions of Phasianidae (pheasants, excluding quail) in black and Megapodiidae in grey (adapted from Figure 1 of Olson 1980). Areas of overlap between pheasants and megapodes are shown with arrows (Palawan, northern Borneo, Lesser Sunda Islands).

Hypothetical megapodes

One curious report originates from the second voyage of Captain James Cook (1772-1775). The naturalist on that expedition, William Anderson, briefly made reference during his time on New Caledonia to a bird that he called *Tetrao australis* ('southern grouse'), with the very short description '*Fusca nigraque; pedibus nudis*' ('brown and black; legs bare'). Many years later Robert Gray (1861) erected the name *Megapodius andersoni* on the basis of the original account in Anderson's unpublished papers (Figure 8). Gray supposed it could not be attributed to any bird then known from New Caledonia. While the description could possibly have referred to a large rail, Anderson should have been able to distinguish such from a fowl-like bird. No megapodes occur in New Caledonia today, although Holocene-aged fossils have been recovered (see below).

A former resident on Sunday Island (now known as Raoul Island and uninhabited) in the Kermadec Islands (1100 km north-northeast of New Zealand and 900 km south-southwest of Tonga) recounted the presence of birds and their mounds in the mid-1870s (Figure 8a). These lived on the floor of one of the volcanic craters that dominate the island (Lister 1911). His observations imply the presence of a megapode on the island, although some workers suggested other possibilities. In any case, a volcanic eruption in 1876 razed the crater floor and with it, any obvious evidence of the bird's existence.

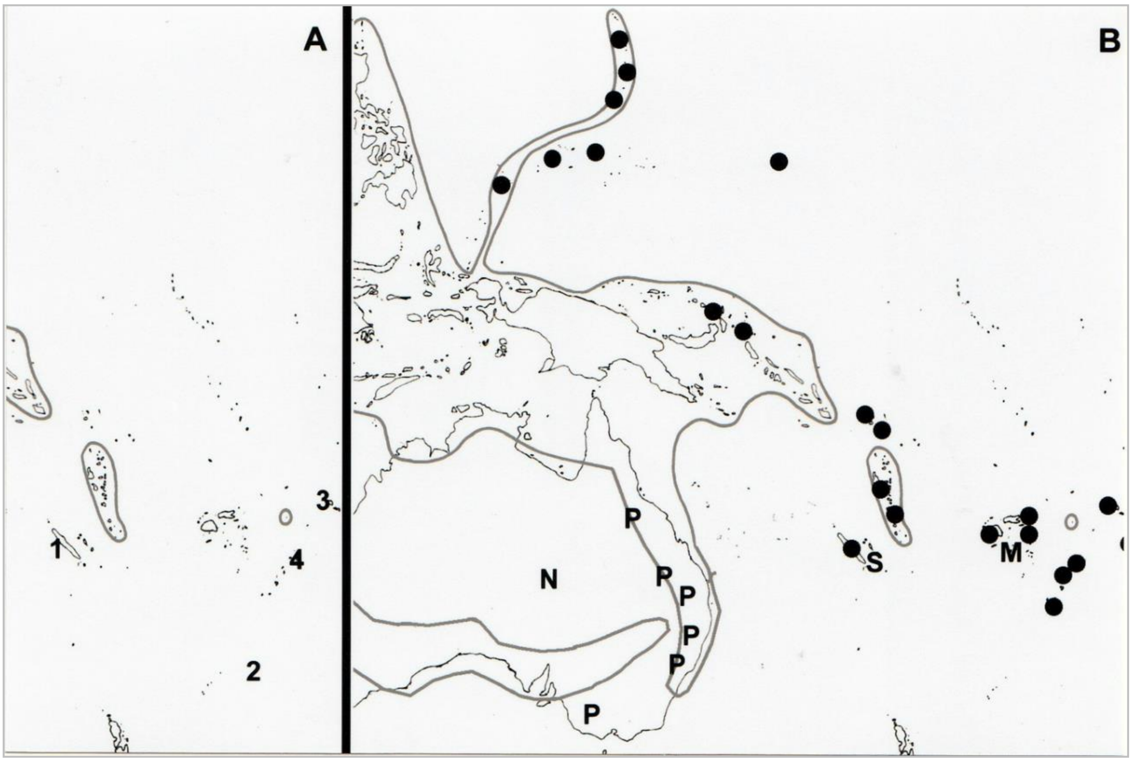

Figure 8. A. Hypothetical records of megapodes. 1. *Megapodius andersoni*. 2. Sunday Island, Kermadec Islands. 3. *Megapodius stairi*, based on egg. 4. *Megapodius burnabyi*, based on egg. **B.** Fossil records of megapodes. Black dots, extinct populations (both described and unnamed) of *Megapodius*. S, *Sylviornis neocaledoniae*. N, *Ngawupodius minya*. P, *Progura gallinacea*. M, *Megavitiornis altirostris*.

Two species were each named on the basis of only a single egg donated to the British Museum by explorers in the 1800s (Gray 1861) (Figure 8a). These were from Western Samoa (*Megapodius stairi*) and the Ha'apai Group, Tonga (*M. burnabyi*), where megapodes do not occur today. Given the absence of other evidence, together with the practice of humans to transport eggs between islands, it was long considered that these eggs were those of *M. pritchardii* (Polynesian Megapode), today found elsewhere in Tonga (surviving only on Niuafo'ou). In addition, the size of the eggs overlapped those of *M. pritchardii* and several other species in the Pacific. The eggs were studied by David Steadman, an expert on megapodes of the Pacific islands.

He concluded that neither egg could indisputably be attributed to *M. pritchardii*, another living species or a recently extinct one (Steadman 1991). Given their unsettled attributions to any megapode living or dead, Steadman regarded them as *nomina dubia*.

Fossil and archaeological record

Some galliform fossils from late Eocene and early Miocene deposits in France were initially thought to be primitive representatives of the megapodes, hence the name Quercymegapodiidae after Quercy, one of the sites at which they were found (Mourer-Chauviré 1992). Subsequently, additional species were described from specimens elsewhere in Europe and from Brazil. Further studies since then have concluded that the quercymegapodes are early galliforms that share primitive characters with true megapodes, but were not particularly closely related within the Order (Mayr 2009). With the removal of this group, most of the megapode fossil record is confined to the last 1.6 million years (Quaternary).

The oldest known megapode is *Ngawupodius minya* from the Late Oligocene (26-24 million years ago) of north-eastern South Australia (Boles & Ivison 1999). It was described from a tarsometatarsus (foot bone), although other bones are now known but not yet described. This was a very small bird, about the size of a large quail. The proportions of the tarsometatarsus most closely resemble those of the living Malleefowl and it is conceivable that *Ngawupodius* was in the lineage leading to the Malleefowl.

Other than *Ngawupodius*, all other extinct forms come from Quaternary fossil deposits and archaeological sites (primarily Holocene; 10,000 years ago to the present), mostly on Pacific islands (Steadman 1999). With the exception of a few large and remarkable species, fossil megapodes of this age belong to the genus *Megapodius*. These demonstrate that the distribution of this genus (and hence family) was once more extensive than at present and that the number of species of *Megapodius* was previously considerably greater. David Steadman (1999) and others have documented the presence of both extant and extinct taxa from deposits throughout the Pacific, including from islands that do not currently support any megapodes (New Caledonia, Fiji, several island groups of Tonga, Samoa, Niue, and Pohnpei). The Samoan records extend the distribution of megapodes further east. The prehistoric presence of *Megapodius* on New Caledonia could conceivably be related to the hypothetical megapode *M. andersoni* of Captain Cook's expedition. The fossils also show that on even some small islands three species of *Megapodius* co-existed. Steadman attributes the loss of these populations to the arrival of humans. No doubt any commensal animals (pigs, dogs, rats, etc.) would have also had major impacts. The naïve birds, plus the eggs supplied by the obvious mounds, would have been easily exploited food sources. This pattern of anthropogenic extinctions of not only megapodes but many bird groups has been documented across many Pacific islands. Steadman (1999) estimated that had people not exterminated so many populations, the number of megapode species would have probably been closer to 45-55.

Three large, now extinct, non-scrubfowl species warrant further comment. The largest galliform bird known to have existed, *Sylviornis neocaledoniae*, occurred in New Caledonia and the Île des Pins up until the Holocene. This was originally described as a ratite (Poplin 1980) and subsequently a megapode (Poplin *et al*. 1983) but further work has concluded that, while related to megapodes, it warrants placement in its own family (Mourer-Chauviré & Balouet 2005). This remarkable bird averaged 1.7 m in length and about 30 kg in mass. *Sylviornis* was flightless, its wings being greatly reduced. The bill was laterally compressed, dorsoventrally high and sported a large knob. Like megapodes, this bird apparently also incubated its eggs in mounds. Mounds 5 metres high and 50 metres wide found on the Île des Pins have been suggested as remnants of *Sylviornis* mounds. Humans wiped *Sylviornis* out soon after arrival on New Caledonia in 1,500 B.C.

Another large island form, this one a true megapode, was *Megavitiornis altirostris* from Late Pleistocene-Holocene deposits in Fiji (Worthy 2000). Like *Sylviornis*, it was flightless and had a markedly enlarged, laterally compressed bill. Trevor Worthy, who found and described this species, considered that the massive bill may have been used for cracking large, hard seeds. Fiji has several trees that produce seeds, but there are not animals now living on the islands that can open them. *Megavitiornis* was also a victim of humans soon after they colonized the islands.

Progura gallinacea was a turkey-sized megapode from south-eastern Australia. It was described in 1888 by C. W. de Vis, the head of the Queensland Museum from among fossilized bones from the Darling Downs region (c. 5-1 million years ago) (de Vis 1888). He is now known to have frequently assigned his fossils to the wrong groups and regarded *Progura* as a relative of the crowned pigeons (Goura) of New Guinea.

Nothing more was done with *Progura* until new bones were found at Naracoorte Caves, South Australia, leading G. F. van Tets of CSIRO Division of Wildlife Research to restudy the de Vis specimens together with the new ones (van Tets 1974). *Progura* has been well represented in this area because of the many caves and the birds' apparent inadvertent practice of falling into them at regular frequency. Van Tets discerned that four of de Vis' fossil birds (*Progura*, a purported stork, a purported bustard and a genuine megapode) actually represented a single species, which was in fact a very large megapode. The name *Progura,* having been published first, had priority for this bird. On the basis of the new specimens, van Tets also named a second, smaller species *P. naracoortensis*, which he distinguished on relative leg length and overall size. A few years later, however, he suggested that the two species of *Progura* might represent different sexes of the one species.

The discovery of additional and more complete specimens at Naracoorte and the surrounding area allowed a new study that revisited the conclusions of van Tets (Boles 2000). It addressed whether one or two species of *Progura* should be recognised and attempted to identify the closest living relative among living megapodes.

Modern megapodes exhibit minor differences in size related to gender, but show considerable variation between individual birds. The greater assemblage of *Progura* specimens provided no evidence of obvious sexual dimorphism. Instead, the variation seen appears individual in nature. This also led to the proportionally different leg lengths noticed by van Tets because the comparisons where made between bones from different individuals. This, together with the absence of an obvious break in the size range of specimens, implied that one species of *Progura* should be accepted. Thus, *Progura naracoortensis* van Tets, 1974, was synonymised with *Progura gallinacea* De Vis, 1888 (Boles 2008).

Of all living megapodes, that closest to *Progura* in morphology is the Malleefowl. In fact, the differences between the two are mainly quantitative (size), with essentially no other differences of significance (Figure 9). So close are *Progura* and *Leipoa* that recognition of two genera is not justified. Thus, *Progura* De Vis, 1888, becomes a synonym of *Leipoa* Gould, 1840 and the species name becomes *Leipoa gallinacea* (De Vis) (Boles 2008).

During the Late Pleistocene (more or less the last 100,000 years until 10,000 years ago), many groups of Australian animals began to show increases in body size. It was at this time that *Diprotodon optatus*, the largest marsupial ever to have lived, appeared. Collectively called the megafauna, these animals also included giant kangaroos, wombats and other mammals. Suddenly, about 30-40,000 years ago, these large animals went down one of two paths. Along one, the lineage died out. Along the other, the animals started getting smaller, a process called dwarfing. Much of the megafauna, such as *Diprotodon*, went down the former path. Others like the koalas and Tasmanian Devils went along the latter, as did the Eastern Grey Kangaroo (*Macropus giganteus*), reaching its modern proportions. The decrease in size ranged from only 4% in the Devils to more than 25% in the Kangaroo.

Progura gallinacea was a megafaunal member of *Leipoa*, which gives rise to the question, did it turn into modern *Leipoa ocellata* by dwarfing (analogous to Eastern Grey Kangaroo)? This would have required a reduction in size of 25-30%. While almost all of the fossil material from the Naracoorte region represents *gallinacea*, there is some evidence that *ocellata* was also present, which conflicts with the suggestion of dwarfing. Until further information become available, the two are retained as separate species.

Figure 9. Comparison of skeletal elements of *Progura gallinacea* (left) and *Leipoa ocellata* (right). Top to bottom, humerus, ulna, carpometacarpus. Left to right, femur, tibiotarsus, tarsometatarsus. Line equals 10 mm.

As yet unpublished information from recently discovered fossil deposits in caves in the Nullarbor Plain points to an undescribed species present at the same time as *Progura*. Another intriguing aspect is the presence of large mound-like piles of stones known through parts of western New South Wales and elsewhere (Noble 1999). These do not appear to be geological formations, often differing strikingly from the underlying strata. The suggestion that these represent the remnants of old *Progura* mounds is a fascinating one, awaiting further study.

The future for megapodes

Work on archaeological sites through the Pacific has demonstrated the negative influence that human contact has had on megapodes in numerous locations, with many populations now extinct. This trend is continuing. A number of megapodes species are included on the IUCN Red List of Threatened Species as Endangered or Vulnerable, based on the evaluation of a range of criteria (Figure 10). An Endangered species is regarded as facing a very high risk of extinction in the wild in the near future. Four species of megapodes are listed as Endangered. A Vulnerable species, while not Endangered, is facing a high risk of extinction in the wild in the medium-term future. Six megapodes species are included in the Vulnerable category. One species has been evaluated and, while it does not satisfy the criteria for Endangered or Vulnerable, it is close to qualifying for the latter and so is listed as Near Threatened (NT). Those species that are considered Endangered, Vulnerable and Near Threatened are noted in Table 1 and their localities in Figure 10. It is worth noting that even most of the species regarded as Least Concern (those that do not qualify for any of the other categories) are nonetheless noted as decreasing.

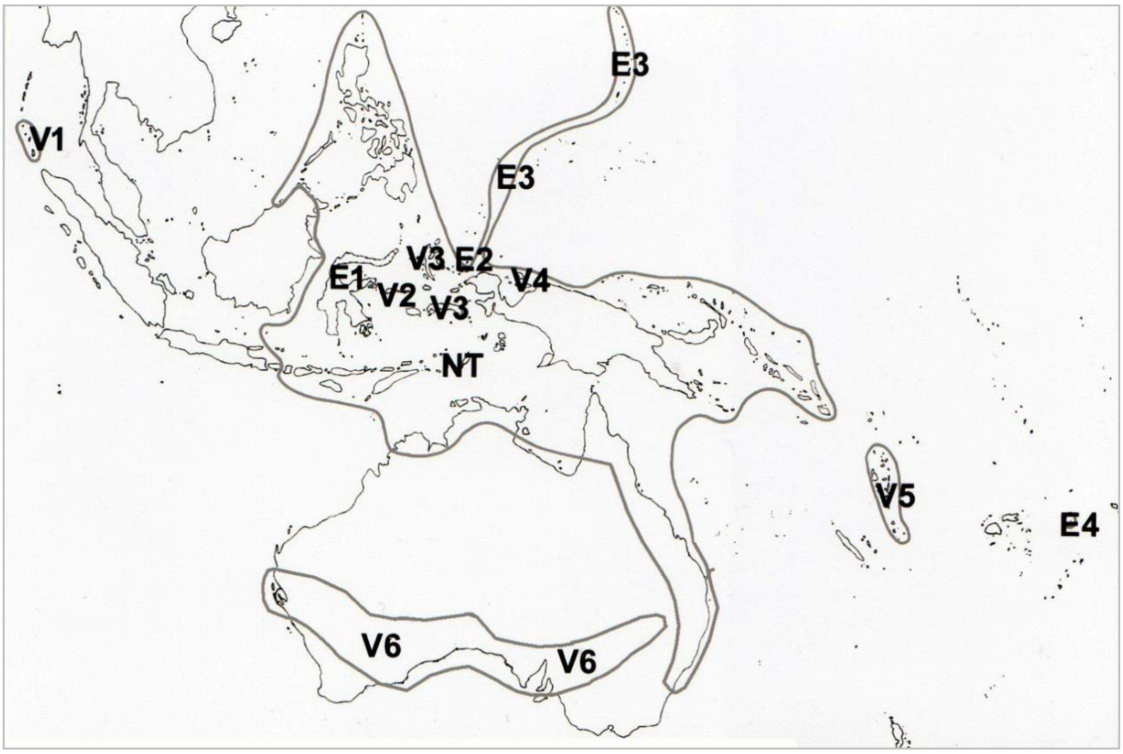

Figure 10. Species of megapodes in the Endangered, Vulnerable or Near Threatened categoris of on the IUCN Red List of Threatened Species. NT, *Megapodius tenimbarensis*. V1, *Megapodius nicobarensis*. V2, *Megapodius bernstenii*. V3, *Eulipoa wallacii*. V4, *Megapodius geelvinkianus*. V5, *Megapodius layardi.* V6, *Leipoa ocellata*. E1, *Macrocephalon maleo*. E2, *Aepypodius bruijni.* E3, *Megapodius laperouse*. E4, *Megapodius pritchardii.*

Most megapode species face a similar suite of detrimental factors, with a scattering of other threats that may vary among species. Predation by humans on birds or, more often, overexploitation of eggs is common for the majority of populations outside Australia. Unsustainable harvesting of eggs, frequently illegal, can exceed the rate at which new individuals enter the population. Human-introduced animals often take a heavy toll on chicks and eggs. Competition with non-native grazing animals, such as goats and cattle, is a hurdle in some locations. As populations are reduced in size and area they can become increasingly susceptible to native predators that are not a problem in less disturbed situations. Loss of habitat and destruction of nesting areas from logging or agriculture are threatening processes for many species, while mining, road development and even tourism are implicated for some. Other risks come from fire, invasive vegetation and, for some populations on small islands, severe weather events. Of these causes, unregulated overexploitation by humans, predation by feral animals and habitat loss are probably the most severe.

The Malleefowl is somewhat unusual among the threatened species because it is the only one that has a continental distribution, rather than an insular one. Hunting of birds and eggs is not an important contributing factor to its decrease, but habitat loss, predation by feral animals, competition for habitat and fire are still significant dangers.

There are organisations in Australia and elsewhere working to conserve megapodes. This is not an easy task: there are many obstacles in their way. But many megapodes depend on it if they are to have a future.

Appendix 1. Genera and species of living Megapodiidae (following Jones *et al.* 1995), giving the scientific name, describer and date; IUCN category for threatened species; English name; and distribution. The IUCN categories are (V) Vulnerable, (E) Endangered, (NT) Near Threatened.

Scientific Name; Author; Date; (IUCN Category)	English Name	Distribution
***ALECTURA* Latham, 1824**		
lathami J.E. Gray, 1831	Australian Brush-turkey	E Australia: N Queensland to EC NSW
***AEPYPODIUS* Oustalet, 1880**		
arfakianus Salvadori, 1877	Wattled Brush-turkey	Montane New Guinea; Yapen Is; Misool, West Papuan Islands
bruijnii Oustalet, 1880 (E)	Bruijn's Brush-turkey	Waigeo, West Papuan Islands
***LEIPOA* Gould, 1840**		
ocellata Gould, 1840 (V)	Malleefowl	SW, SC Australia
***TALEGALLA* Lesson, 1828**		
cuvieri Lesson, 1828	Red-billed Talegalla	Lowland W New Guinea
jobiensis Meyer, 1874	Black-billed Talegalla	Lowland NE, N, SE New Guinea; Yapen Is
fuscirostris Salvadori, 1877	Brown-collared Talegalla	Lowland NE, S New Guinea; Aru Islands
***MACROCEPHALON* Müller, 1846**		
maleo Müller, 1846 (E)	Maleo	Sulawesi, Sangir Is, Bufon Is
***EULIPOA* Ogilvie-Grant, 1893**		
wallacei G.R. Gray, 1860 (V)	Moluccan Megapode	Moluccas; Misool, West Papuan Islands
***MEGAPODIUS* Gaimard, 1823**		
freycinet Gaimard, 1823	Dusky Megapode	Northern Moluccas; Buru; West Papuan Islands
laperouse Gaimard, 1823 (E)	Micronesian Megapode	North Marianas Islands; Palau (formerly South Marianas Islands, Guam)
reinwardt Dumont, 1823	Orange-footed Megapode	Lesser Sundas; W, S New Guinea; N Australia: N Western Australia and Northern Territory, N to EC Queensland
nicobariensis Blyth, 1846 (V)	Nicobar Megapode	Nicobar Islands
forstenii G.R. Gray, 1847	Forsten's Megapode	Seram, surrounding islands, South Moluccas

cumingii Dillwyn, 1853	Philippine Megapode	Philippine Islands; Sulawesi and intervening islands; NE coastal Borneo
pritchardii Gray, 1864 (E)	Polynesian Megapode	Niuafo’ou, Tonga
layardi Tristam, 1879 (V)	Vanuatu Megapode	Vanuatu
bernsteinii Schlegel, 1866 (V)	Sula Megapode	Sula Is; Banggai Is.
eremita Hartlaub, 1867	Melanesian Megapode	Bismarck Archipelago; Solomon Islands, peripheral islets
geelvinkianus Meyer, 1874 (V)	Biak Megapode	Islands of Geelvink Bay, including Biak Is, Numfoor Is, Mios Num Is
decollatus Oustalet, 1878	New Guinea Megapode	N New Guinea; Yapen Is; offshore islands
tenimberensis Sclater, 1883 (NT)	Tanimbar Megapode	Tanimbar Islands

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18. Update on the National Malleefowl Monitoring Database: recent developments and new gear

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Abstract

The National Malleefowl Monitoring Database (NMMD) has become central to the monitoring effort across Australia, providing centralisation of records, secure storage, and a range of data management and reporting facilities. We have formed a data-handlers group for the NMMD comprising representatives from each state who are responsible for the collating and validating data onto the NMMD. We provide an overview and an update on recent NMMD developments and discuss directions for the future. In addition, we discuss the latest developments in field devices, particularly the Android smartphones. Smartphones are not as weatherproof or tough as Mobile mappers, Nomads or other devices, but they are much more powerful, take better photos and are much cheaper. The increased power of the Androids makes it easier to take photos than with the Mobile mappers, and recent developments that we commissioned in Cybertracker enable automatic extraction and naming of photos. These improvements greatly increase the efficiency of photo handling and make the Androids especially appealing for monitoring Malleefowl.

Introduction

Malleefowl conservation is the goal of the monitoring program in which volunteer 'citizen scientists' collaborate with agencies and academics to track the breeding numbers of these special birds across Australia. The rationale is simple enough: tracking breeding numbers through time provides us with information on trends in the population size of reproductive individuals – the all-important 'effective population' that contributes to the next generation – and clarifies the species' conservation status, while doing so at multiple sites also enables us to identify where Malleefowl are doing well and where they are doing poorly, providing us with the opportunity to learn about the species requirements, improve management, and target areas where intervention is most beneficial. A rigorous monitoring program is an essential foundation for conserving a species where there is uncertainty about effective management, which is why monitoring has been given a high priority in the National Recovery Plan for Malleefowl (Benshemesh 2007).

However, monitoring is not easy. There is, of course, the considerable effort required for people to annually visit mounds to check on their status which typically involves several days a year of walking in demanding conditions. But this is only part of a larger set of activities that constitutes the monitoring cycle. This annual cycle involves four broad steps:

1. Organising people to undertake the monitoring. This is usually done at a local or state level and involves training people (equipment use, data and safety protocols), allocating people to sites to ensure that all sites are monitored, making sure people receive what they need (equipment, maps, lists, etc.), and that all the equipment is up-to-date.
2. Collecting data. In the field, people need to navigate to each and every mound on the lists (updated each year), collect data, and return the data and equipment for processing.
3. Validate and update lists. Each year the data collected needs to be checked for errors and, where possible, these errors need to be rectified while things are still fresh in people's mind. Often, changes need to be made reflecting what people have found in the field: new mounds need to be added to sites, erroneous records need to be removed, and very old and inconspicuous mounds may be designated optional for most years but mandatory every fifth year. Checking the data also provides an opportunity to point out where people might be making mistakes and thus helps maintain high standards. Without an effort to keep things on track, any system is bound to wander and become corrupted in time, and eventually unintelligible.

4. Store and secure. Storing data so that it can easily be found and accessed for analysis is obviously essential; what's the point of collecting data otherwise? But it's also important to secure it so that it does not fall into the hands of people who might do harm. Experience has shown that local groups are not well placed to provide either of these data services and, alas, nor are governments.

Considering that there are over 130 sites across Australia containing a total of 4,000 mounds and that hundreds of volunteer citizen scientists are involved in the national monitoring effort for Malleefowl, it's easy to see the organisational challenge to support the field work is substantial. Yet it is essential to maintain a high standard of incoming data and to provide an efficient experience for volunteers and to make sure the efforts of volunteers is not wasted. Indeed, some data in the early days of monitoring was lost due to failures in data quality control or data storage; this seems such a waste considering the effort involved in the field to collect the data.

NMMD: a national solution to organising monitoring

The National Malleefowl Monitoring Database (NMMD) was developed by Richard, Margaret and Becky Alcorn to meet the national challenge of organising the monitoring. Its purpose is to support the great work done by communities across Australia in collecting the essential data on Malleefowl trends in different areas. The NMMD provides a centralised repository of monitoring data, and facilitates the organising that precedes fieldwork and the careful checking and validating that follows it, ensures the data is good and ready for analysis and helps to maintain standards by providing avenues for feedback.

The NMMD looks after the monitoring effort, but who looks after the NMMD? We have a data-handlers group comprising all those involved in handling data and equipment behind the scenes across Australia (Table 1). These are the people that keep the data flowing and ensure that the data is treated with the respect it deserves given both the enormous effort it represents, and the irreplaceable information it contains. The data-handlers group's main responsibility is moving data onto the NMMD and checking it (validating), but the group also makes decisions about further developments of the NMMD, chooses equipment, and generally looks for ways to make processes more efficient for everyone. This is critically important, because efficient processes are more sustainable in the long term, and Malleefowl monitoring is necessarily a long term activity. The data-handlers group only get to meet once a year (or less), but we keep in contact via email and of course through the NMMD.

Table 1. NMMD data-handlers in 2014-15.

WA	SA	Vic	National Administrators
June Meredith Joy McGilvray Carl Danzi	**Graeme Tonkin Dave and Heidi Setchell Sharon Gillam**	**Peter Stokie Joe Benshemesh**	**Beckie Alcorn Joe Benshemesh**

Understanding the NMMD

The NMMD is a secure database: access to it is controlled by passwords, and there are several levels of access that ensure that sensitive information (such as the location of mounds or sites) is only available to the few people who need it (such as people who visit particular sites and those who validate records). Anyone who contributes data can obtain a password to the NMMD so that they can see their data, leave comments or corrections, and view photos (Figure 1), but they can't see other people's data unless permission has been granted. Conversely, they may not want others to see their data and this can be arranged so that their site's location does not appear on maps or tables.

What Contributors can do on the NMMD

- **Review and annotate** their records
- **View** mound photographs
- **Download** monitoring forms, manuals and information
- **Look at** Maps of sites and mounds
- **Examine** Reports: Inspection, Activity and Environment

Figure 1. What contributors can do on the NMMD.

There are three main levels of access to the NMMD that reflect the differing tasks (Figure 2). Put simply, Coordinators organise people and gear; Contributors collect field data; and Ecologists make sure the data is complete and as error free as possible. They are all big jobs in their own ways but manageable provided protocols are followed because the NMMD expects data in a certain form and is designed to process this information.

Coordinator

1. Allocate people to sites
2. Register new people
3. Upload Cybertracker to smartphone/mobilemapper
4. Upload Waypoints to GPS
5. Send gadgets, maps etc. to Contributors

Contributor

6. Receive gadget, download info from NMMD
7. Collect data
8. Return gadget and data to Coordinator

Coordinator

9. Receive gadgets and data from Contributors
10. Upload data to NMMD
11. Extract photos and send to Ecologists

Ecologist

12. Receive photos: rename/stamp/resize & upload to NMMD
13. Validate records: correct and annotate records/register new mounds/assess mound status (regular/optional/omit)/ resolve duplicates/ search for missing records/provide feedback where required

Data ready for reporting, analyses, and next monitoring

Figure 2. Routine tasks that make up the annual monitoring cycle. Tasks are colour coded to indicate those undertaken by contributors (red), coordinators (blue) and ecologists (green). Reporting and analysis of the monitoring results can only occur once all the listed tasks are complete.

New developments and gadgets

In an effort to make monitoring Malleefowl simpler and more efficient we have introduced various tools and innovations over the years, and expect to keep on the lookout for anything that might help people contribute to this important program. Realistically, only citizen scientist volunteers can collect Malleefowl monitoring data at the necessary scale, and we owe it to the volunteer community to make the tasks as smooth as possible, and to make the data as useful to Malleefowl conservation as possible.

Accordingly we introduced GPS units to the monitoring as soon as they became accurate enough (2000) and starting using Cybertracker on Palm handheld computers soon after (2002). Similarly we started using digital cameras in the mid-2000s and moved on to Mobile mappers several years ago because they offered a great improvement over the Palms - they could take photos and had a built in GPS - providing a neat package.

This season (2014/15) we have something much better than the Mobile mappers. We are now moving to Android smartphones because they offer more power, much better photos, a much larger screen, and generally better integration at a small fraction of the cost of Mobile mappers (about a tenth the cost!). The Androids are not as weather and shock proof as the Mobile mappers, but at that cost it hardly matters because even if they are broken or wetted, the data on the SD card should be safe. We have chosen a particular model on the basis of the size of the battery (longest lasting on the market) and cost, and they have been popular with Malleefowl monitoring because the smartphones are faster to respond and generally user friendly; they leave the Mobile mappers in the dust! The move to smartphones also means there is now no need to use digital cameras; the quality of the smartphone photos is superb and there is no unsettling delay as there was with Mobile mappers.

This means we can take all photos through Cybertracker, and to make things easier for the behind-the-scenes data handlers, we commissioned Cybertracker to make some modifications that have greatly reduced our handling time in processing photos. Each year, thousands of photos need to be labelled so that the NMMD can find and display them when you (and validators and analysts) examine the data on-line. Cameras automatically name photos (e.g. Photo0001) but these names need to be replaced with names based on the site code, nest number and season. Cybertracker also gives arbitrary names to photos embedded in data records, but the facility we commissioned will now export photos and give them a new name based on other data collected (such as site, mound number and season). This means that we don't have to laboriously re-name thousands of photos, which is a great saving in time. Photos taken with separate digital cameras still have to be re-named the old way by hand, so please take photos using Cybertracker!

Bugs and Gremlins

While the smartphones have made data collection easier, they are almost too smart by half. One problem that has concerned us is that using the smartphones to navigate to mounds is less reliable than it previously was in Cybertracker or by using a separate GPS. While the smartphones are as good as a separate GPS most of the time, every now and then the direction arrow points the wrong way. We have traced this to the compass feature in the smartphones (they have a digital magnetic sensor in them) which occasionally goes wonky. This does not happen often, but is disconcerting when it does. We will be trying to rectify this by next season by commissioning some changes to Cybertracker to compensate for what is actually a shortcoming of the smartphones (it seems to occur with other makes of smartphone too). Meanwhile, we have been recommending that people use separate GPS units to navigate to mounds, or if using a smartphone to pay more attention to the bearing and distance to target than the direction arrow.

Conclusion

The NMMD and progressively improved field gadgets have resulted in monitoring Malleefowl now being simpler and easier than ever before. The NMMD has become central to the monitoring effort, with its development overseen by the data-handlers group which provides a valuable service to data collectors, and implemented by professional database programmers (Becky Alcorn). Due to the efforts of the volunteer citizen science community, we are collecting more and better quality data than ever before, and processing it more quickly and efficiently due to the NMMD and efforts of the data-handlers.

There is, however, more to do. As the Malleefowl monitoring effort grows, so have the opportunities to value-add to the monitoring, such as through the Adaptive Management (AM) Project which aims to improve management through evidence-based analyses. The AM Project will rely heavily on the flow of monitoring data and we will have to develop ways of delivering data from the NMMD to the team so that each year they are provided with the data they need to assess Malleefowl trends in relation to other variables, such as the abundance of predators, management actions, rainfall, etc. While much of this information is already on the NMMD, we will also wish to capture more, especially detailed management information and the results of the camera-trap program that is providing information on the trends of other animals, particularly foxes, cats and dogs.

Another direction for further development of the NMMD is in regard to the Malleefowl monitoring work undertaken in central Australia by Aboriginal communities. While our aboriginal colleagues collect information at mounds for the NMMD, other monitoring methods are also used, such as systematic tracking, and may be more appropriate in the sparsely distributed Malleefowl populations in the arid zone. The NMMD does not support systematic tracking yet, but may do so in the future. Having these alternative data on the NMMD would clearly benefit Malleefowl conservation by providing information on Malleefowl trends at the edge of their range where climate changes are likely to have major impacts, but would also greatly assist the efforts of Aboriginal groups by providing on-line tools for managing their monitoring data, offering safe data storage, and by demonstrating that they are part of a larger community of citizen scientists that are concerned about Malleefowl conservation and want to do something about it.

The main focus of the data-handlers group is undeniably to improve the flow of data, ensuring that every step from collecting data in the field, to its end use in analysis, is as easy, simple and reliable as possible. The entire system is purpose driven, and we want to make the system as efficient and sustainable as we can. But we are also keen to make the NMMD a useful portal for the contributors who are the backbone (and heart and guts!) of the Malleefowl monitoring effort. In the past we have introduced a number of features specifically for contributors (maps, photo views, reports, etc.) but we are always after more. Any other thoughts on how we can improve the NMMD for contributors will be greatly appreciated: please talk to your state representatives!

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19. Malleefowl (Nga<u>n</u>amara) as a flagship species for Indigenous Land Management in the Great Victoria Desert of WA, with notes on new sites & implications for Nga<u>n</u>amara distribution

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Abstract

Malleefowl (Nga<u>n</u>amara) has been an important element in the evolution of the Spinifex Land Management (SLM). Nga<u>n</u>amara has cultural significance to Spinifex People (A<u>n</u>angu living in the Great Victoria Desert of Western Australia) and is a traditional source of food, particularly Nga<u>n</u>amara eggs. More recently, Nga<u>n</u>amara has found significance as one of the primary vehicles through which indigenous rangers from SLM have engaged in threatened species surveys and monitoring. Survey has occurred through implementation of a track-based monitoring methodology using the Cybertracker Program, while monitoring has occurred through repeated visits to known sites and through installation of remote sensor cameras to monitor known nesting sites. As a result, rangers have located three nests (one known to be active in the last three years) contributing to six new records for Nga<u>n</u>amara in the Great Victoria Desert. In doing so, these records have filled vital gaps in the current and historical distribution of Nga<u>n</u>amara in Australia. Through these activities, rangers have not only gained practical skills in the use of GPS software and equipment but also knowledge of threatened species conservation and threat abatement processes. Nga<u>n</u>amara sightings have also provided a useful way of engaging the wider community in land management activities as community sightings are reported to rangers who then inform the survey program. This, in turn, has seen cultural knowledge of Nga<u>n</u>amara passed on from older to younger generations, thereby reinvigorating traditional conservative use of Nga<u>n</u>amara resources.

Introduction

As Benshemesh (2008, p6) states “Malleefowl provide an opportunity for strategic investment as the species may be viewed as both an indicator species of the general condition of their habitat, and a flagship species that may engender support from the public on a range of conservation issues”. In the case of the Spinifex Land Management (SLM), both elements of this statement are true. The topic of this paper is the latter – Malleefowl as a flagship species for conservation by the public, in this case indigenous people from a remote community in the Great Victoria Desert of Western Australia.

This paper follows the timeline of evolution of SLM and highlights how Nga<u>n</u>amara has been a constant theme in this evolution from inception of the program to the current day – as SLM has grown, so too has the profile of Nga<u>n</u>amara in the Indigenous community of Tjuntjuntjara, one of the most remote in Australia, home to the Spinifex People and SLM.

This paper also reports the results of survey and monitoring work that has been undertaken within and around the Spinifex Native Title Determination Area (Spinifex Country), implications of these results for the current and historic distributions of the species in Western Australia, as well as the suite of skills and knowledge developed by rangers through SLM.

Background

Spinifex Country and Spinifex People

The Spinifex People are the holders of a native title determination over 5.5 million hectares of land in the Great Victoria Desert of Western Australia – the Spinifex Native Title Determined Area, or Spinifex

Country as it is better known (Figure 1). The remote community of Tjuntjuntjara is the on-country population centre of the Spinifex People and, at 700 km northeast of Kalgoorlie, is one of the most remote communities in Australia.

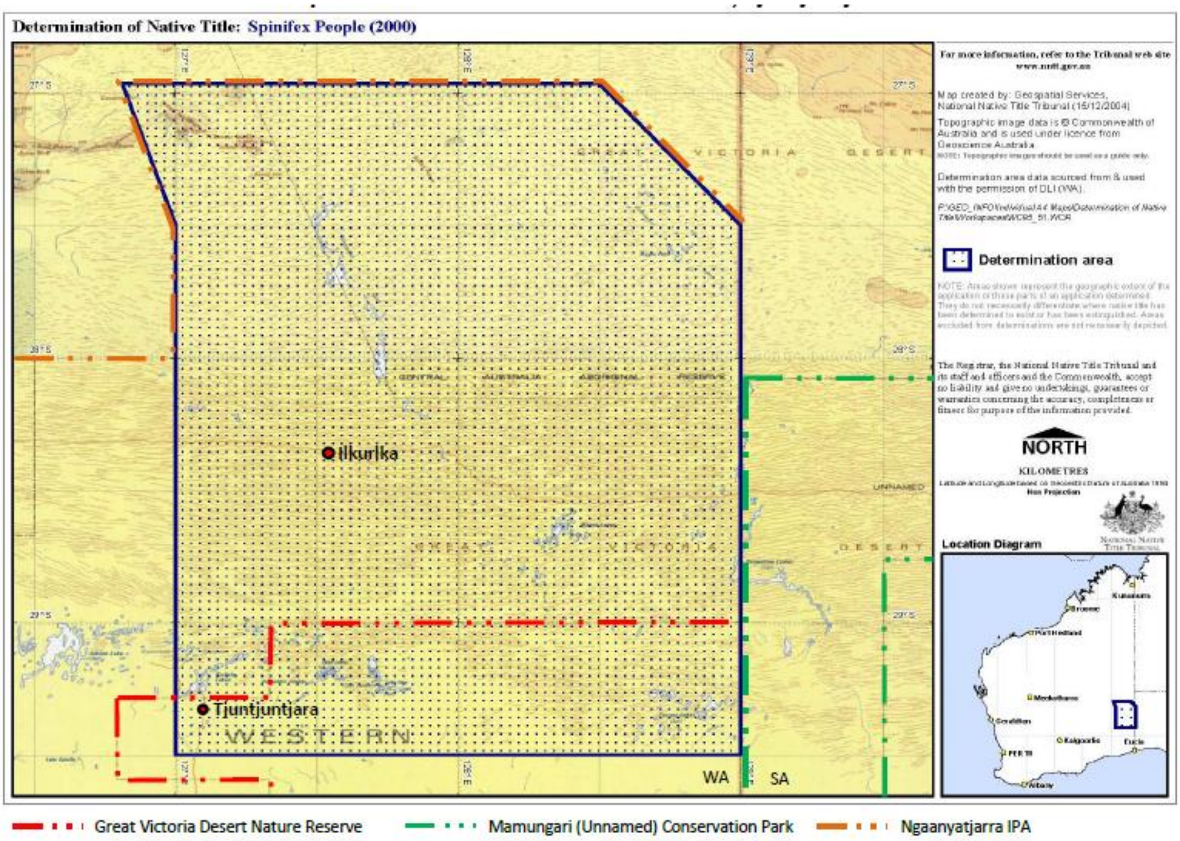

Figure 1. Location of Spinifex Country, Tjuntjuntjara and Ilkurlka.

Spinifex Country is dense with culturally significant sites and Tjukurpa (broadly – but inadequately – a combination of business, law and religion; Cane 2002). Owing to Spinifex People's comparatively recent contact history (the last family 'came in from the bush' in 1986), maintenance of traditional ways of life and connections to country, Spinifex People are in the unique position of maintaining the vast majority of cultural knowledge. The prevailing land use within Spinifex Country is subsistence hunting and gathering, as well as maintenance of cultural obligations to country. Spinifex People still retain a vast, active body of ecological knowledge.

Spinifex Country spans a transition in ecosystems from the northern edge of the Nullarbor Plain through the salt lakes and sand hills of the Great Victoria Desert, and into the foothills of the Central Ranges. Spinifex Country remains overwhelmingly in pre-European condition and extent, and contains threatened fauna species and endemic flora with localised distributions, including: Princess Parrot, Southern Marsupial Mole and *Grevillea ilkurlka*. Suitable potential habitat also exists for a number of other threatened fauna species including Sandhill Dunnart, Great Desert Skink, Greater Bilby and Black-flanked Rock Wallaby.

Of course, a significant element of the suite of extant threatened fauna species occurring in Spinifex Country is Malleefowl, or Nganamara to Spinifex People.

Spinifex Land Management

Spinifex Land Management is the natural and cultural resource management arm of Pila Nguru Aboriginal Corporation (Pila Nguru). Pila Nguru was established in 2001 to hold native title rights and interests on trust on behalf of Spinifex People.

Spinifex Land Management was established in 2011 following receipt of Caring for Our Country funding for the *Keeping Desert Country Healthy Project*. The emergence of Spinifex Land Management and receipt of Australian Government funding merely formalised what Spinifex People had been doing for countless generations – looking after country for all its inherent value and managing those values sustainably.

The core of Spinifex Land Management are the Spinifex Rangers – five young Anangu men from Tjuntjuntjara working part-time (3 days per week). Spinifex Rangers are funded until the end of June 2017 through round one of the Biodiversity Fund (Australian Government).

Nganamara as a vehicle for engagement in threatened species work

Through the coincidental timing of a few fortunate events, Nganamara became a flagship species for the threatened species work undertaken by Spinifex Land Management and was the driver for not only threatened species surveys and monitoring, but also in raising community awareness in the work being done by Spinifex Rangers, as well as instilling a sense of pride on behalf of the rangers in land management activities they were carrying out and the fact it was part of a much bigger, national picture.

A Conspicuous Beginning - Nganamara & Caring for Our Country funding arrive in Spinifex Country

Nganamara appeared on the land management scene in Spinifex Country in September 2011 just after Pila Nguru and Spinifex Land Management received their first Caring for Our Country grant through Central Desert Native Title Services and Rangelands NRM as part of the *Keeping Desert Country Healthy Project*. This project was aimed at engaging Indigenous people in remote communities in land management work, principally through fire management and threatened species surveys.

As the fledgling Spinifex Land Management team was driving to a remote cultural site to erect a water tank and feeder roof (shed tank) and meet with funding body staff to discuss the project, two Nganamara darted across the disused exploration track. The lead vehicle, in a fleet of about eight, came to a sudden stop amid a flurry of sand and dust, opening and slamming doors, and shouts directing Senior Traditional Owners (STO) in the direction the birds scurried.

One Senior Traditional Owner set about following the tracks of the birds with younger Traditional Owners hot on his tale, keen to learn (and maybe sample an egg or two). No nest was found after about half an hour searching but a flame of interest was lit – the project hadn't even started and already it had its first threatened species.

Over the coming days another series of tracks were discovered in the vicinity of the shed tank (50 km from the first Nganamara site described above), knowledge of Nganamara was passed from older to younger generations in a culturally appropriate context and all involved were excited about the project.

The Nganamara Connection

As Spinifex Land Management grew from a casual program based on funds filtered through a number of organisations into a permanent one with its own significant amount of funding, so too did the profile of Nganamara as a symbol of the land management program and an interactive point of connection between the wider community and the program itself on a number of levels – threatened species conservation in both scientific and traditional senses, as well as traditional use of Nganamara eggs. The connection between the Tjuntjuntjara community and Spinifex Land Management provided a foundation for engagement with the community on other threatened species (e.g. Greater Stick-nest Rat (Tjuwalpi), Great Desert Skink (Tjakura) and Brush-tail Possum (Wayuta).

An example of the above was exhibited on two obvious occasions in 2013 when community members travelling form other communities advised rangers employed in the land management program they had seen Nganamara and that the rangers should go and have a look. Rangers instigated surveys at both sites resulting in two confirmed records of Nganamara in Spinifex Country. One of these sites contained tracks, feathers and a large, circular digging. The Nganamara connection had clearly been made.

Surveys to on-going monitoring

Throughout 2012 Spinifex Land Management surveyed 18 plots (plus six repeat visits to plots containing Nganamara and other threatened species sites) using a track-based monitoring (TBM) methodology discussed below. Out of 18 plots, Nganamara was recorded in three (16.7%). Additional Nganamara sites were also known previously and were added to the monitoring program that could now be established due to the securing of additional funding.

This funding arrived mid-2012. At the same time, the Australian Feral Camel Management Project provided a swag of motion-sensor cameras and a vote was held as to where to put the first one. The unanimous verdict was at Site 2: Ilkurlka – Southeast (described below), the site where Nganamara conspicuously appeared in September 2011. Nganamara tracks had also been recorded during subsequent visits to the site. Cameras were placed at two other Nganamara sites for on-going monitoring.

Thus, the community was now taking an active role in monitoring of threatened species, taking the Nganamara connection to another level.

Survey and Monitoring of Nganamara in Spinifex Country

Methods

Survey for Nganamara undertaken by Spinifex Rangers utilised the track-based monitoring (TBM) methodology as outlined in Southgate & Moseby (2008) and Moseby, Nano & Southgate (2009). The TBM methodology has been widely used by indigenous ranger and land management groups in the arid zone for a number of years and has provided a considerable amount of meaningful data on the distribution of threatened and invasive species which has been used to inform management to varying degrees.

Using the TBM methodology, 2 hectare plots are searched for a set period of time based on the number of searchers. Presence (and absence) of species is based on tracks and other signs (scats, burrows, diggings, etc.). Other data collected includes tracking conditions (suitability of tracking surface, wind, strength of shadow, etc.) as well as a description of the vegetation across the plot.

Where a species of interest, predominantly Nganamara in this case, has been recorded as present at a site, monitoring has occurred using two methods: repeat visits using TBM methodology and establishment of motion-sensor cameras. The method used was determined by the type of sign indicating the presence of Nganamara.

Nganamara Sites in Spinifex Country

Nganamara has been recorded at five sites in Spinifex Country. Figure 2 indicates the location of these sites. Two of these sites are nests, one of which was recently active when discovered in October 2010 (Figure 3). A further two sites are sightings of live birds, both of which are accompanied by scratchings/excavations. Live birds were also captured by motion-sensor camera in May and September 2013 (Figure 4). Tracks were also observed at these times.

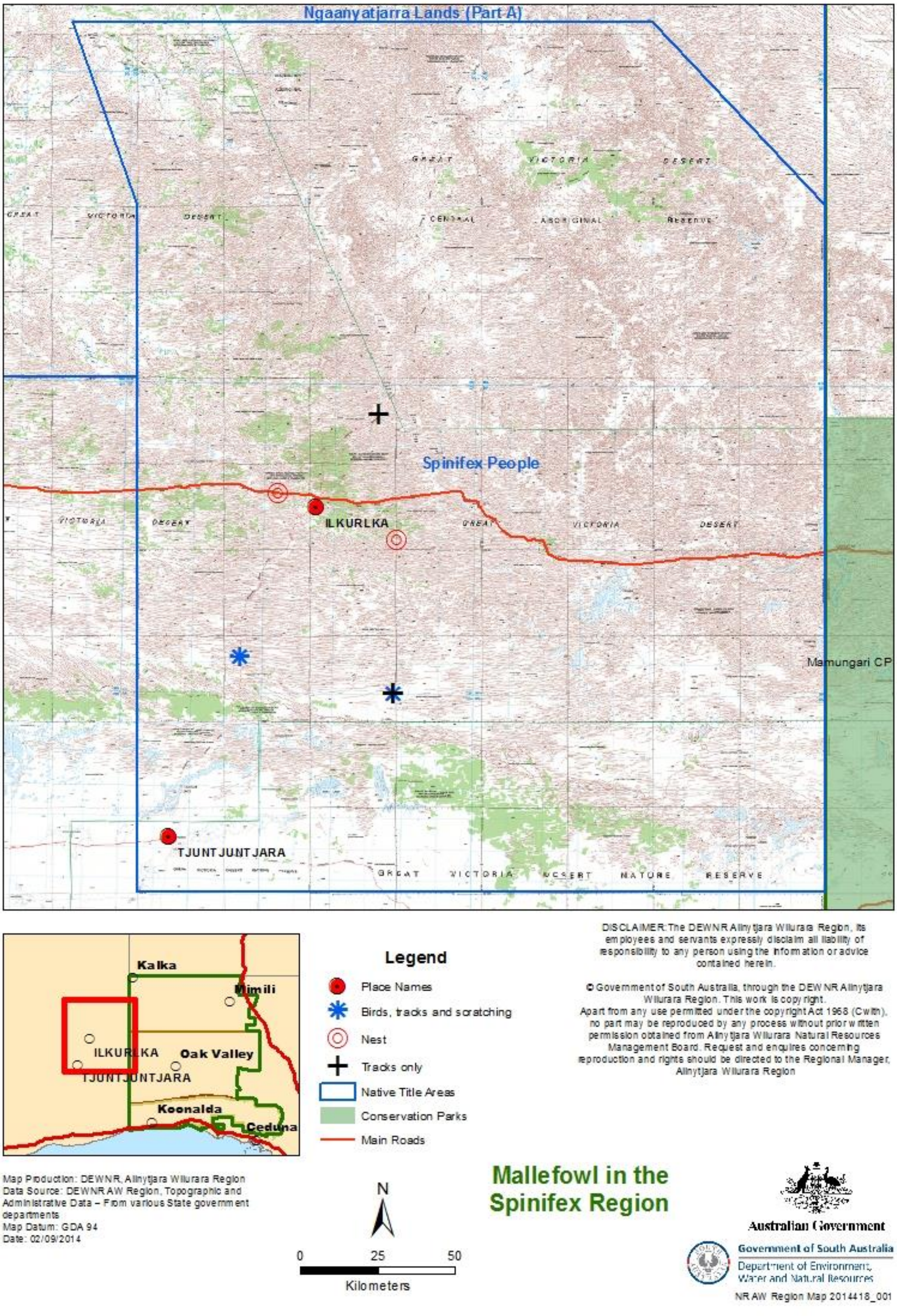

Figure 2. Location of known Nganamara observations recorded by SLM in Spinifex Country.

Figure 3. Nganamara nest recently active in October 2010. Note transition in vegetation from spinifex to Mulga. Photo: Karl Brennan.

Figure 4. Images containing Nganamara captured at the same site in May 2013 (L) and September 2013 (R).

Unfortunately each time a bird was caught on camera at this site a feral cat was also caught in images that followed. This latter site was last visited in May 2014. No tracks were recorded. The fifth site comprises tracks observed by a Senior Traditional Owner in September 2011. One repeat visit did not observe any tracks or other sign of Nganamara at this site.

A brief history of each site since first recorded by Spinifex Land Management, as well as an outline of subsequent observations, are presented in the table in Appendix 1.

Implications for Current & Historic Distribution of Nganamara

Five out of six observations presented here are considered to be valid. Observations of Nganamara presented here were considered to be valid if one or more of the following were provided:

- Observation by Senior Traditional Owners*
- Nest present
- Photo of track confirmed (by ecologist and/or Senior Traditional Owner)
- Photo of individuals.

The observations fill vital gaps in the current distribution of Nganamara and, by logical extension, the historic distribution of the species. Figure 5 indicates the location of records from Spinifex Country in relation to the currently accepted known distribution of Nganamara.

These records for Nga<u>n</u>amara increase the current and historical range of the species significantly, if not on a national scale then, at least, in the Great Victoria Desert.

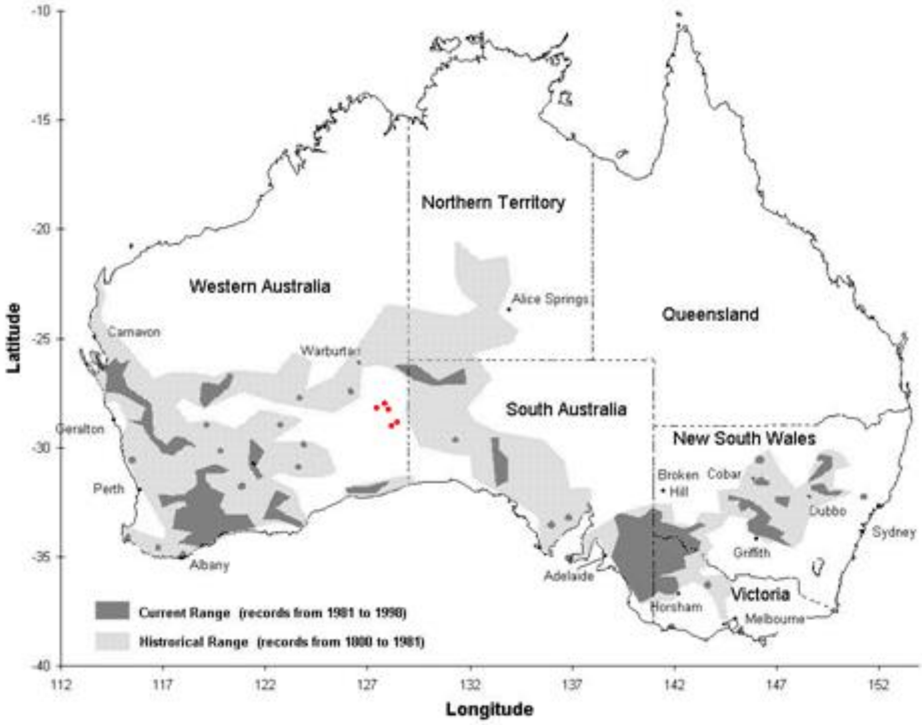

Figure 5. Location of records from Spinifex Country in relation to the currently accepted known distribution of Nga<u>n</u>amara (adapted from NMRT website; reproduced with permission).

This is, in part, a reflection of a paucity of survey effort in the Great Victoria Desert region. For example, Benshemesh (2007) reported that there were less than ten scientific records of Nga<u>n</u>amara (Malleefowl) from the Great Victoria Desert in the last decade up to 2007. In 2012, a survey conducted by Brennan *et al.* (2012) added one record to this list – the Nga<u>n</u>amara nest pictured in Figure 3.

Brennan *et al.* (2012) also report that Brennan *et al.* (2009) and MBS Environmental (2009) did not record Nga<u>n</u>amara during a large-scale survey of the Neale Junction Nature Reserve but did report recent records from both Plumridge Lakes Nature Reserve and a proposed gold mine nearby. Nga<u>n</u>amara (Malleefowl) are present also in the *Anangu-Pitjantjatjara* Lands of north-western South Australia (Benshemesh 1997, Nesbitt *et al.* 2001, Robinson *et al.* 2003).

Combining this information with records from Spinifex Country presented here, and Senior Spinifex Elders knowledge of the species current and historic distribution, makes a worthy case for expanding the historic range of Nga<u>n</u>amara in the vicinity of Great Victoria Desert and surrounds (Figure 6).

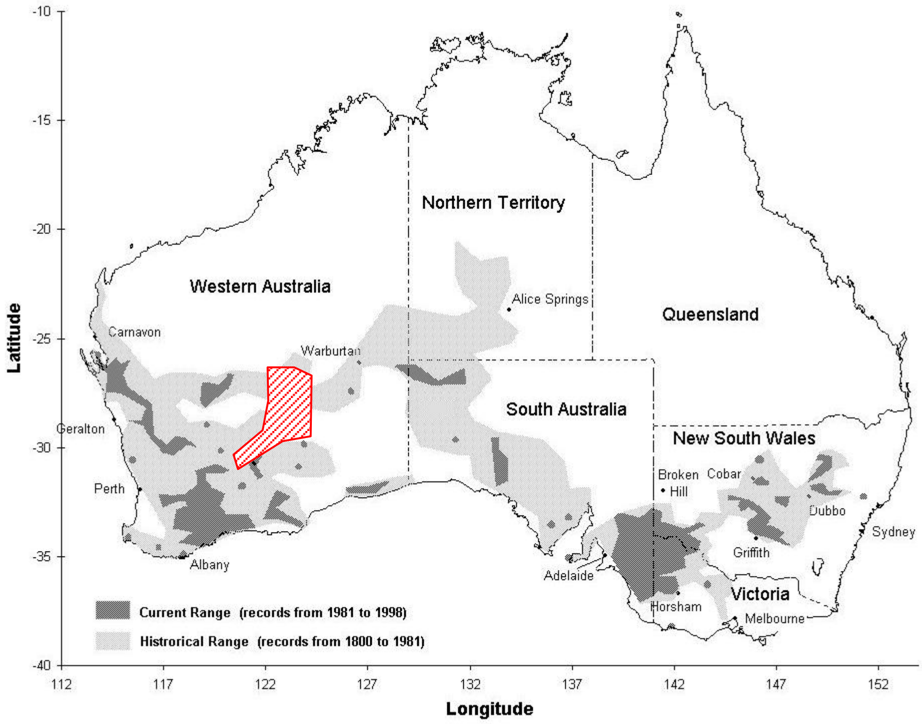

Figure 6. Current and historical range of Malleefowl across Australia as per National Malleefowl Recovery Team website. Red shaded area indicates potential expansion of historical range based on sightings presented here and Spinifex People's knowledge of Nga<u>n</u>amara distribution (adapted from NMRT website; reproduced with permission).

Spinifex Country, and the Great Victoria Desert generally, remain markedly under-surveyed. Additional survey work conducted by SLM and others associated with possible mining developments will no doubt continue to fill in the gaps of Nga<u>n</u>amara distribution in the Great Victoria Desert of Western Australia.

Capacity Building & Skill Development

The occurrence of Nga<u>n</u>amara in Spinifex Country, and the timely appearance of two birds prior to the beginning of a threatened species project (the first funded land management activity in Spinifex Country), provided a connection between Spinifex Rangers and an iconic threatened species.

This connection, combined with meaningful employment and the opportunity to get out on-country, created a productive space within which A<u>n</u>angu from Tjuntjuntjara gained skills in the use of a number of pieces of technology including GPS, rugged laptop computers, rugged handheld PDAs, motion-sensor cameras as well as software packages including Cybertracker and Microsoft Excel (rangers analyse images from motion sensor cameras on return to Tjuntjuntjara).

Rangers have also gained knowledge of traditional use of the species and the role of Nga<u>n</u>amara in Spinifex Tjukurrpa. For example, people traditionally ate Nga<u>n</u>amara eggs but not adult birds, while some eggs were always left to hatch. In addition, an individual Spinifex person would own the rights to collect eggs from a particular nest.

This wide-ranging capacity building, skill development and enhancement of knowledge are all linked to Nga<u>n</u>amara, a visible threatened species in Spinifex Country. If not for the sighting, cultural knowledge and timely discoveries of tracks (to maintain people's interest) then knowledge of threatened species work wouldn't have been as easy to facilitate.

Summary

In summary, Nganamara has been integral to development of the Spinifex Land Management program and has been there from the start. The presence and timely appearance of the species in Spinifex Country has accelerated development of SLM and Spinifex Rangers, and has been a constant theme in the program and one that has captured interest of Spinifex Rangers and the Spinifex community in Tjuntjuntjara.

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Appendix 1. Record of activities at each Nganamara site within Spinifex Country.

Site	Observation Type	Pre-2010	2010	2011	2012	2013	2014
FMSP02a	Live birds, scratchings, tracks	-	-	2 birds sighted Fresh tracks	Fresh track (> 2 days) Linear & circular scratching	2 birds captured on camera (+ cat) Fresh track + scratching	No sign
FMSP02b	Live birds, tracks	-	-	-	Old track (>7 days) Cat track observed	1 bird captured on camera (+ cat)	-
FMSP06	Tracks	-	-	Fresh tracks	-	No sign	-
FMSP13	Live birds, scratching	-	-	-	Birds (3) sighted + scratching	-	-
Nest (Warru Rd)	Nest	-	Nest found with egg shell	-	No activity	No activity	No activity
Nest (Anne Beadell Hwy)	Nest	Long disused nest next to road	No activity	No activity	No activity	No activity	No activity

20. Progress towards a method of monitoring Malleefowl in the Maralinga Tjarutja Lands, South Australia

Joe Benshemesh, La Trobe University, Vic; Member National Malleefowl Recovery Team

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Abstract

Monitoring Malleefowl in arid regions presents distinct challenges. These regions tend to be very remote, and the Malleefowl typically occur at very low densities making thorough searches of areas large enough to encompass several active mounds very difficult. Consequently, mound based forms of monitoring, as used in semi-arid regions, are not suitable in the arid zone. On the other hand, the sandy and open substrates typical of arid areas provide excellent opportunities for tracking which are not available in southern areas. Malleefowl footprints are distinctive and tend to accumulate over several days, thus providing a rich source of information on where Malleefowl have been.

Malleefowl occur over much of the western half of South Australia on Aboriginal lands. In this study in the Maralinga Tjarutja Lands, members of the local community at Oak Valley tried a variety of tracking methods to obtain data that may be useful for monitoring, including revisiting locations of past sightings and mounds, and various types of systematic tracking. We used CT Cybertracker to record data in the field, and photographs of prints to verify records. An important component of a sustainable monitoring program is the willingness and capacity of the people collecting the data. In this regard, and in terms of the efficiency and usefulness of the ensuing data, we conclude that a method of “leapfrog long-walks” was most suitable for monitoring Malleefowl at a landscape scale in the Maralinga Tjarutja context.

Introduction

Nganamara, or Malleefowl (*Leipoa ocellata*), inhabit the mallee and acacia shrublands of arid and semi-arid Australia. Internationally renowned for its unique and extraordinary mound-building behaviour (Frith 1962), the species has been valued from time immemorial by Anangu, the traditional owners of the Maralinga Tjarutja Lands (MTL) in the eastern Great Victoria Desert, both as a food item and because Nganamara are important Tjukurpa animals and totemic ancestors of Anangu.

For a bird with such atypical, laborious and complex nesting habits, Malleefowl were remarkably successful, occurring over much of the southern half of Australia from the west coast to the Great Dividing range in the east, and were widespread in every mainland state except Queensland. In arid Australia, the species occurred in the Great Victoria Desert (GVD), southern parts of the Great Sandy and Gibson Deserts, and as far north as the Tanami Desert in the Northern Territory (Kimber 1985). Since European settlement, Malleefowl have declined considerably in the arid zone and are now thought to be extinct in the Northern Territory. Although the species still occurs in the Anangu-Pitjantjatjara-Yankunytjatjara Lands (APYL) (Benshemesh 1997, Benshemesh 2007b) and MTL (Bellchambers 2007), its status in these remote Aboriginal lands is poorly known.

Bellchambers (2007) provided the first survey of Malleefowl in the MTL as part of a larger study site of the southern Great Victoria Desert in SA. He concluded that the species was widespread throughout the region but that it occurred at very low densities. Within the MTL, records were especially sparse and scattered and most were from the south of the MTL, possibly reflecting survey effort, higher rainfall, or habitats. Nonetheless, the distribution of Malleefowl in the MTL is poorly known and the scattered historical records suggest that Malleefowl may occur over much of the MTL with the exception of the Nullarbor Plain in the south west, and in the north east (Figure 1 and 2).

The importance of monitoring trends in Malleefowl has been emphasized in the National Recovery Plan for Malleefowl (Benshemesh 2007b) and also for the MTL in particular by Ward and Clarke (2007), Ward (2008) and Ward and Bellchambers (2008). While monitoring Malleefowl is well established in semi-arid areas in a national program involving over one hundred sites, the techniques used rely on relatively high breeding densities and are less suitable in arid areas where the species is scarce (Benshemesh 2004a).

Rather than basing monitoring on the activity at mounds, a more efficient approach in the arid zone is to search areas for the distinctive foot prints (or tracks) of Malleefowl. Loose, sandy substrates are typical of the areas inhabited by Malleefowl and provided the weather is dry and not too windy, their tracks are likely to accumulate over several days. The abundance of prints in an area provides a useful and efficient indicator of the birds' activity in an area: where birds are resident their prints are likely to consistently occur through their home range (1-4 km^2), whereas where birds have merely passed through an area their prints are likely be less prevalent in space and time.

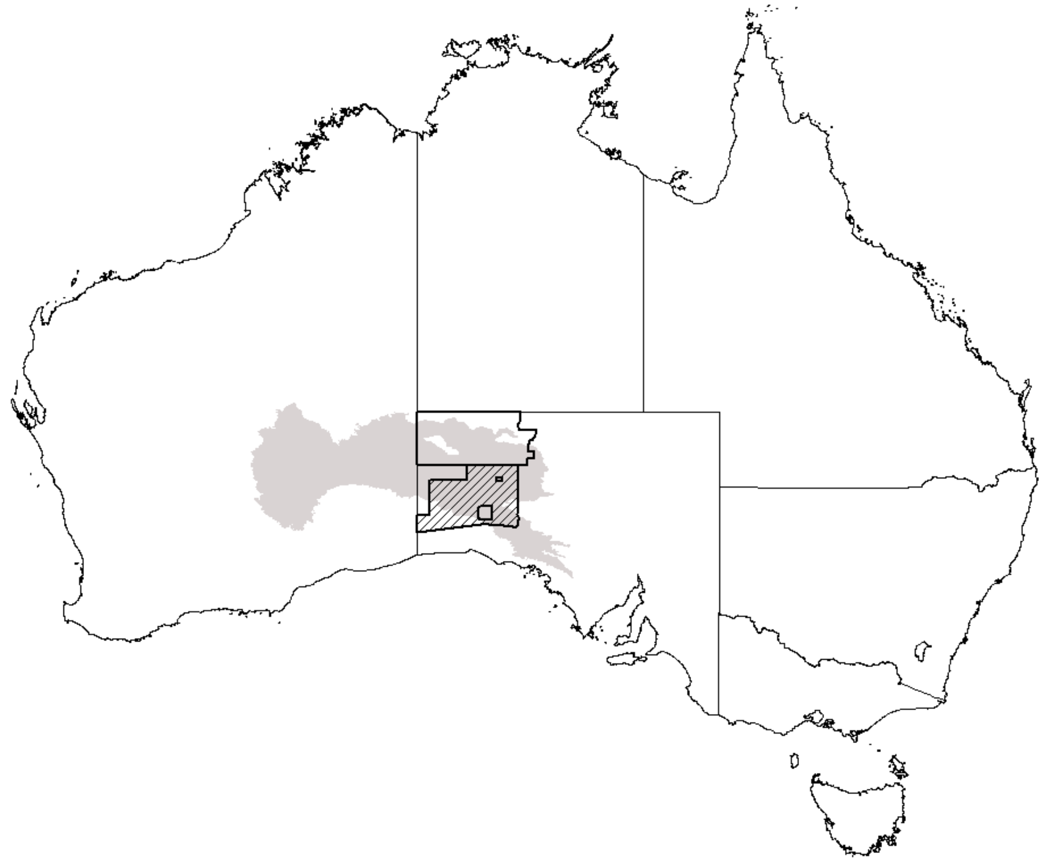

Figure 1. Map of Australia showing the location of the Maralinga Tjarutja Lands (MTL; outlined and hatched) in South Australia. Most of the MTL lies in the Great Victoria Desert (grey). The Anangu Pitjantjatjara Yankunytjatjara Lands (outlined) are also shown situated above and adjoining the MTL.

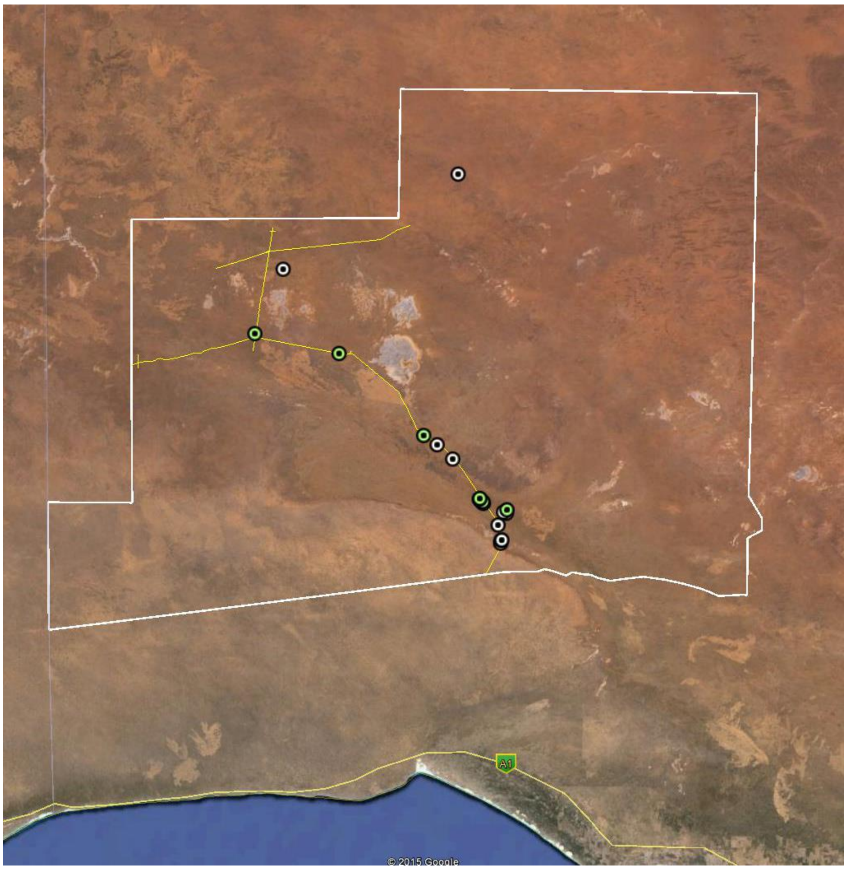

Figure 2. Map showing MTL boundary (white line) and records from Bellchambers' surveys and subsequent monitoring in 2008. For clarity, records outside the MTL are not shown. Colour key: Green= mounds; white= sightings of birds and prints.

In the past, most Malleefowl records in the MTL have been obtained opportunistically. Where targeted searches have been undertaken in the past, details of search effort have not been recorded; it is difficult to detect trends in data without knowing the search effort involved. Techniques have been proposed to obtain information more systematically on Malleefowl abundance by tracking along square transects (Benshemesh 2007a, Ward and Clarke 2007 and Ward) but these methods are not often employed.

Whatever technique is considered, a critical component in its successful application will be how the technique is received by Anangu at Oak Valley, the community in the MTL. Anangu have expressed an interest in land management jobs and are geographically well placed to undertake regular monitoring. Moreover, their traditional skills and aptitude for reading their country makes them ideal candidates in an ongoing Malleefowl monitoring project.

The current project had three basic aims: 1) to train Anangu in monitoring techniques, 2) to trial different techniques with Anangu, and 3) to collect data on the distribution and abundance of Malleefowl.

Methods

We undertook systematic searches for Malleefowl prints and other signs in areas in which the birds had been detected in the past decade. In total, 18 discreet sites (eight mounds and six point localities representing prints or sightings) were revisited from historical records, the Alinytjara Wilurara NRM database and from Bellchambers' report.

Monitoring

Monitoring involved searching for Malleefowl signs at and around each previous record in a nested square pattern: the location of the record was searched for prints, and 200m and 500m sided squares centred on the record were also searched (Figure 3). This provided an efficient means of searching the vicinity of each record in a systematic and repeatable way. Navigation was performed by GPS: site locations, and the eight points defining the corners of square transects at 18 sites were entered into the Cybertracker sequence (see below) and the GoTo function (Benshemesh 2009) was used to navigate from corner to corner within the Cybertracker application.

Survey

Survey at a landscape scale was accomplished by Long Walks along established tracks and roads. A method was trialed in which pairs of observers were dropped off by vehicle every 2km along tracks. Each pair then walked the 2km stretch to the next drop-off, searching for Malleefowl prints parallel to and about 50-150m from the road. The number of pairs of observers varied with their availability, but the technique enabled large distances to be covered quickly: five pairs of observers could search 10km in about one hour. We also searched for Malleefowl prints from vehicles along one 14km stretch of disused vehicle track by driving at about 10km/hr while observers attempted to spot Malleefowl tracks from the windows.

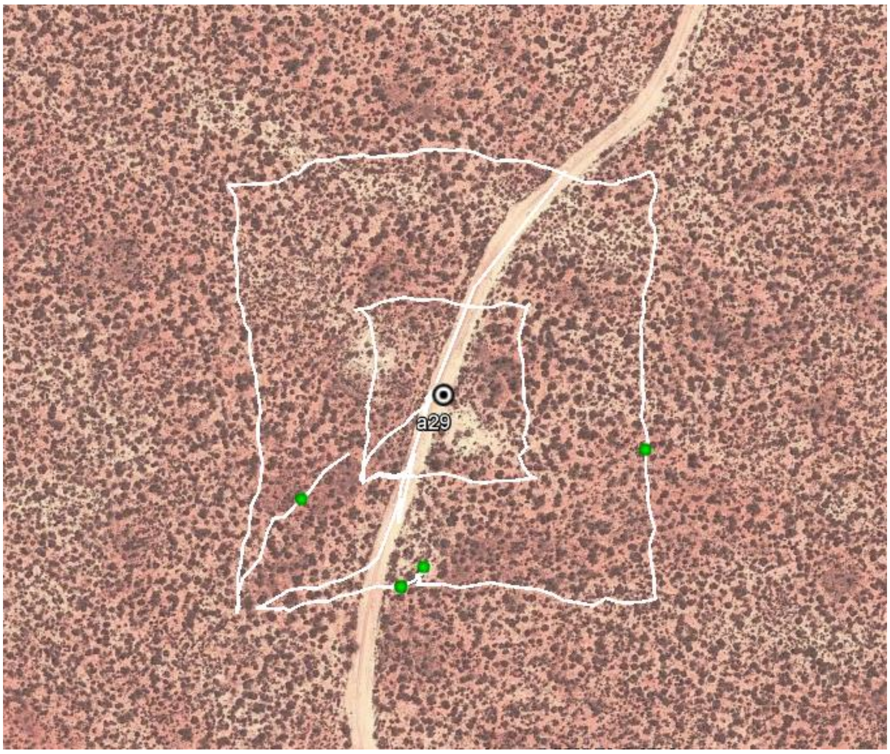

Figure 3. Concentric square transects centred on record AWMF29. The white lines show the paths searched by observers along 200m and 500m sided square transects. Green dots indicate fresh Malleefowl prints (other species not shown).

Verification

Observers were instructed to take a photo of Malleefowl tracks to provide verification of their identification, but not of other animals which were regarded as of secondary importance. Nonetheless, the recording of other animal's tracks was of some interest, and was also beneficial in that it provided many opportunities to practice recording data. Photos were taken within Cybertracker (below) and were linked to the record. A scale-card or other scale was included in each photo. Malleefowl tracks were often clumped and in practice, not every track was photographed, but the aim was to obtain some photos for verification in each new area. Observers were instructed to always take a photograph of prints that they were uncertain about, particularly if they thought they might be of Malleefowl.

Data recording in field with Cybertracker

Data recording was accomplished with a custom Cybertracker sequence on ruggedized handheld computers (Magellan/Ashtech Mobilemapper6) with built-in camera and GPS. Ten of these units were borrowed from the Victorian Malleefowl Recovery Group for the current study. The Cybertracker sequence enabled observers to enter their names, select whether they were undertaking monitoring or survey, and record the prints of a variety of animals they encountered, including Malleefowl (single or paired prints, mound), dog/dingo, fox, cat, camel, red and grey kangaroo, emu, bustard, rabbit, echidna, and Itjaritjari (southern marsupial mole). When Malleefowl was selected, a screen requesting a photo automatically appeared. Whenever an animal's tracks were recorded, the GPS location was automatically recorded along with the observers name, date and time, and photos. At the end of each square transect side (i.e. when a corner was reached) or long-walk section, observers were instructed to estimate the tracking conditions by choosing one of five categories from 'all ok' to 'none-ok'. These categories were described in terms of the likelihood of detecting Malleefowl if they walked through the area and reflected a combination of many factors that may affect the clarity of tracks such as substrate, recent weather, and lighting. The sequence was designed to be simple and quick in order to keep people interested and moving while recording the most essential information.

Training

Aṉangu and other participants were trained in the use of Cybertracker to both record data and to navigate from point to point. Most Aṉangu were familiar with the prints of different animals, including Malleefowl, but special attention was paid to the identification of Malleefowl prints. Aṉangu also tended to discuss print identification amongst themselves and learn from each other. The reasons for doing monitoring and survey, and the techniques used, were also discussed at length and the Cybertracker sequence was improved following feedback from Aṉangu. The results of searches was usually downloaded from Cybertracker at the end of each day and displayed on maps on a laptop. This provided an opportunity to discuss issues with navigation and recording and the concepts involved in the work.

Results

Between the 19th to 30th July 2012 the team spent eight days undertaking survey and monitoring, two days travelling and setting up remote camps, and one day each was spent in training and resting. During this time the team searched more than 131 kilometres and recorded 2,288 animal tracks on Cybertracker, including 282 tracks of Malleefowl which were the primary target of the surveys.

Print confirmations

Of the Malleefowl tracks recorded during surveys and monitoring, 93 (33%) were associated with digital photos for validation. Of these, 81 (87%) were confirmed as Malleefowl, and two (2%) were too indistinct to identify. Ten photos (11%) were considered to be other bird species: one was the track of a corvid, and nine were the tracks of small birds. All of the misidentified track photos were taken by white people assisting Aṉangu and most were taken in the spirit of demonstrating to Aṉangu that uncertain cases should always be photographed. While 67% of Malleefowl tracks recorded were not photographed, these all occurred in the vicinity of records confirmed by photos, providing no reason to doubt the accuracy of identifications.

1. Searches at previously known sites

Searches for Malleefowl prints at known sites usually involved nested square transects involving a localised search at the previous record, and 200m and 500m sided square transects centred on the record. Previous records included mounds and locations at which Malleefowl or their prints had been sighted.

Searches at mounds

The team attempted to find all seven of the previously listed mounds. In 2012 we were only able to locate four of the known mounds: one mound was clearly being renovated for use by Malleefowl and being filled with leaf litter, while the other three were old and disused. Of the mounds we were unable to re-find, one may have been destroyed during road widening works over the past few years; the scarcity of prints in this vicinity suggests that if the mound does still exist, it was not being prepared for use in the 2012-13 breeding season. Of the two other mounds we were unable to find, one had been recorded as active in 2007 but was unlikely to have been active in 2012 as there were no Malleefowl footprints recorded within 250m of the mound location. The other mound had not previously been recorded as active but might have been active in 2012 as there was an exceptionally high density of Malleefowl prints in this area (18 prints per km), many of them paired, it was thus likely that an active mound was nearby.

Searches at sites where prints or birds were previously recorded

Apart from mounds, Malleefowl signs or sightings were recorded at eleven sites between 2006 and 2008, and all but one of these was visited in 2012. At each of the ten sites revisited, we walked nested transect. Malleefowl signs were detected at six of the ten sites. However, at none of these sites were Malleefowl recorded in the vicinity of the original record: at two of the sites Malleefowl prints were only recorded along the 200m transects, at another three sites they were only recorded along the 500m transects, and at one site prints were recorded along both the 200m and 500m transects. The density of prints at the six sites where prints were recorded was generally low (0.6 - 2.0 prints per km of transect).

Comparison of success at mounds and sightings

The detection of Malleefowl prints at previously known mounds and previous sightings were similar: Malleefowl prints were detected at five of the seven previously known mounds (71%) compared with at six of the ten (60%) of previous sightings. Nonetheless, there were major differences between mounds and sightings where at least some prints were detected in 2012. Print densities tended to be much higher around mounds (average=8.5 prints/km, n=5) compared to past sightings (average=1.0 prints/km, n=6).

The difference between the detectability of Malleefowl prints around mounds and sightings was also evident at sites where at least some Malleefowl prints were detected in the square transects. There were seven mounds at which searches revealed prints somewhere within the surrounding 25 hectares (ha), and six sites that were based on previous sightings where searches revealed prints somewhere within the surrounding 25ha. Malleefowl prints were detected on or near 71% of mounds where prints were eventually detected somewhere in the 25ha search (Figure 4), and prints were similarly detected in six of the seven 200m square transects. Checking the vicinity of the mound, and undertaking a 200m square transect around it would have identified Malleefowl prints at all seven mounds. The 500m square transect also detected Malleefowl at all sites.

In contrast, Malleefowl prints were not found in the local vicinity of any of the six sites based on sightings, and on only 50% of the 200m transects and 67% of the 500m transects (Figure 4). A combination of both 200m and 500m transects was required to detect Malleefowl at these sites, and local searches of the point locality were completely ineffective.

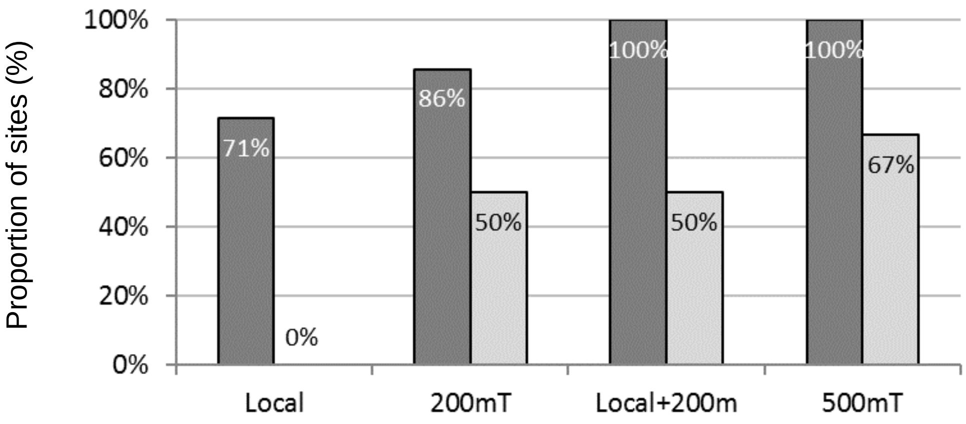

Figure 4. Comparison of search type in detecting Malleefowl prints. The proportion of sites at which Malleefowl would have been detected is shown for different components of searches for mounds (dark bars) and sightings of prints or birds (light bars). Only sites where at least some prints were detected in 2012 are included in the graph.

2. Survey: new sites

Newly recorded mounds

In addition to the previously known mounds, the team recorded three mounds that had not previously been represented in the database. One of these was a well-known and active mound within the Prohibited Area, whereas the other two mounds were found by the team in the south east of the study area and were long disused. Nonetheless, Malleefowl print densities were high (>10 prints/km) around both mounds which were separated by about 650m. An active mound was known about one kilometre from each of these old mounds, and it is possible that the birds from the active mound ranged this far.

Long walks

Linear transect walks of 16-28km length alongside existing tracks provided a useful means of broadscale survey. Four walks were undertaken (Figure 5), two of which occurred in areas where Malleefowl had previously been recorded south of Oak Valley along the main road (southwest and southeast), and two along a relatively new track that ran east-west about 40-50km south of the Anne Beadell Highway (northwest and northeast) in areas that are more remote and where there were no previous records of Malleefowl. Malleefowl were most frequently recorded in the southern transects where they were recorded in 45 - 50% of one kilometre stretches of transect (Table 1), compared to 0 - 7% in the northern transects. The number of Malleefowl prints recorded also showed relatively low values in the northern transects (0 - 3 prints per 10km) compared with southern transects. The southeast transect showed the highest number of prints averaging 48 Malleefowl prints per 10km, compared with six prints per 10km in the southwest transect. Thus, while Malleefowl prints were widely distributed across both the southwest and southeast transects, they were much more abundant in the southeast.

Table 1. Search length and Malleefowl signs along the four long-walks.

	Km	*%Km with prints*	*No. prints*	*Prints/10km*
Northwest	28	7%	9	3.2
Northeast	24	0%	0	0
Southwest	20	45%	12	6.0
Southeast	16	50%	77	48.1
	88	22%	98	11.1

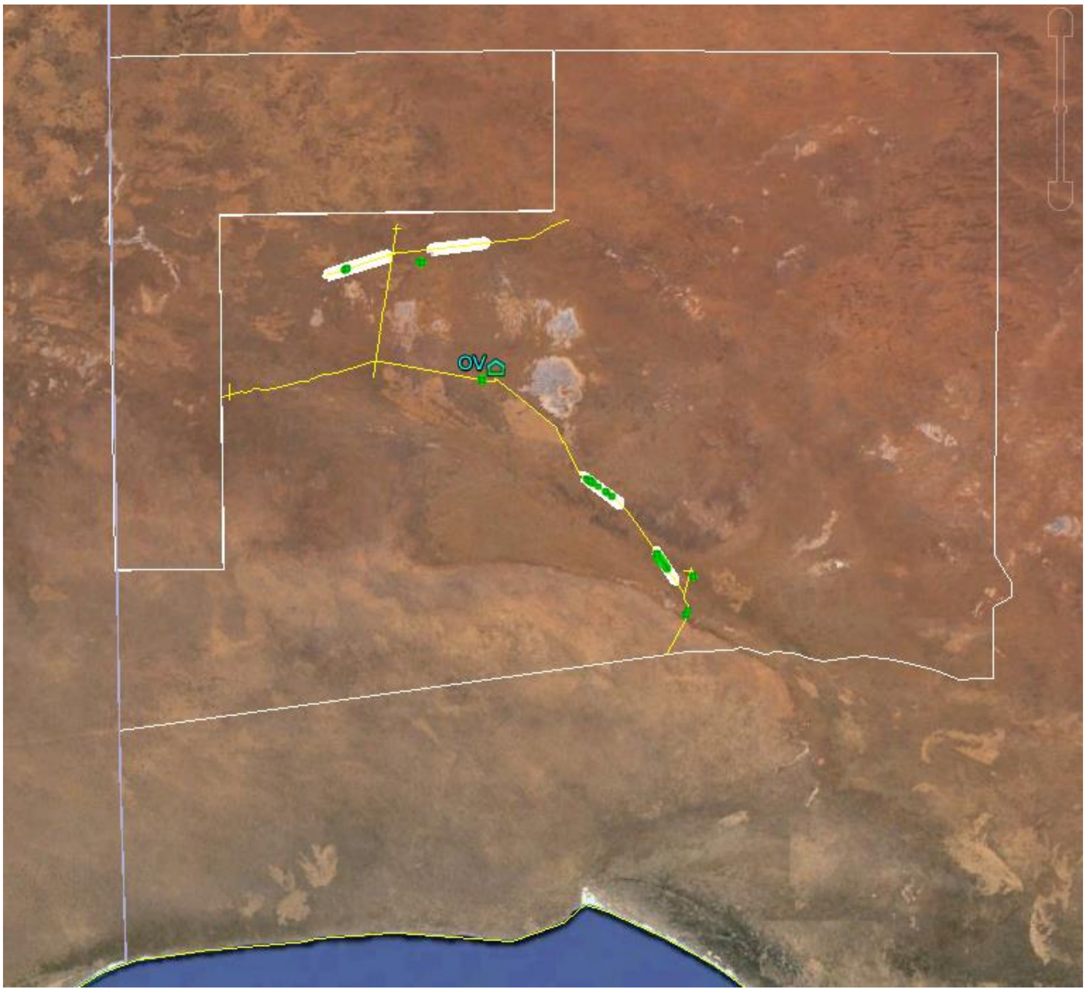

Figure 5. Location of the four long-walks (thick white bars) in the MTL. Green dots indicate where Malleefowl prints were found.

14km drive and searches north of AWMF45

We searched for Malleefowl prints from vehicles along a 14km stretch of the disused, old Vokes Hill Road vehicle track because our square transect search at AWMF45 found no Malleefowl signs, although the area was previously known to support Malleefowl. The occurrence of Malleefowl prints at AWMF45 was recorded in both 2007 when a 'recent track' was noted, and in 2008 when 2 'very old tracks' were noted. In addition, a 500m square transect around this point locality was undertaken in October 2007 when one of us (JB) was in the area on another project. In 2007, 13 print locations were recorded scattered through the south western half of the square transect, including paired prints that differed in size consistent with a male and female pair. A mound was not found, but given the pattern of prints it was strongly suspected that an active mound occurred close by. Print density along the 500m square transect in 2007 was about 6.1 prints/km.

Malleefowl prints were not recorded in the square transects around AWMF45 when they were returned to in 2012, however the team did detect Malleefowl prints about 7km along the 14km drive to the north at two locations separated by several hundred metres. A 500m square transect and local searching around the centre point between these records (named J03, see below) revealed a high density of Malleefowl prints in the area: 19 prints were recorded along about 4.5km of search path (500m transect plus local searches) in the area, suggesting a print density of 4.2 prints/km.

Aggregate Grid-cell metrics

The proportion of all grid cells visited in this study in which particular species were recorded provides an alternative metric of their abundance. In this study we recorded animal prints in a total of 127 one-kilometre square grid cells, of which 37 (30%) contained Malleefowl prints (Table 2). On average, Malleefowl prints represented 10% of prints in grid cells, with a coefficient of variation of 2.1 suggesting a patchy distribution. The most widespread animals were camels which were recorded in 84% of cells and on average represented more than a quarter of recorded prints, and fox and cat which were recorded in 78% and 73% of cells respectively. Low coefficients of variation for these abundant animals suggest a relatively even spread across the grid cells visited. Dingoes and kangaroos (both red and western grey combined) were also well represented and occurred in most grid cells, whereas rabbits occurred in about one third of cells. In contrast, emu, echidna and bustard (kipora) were relatively rarely recorded.

Table 2. Aggregate statistics for animal signs in 1km^2 grid cells. K'roo represents both western grey and red kangaroos.

	Mf	Camel	Fox	Cat	Dog	Emu	Kipora	Rabbit	Echidna	K'roo
%cells	30%	84%	78%	73%	60%	2%	16%	35%	2%	55%
Mean %/cell	10%	27%	15%	14%	10%	0%	2%	8%	1%	13%
Stdev %/cell	20%	22%	15%	16%	16%	1%	9%	14%	9%	17%
Cov %/cell	2.1	0.8	1.0	1.2	1.6	7.9	3.5	1.8	10.0	1.3

Discussion

Anangu training and competence

Anangu were impressive in their tracking abilities and attitude to the work at hand, which often involved walking many kilometres while navigating and recording information on the handheld devices.

Anangu typically learnt to use Cybertracker competently. However, it was also clear that some members of the team were still having difficulty recording information even on the last day of surveys. This occurred despite a genuine enthusiasm for the work by the person in question. The lesson in this example is that it is easy to overestimate the proficiency (or perhaps comfort level) of people involved in data collection using equipment they are unfamiliar with. The situation reinforces the need to keep processes as simple and streamlined as possible in order to reduce the opportunities for confusion, especially if the goal is for participants to work unsupervised.

Overall, the Anangu participants in this study demonstrated an enthusiasm and aptitude for the Malleefowl survey and monitoring work, and the Cybertracker sequence developed for them served its purpose in providing a quick and simple means of recording information without slowing down the walking and searching through country. There is certainly a great deal to be gained environmentally and socially in developing the Malleefowl program further, and we have no doubt that continuing in-house training and practice would consolidate the skills learned and result in the collection of valuable information on Malleefowl conservation.

Malleefowl in the MTL

Malleefowl were noted as inhabiting the eastern Great Victoria Desert by the early explorers, such as Giles (1889) and Maurice (Cleland 1942, Gara 1989). Black and Badman (1986) reviewed the records and anecdotal accounts and concluded that the species was still sparsely distributed through the eastern GVD. Interestingly, the most recent records they reviewed were of two recently used mounds recorded in 1981 by the side of the newly created road from Maralinga to Lake Maurice, and the location of these mounds (approximately 18km and 60km north west of Maralinga) coincide roughly with the two main centres of Malleefowl activity recorded in the current survey.

After the early 1980s, there appear to have been no records of Malleefowl in the Maralinga lands until 2007 when dedicated surveys for Malleefowl were undertaken by Keith Bellchambers (Rick Southgate also recorded Malleefowl footprints in a few tracking plots at about this time). In the intervening 25 years, extant Malleefowl populations were 'rediscovered' in the Anangu-Pitjantjatjara-Yankunytjatjara Lands to the north where they were thought to have become extinct (Benshemesh 1997) and on the eastern edge of the Maralinga TL (Robinson, Casperson & Copley 1990). In the APYL, Anangu knew that Malleefowl still occurred at certain localities during the intervening period, and indeed occasionally raided the birds' mounds, but these sightings were rarely passed on to scientists or wildlife authorities. Likewise, the absence of Malleefowl records from the MTL between the early 1980s and 2007 most likely reflects low survey and reporting effort rather than changes in Malleefowl populations.

The Malleefowl surveys by Keith Bellchambers (2007) and his Anangu coworkers clearly showed that Malleefowl were still widely and sparsely distributed in the MTL, despite the previous paucity of records. Bellchambers recorded five Malleefowl mounds, and sighted the birds or their tracks at an additional 10 sites.

In the current study we revisited the locations of previously known mounds and sightings, and searched new areas for signs of Malleefowl. Revisiting previously known sites after a period of five years provided some idea of how Malleefowl have persisted in the landscape: we found Malleefowl prints at about 65% of sites where Malleefowl were previously recorded (ten mounds, seven sighting locations). In contrast, Bellchambers (2007) only recorded Malleefowl prints at 36% of the 11 locations he revisited (including Yellabina/Yumbarra), and Malleefowl prints were found at only 33% of nine previously known sites that were revisited the following year in the MTL (Matt Ward, AW database).

While the current study has reaffirmed the finding of Bellchambers (2007) that Malleefowl are still sparsely and widely distributed in the MTL, the data are insufficient to comment meaningfully on trends apart from stating that Malleefowl appear to be doing well in some areas, especially along the southern sections of the Oak Valley main road. The detection of population trends, which is the purpose of monitoring, requires a consistent and repeatable effort. This has been difficult to achieve but the past and current surveys provide a good basis from which to consider the monitoring options in light of the data collected, and this is discussed in the following section.

Survey and monitoring Malleefowl in the MTL

Understanding the distribution, abundance and trends of Malleefowl populations in the Maralinga Tjarutja Lands is essential for the conservation of the species, to identifying its vulnerabilities, and managing the populations. This study has clearly demonstrated that Anangu are capable and interested in being involved in this work and in providing data of a high standard. The question however remains as to the best approach to achieve a meaningful survey and monitoring program.

The Malleefowl monitoring program in southern areas provides excellent data that has been widely used to assess the population trends (e.g. Benshemesh, Barker & MacFarlane 2007, Walsh *et al.* 2012), but is not generally suitable in arid areas where mound densities are very low over vast areas (Benshemesh 2004b, Benshemesh 2007b, Benshemesh 2008). On the other hand, the sandy and open substrates typical of the Maralinga Lands provide excellent opportunities for tracking which are not available in southern areas. Malleefowl footprints are distinctive and tend to accumulate over several days, thus providing a rich source of information on where Malleefowl have been.

Conclusions and recommendations for future monitoring and survey

The number of sites at which Malleefowl have been recorded in the last few years has increased from 18 in 2007/2008, to 31 with the addition of the 13 new sites recorded in this study. This is a positive outcome, but has implications in planning monitoring in the future because it is becoming increasingly time consuming to visit all of these sites on a regular basis. Furthermore, it must also be asked whether regularly visiting all of these sites is likely to provide the information that is needed on trends in Malleefowl populations.

Monitoring a selection of sites where Malleefowl have been recorded in the past provides information on the persistence of the species at specific localities, but it does not provide information on the population trends across a landscape. For example, a population may be stable even though it does not persist at any particular site for very long. In a vast landscape where a species occurs only sporadically in pockets of suitable habitat, monitoring persistence may be the only feasible means of keeping tabs on a population, and would provide some insights. In the MTL the current project demonstrated that they were capable of walking and tracking over considerable distances, and Malleefowl appear to be sufficiently abundant in the MTL to allow a more broad scale approach than persistence monitoring.

Given that the interest in Malleefowl trends in the MTL is at the landscape scale, the long-walks trialed in this study would seem to provide the best balance between monitoring and survey. Long-walks were popular with Anangu too, especially as they were undertaken as a team effort. Long walks were also relatively simple to perform and repeat, and instilled a strong sense of achievement which was manifest when driving along roads with Anangu, knowing that long sections had been searched and that multiple animal tracks had been recorded. Another advantage of long-walks, as described in this study, is that they can be undertaken using any number of participants, but are especially suited to teams which, when split into pairs, can cover many kilometres rapidly and efficiently. Most importantly, long-walks are relatively easy to interpret because the sampling effort is spread out over large areas, matching the scale of the central question regarding Malleefowl trends across the landscape, rather than simply at small areas where they have previously been recorded.

We hope that regularly repeating the long-walks undertaken in this study will provide information on trends in Malleefowl populations at a landscape scale (comments in the previous section notwithstanding). However, only two of the four long-walks undertaken in this study showed more than occasional signs of Malleefowl; while there is some merit in monitoring these areas, more would be gained by surveying other areas for signs of Malleefowl. In particular, north and east of Maralinga village may be especially rewarding judging by the mallee type vegetation in that area, although there are many other areas that would also be suitable for survey, and if successful in finding concentrations of Malleefowl prints, for regular monitoring.

While a series of long-walk transects, regularly monitored, would seem the simplest and best means of tracking Malleefowl abundance and distribution in the MTL, regularly checking the vicinity of known mounds for prints and signs of breeding activity would also be useful both to learn about the frequency of reproduction in the MTL, and to provide information on the persistence of Malleefowl at points within the landscape. Nested square transects would be appropriate for this activity, although the results of the current study suggest that simply searching the mound, and a 200m square if no Malleefowl signs are found at the mound, would be adequate to provide information on activity and persistence.

Finding more mounds should also be regarded as a priority, second only to landscape scale monitoring, and may be an activity that could involve a range of people from the local community at Oak Valley once concentrations of Malleefowl prints have been located in survey/monitoring. Only a few mounds are currently known in the MTL, but the abundance of Malleefowl prints in some areas in this study was strongly suggestive that several active mounds would have been found if the time was available to search for them. With a little effort, the number of mounds known in the MTL is likely to accumulate, and the value of routinely checking them for signs of activity will increase and provide an additional means of monitoring the Malleefowl population. In this regard, recent developments in remote sensing Malleefowl mounds by photogrammetry and LiDAR show great promise in finding mounds to monitor in this vast landscape.

Given the level of enthusiasm and interest among Anangu in participating in this study, it would be beneficial for Anangu to be involved in further development of a Malleefowl survey/monitoring program in the MTL, along with scientists and other stakeholders. A medium term plan, detailing targets and processing and developed in conjunction with Anangu and state and NRM authorities, would also be beneficial and would provide clarity and a sense of purpose to the program.

Finally, if a systematic and regularly repeated monitoring program for Malleefowl is implemented in the MTL, the ensuing data should be made available to the National Malleefowl Recovery Team. Linkages to the National Malleefowl Monitoring Database (NMMD) should also be investigated. The NMMD is an online database that has been designed to manage the mound based monitoring in southern areas, and features a number of facilities such as data validation processes, preliminary analysis and automatic reporting. Apart from making the data available to the Malleefowl Recovery Team, links to the existing monitoring database will demonstrate to Anangu the importance of their work in a national context and foster a sense of shared purpose with the many community groups, land managers and researchers involved in Malleefowl monitoring across the continent.

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21. The use of LiDAR to determine the presence of Malleefowl mounds

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Abstract

The determination of the presence and number of Malleefowl *Leipoa ocellata* utilising prescribed or predicted habitat is often a prerequisite in development approval processes, typically prior to disturbance and often as part of ongoing monitoring. Given the vast extent of potential preferred Malleefowl habitat across Australia, and the species' ecology, it is difficult to estimate population size based on bird counts. The occurrence of Malleefowl mounds is typically used as a proxy for the bird's occurrence. However, finding Malleefowl mounds can be time consuming, labour intensive, expensive and may not be practical in large areas. To provide greater certainty and transparency in locating Malleefowl mounds, Umwelt has developed a process to identify 'candidate mounds' using LiDAR data and to rank them according to their likelihood of being 'actual mounds'. Because LiDAR can penetrate through vegetation, mounds that are covered or masked by vegetation can also be readily identified. The detection process developed combines rapid analysis of extremely large data sets using Umwelt's in-house software *Anditi*, with the field knowledge and expertise of our experienced ecologists. Where available, aerial photography is incorporated into the software to provide additional information on habitat and landscape context for the area surrounding candidate mounds. The combination of computer analysis and ecological expertise allows candidate mounds to be quickly virtually accessed in 3D on computer, and then GPS locations recorded for subsequent ground-truthing in the field. This provides repeatability and transferability of the Malleefowl survey process through providing a 3D image of ground and vegetation surrounding each site, while significantly reducing the costs and time required for field surveys.

Introduction

The Malleefowl *Leipoa ocellata* is one of three members of Megapodiidae in Australia and is the most southerly distributed in the country. Its distributional range in semi-arid and arid habitats differs from that of other extant megapodes that occupy damp forests. The incubation methods typically used by megapodes (mound building) are not conducive to these dry regions. The Malleefowl has, therefore, developed a highly sophisticated and elaborate technique of incubation of its eggs. Malleefowl eggs are laid in a mound, comprising an inner core of leaf-litter buried under a thick layer of sand. The decomposing effects of the leaf litter generate heat for the developing eggs, aided by the use of solar heat later in the season. Malleefowl tend to the mound frequently during the incubation period, ensuring a constant temperature within the egg chamber. They manage this by adjusting the level of cover over the egg chamber particularly later in the season when they rely more on solar energy. Thus, a thinner layer of sand lets more heat in during the day and a greater layer of sand retains the heat within the mound overnight.

Similar to other megapodes, the chicks are superprecocial, which render them vulnerable to predation. The ecology and distributional range of the Malleefowl have exposed it to major threats including predation, clearing of preferred habitat with associated fragmentation and isolation, and altered fire regimes. These, together with other threats and its declining status, have resulted in the development of a National Recovery Plan for Malleefowl *Leipoa ocellata* (Benshemesh 2007) for this iconic species.

Conservation Status

The conservation status of the Malleefowl in Australia is presented in Table 1 below.

Table 1. Conservation status of Malleefowl *Leipoa ocellata* in Australia.

Jurisdiction	Status	Legislation
Commonwealth	Vulnerable	*Environment Protection and Biodiversity Conservation Act 1999*
State/Territory		
Northern Territory	Critically Endangered	*Territory Parks and Wildlife Conservation Act 2000*
New South Wales	Endangered	*Threatened Species Conservation Act 1995*
South Australia	Vulnerable	*National Parks and Wildlife Act 1972*
Victoria	Threatened	*Flora and Fauna Guarantee Act 1988*
Western Australia	Vulnerable	*Wildlife Conservation Act 1950*
Non-statutory NGO		
IUCN	Vulnerable	IUCN Red List of Threatened Species
BirdLife Australia	Vulnerable	The Action Plan for Australian Birds 2010

Distribution

Malleefowl have declined substantially throughout Australia since European settlement. While this species was formerly widespread across Australia, its range appears to have contracted significantly. An indicative map of the present distribution of Malleefowl is presented in Figure 1 (Department of the Environment 2014). More prescribed distributional maps are presented in Figure 2 (BirdLife International and NatureServe 2014), Figure 3 (ALA 2014 Records), Figure 4 (OZCAM (2014) distributional map) and Figure 5 (NatureMap distribution of records from Western Australia (Department of Parks and Wildlife (DPaW) 2014)).

Figure 1. Indicative map of the present distribution of Malleefowl (Department of the Environment 2014).

Figure 2. Present range of Malleefowl (BirdLife International and NatureServe 2014).

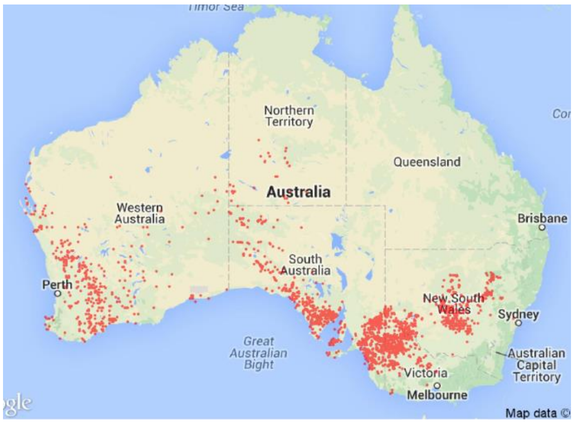

Figure 3. Records of Malleefowl from ALA (2014).

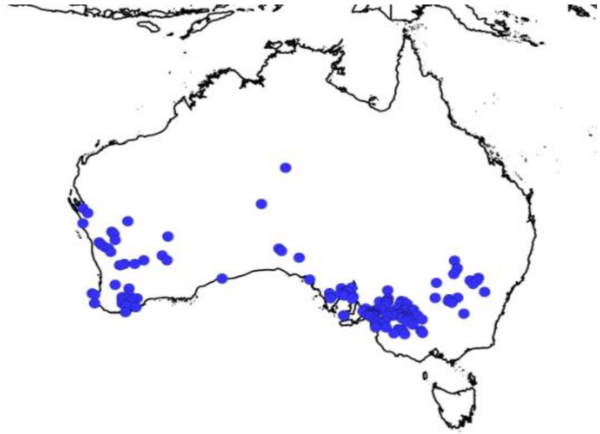

Figure 4. Records of Malleefowl from OZCAM (2014).

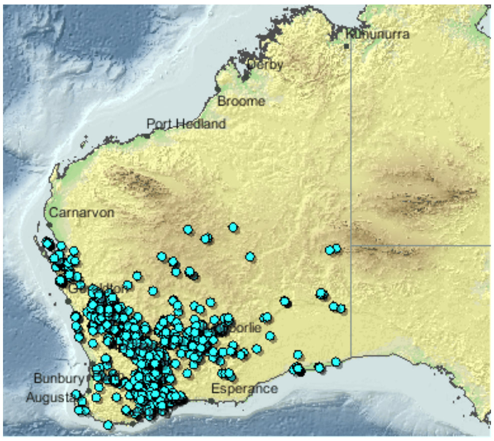

Figure 5. Records of Malleefowl from NatureMap (DPaW 2014).

Monitoring

The determination of the presence and number of Malleefowl is often a prerequisite in development approval processes, typically prior to disturbance and often as part of ongoing monitoring. Monitoring requirements often include or relate to:

- baseline population information;
- a requirement as part of approval applications for disturbances such as clearing of native vegetation, mining projects etc.;
- annual monitoring to determine mound usage/activity and population trends;
- effectiveness of management actions;
- recovery plan actions; and
- fulfilment of conditions from statutory authorities (e.g. Ministerial Statements, project approval conditions etc.).

There are conventionally three methods of monitoring, which include:

- sighting of individuals;
- tracking for signs (tracks, feathers, scats); and
- counting mounds.

While the sighting of birds is the most conclusive evidence of their presence, the second method provides an indication that one or more birds have occurred in the area recently, and the third method determines if Malleefowl have used the area to establish a breeding mound.

A further distinction when counting mounds is determining if they are 'active' (breeding occurring in the current season), recently used or old (moderately old, old or very old). Comments on each of the three methods of monitoring are provided in Table 2.

Table 2. Malleefowl monitoring methods.

Method	Comments
Sighting of individuals	• Elusive • Cryptic • Not a reliable method of determining population numbers or densities
Tracking for signs (tracks, feathers, scats)	• Suitable substrate required • Wind and rain obscure tracks • Not a reliable method of determining population numbers or densities
Counting mounds	• Best indicator of population

While counting of mounds provides the best indicator of habitat use by Malleefowl, a variety of techniques for counting mounds have been developed. Comments on each of the techniques are provided in Table 3.

Table 3. Malleefowl mound counting techniques.

Method	Comments
Aerial searches using helicopters	• Expensive and may not identify all mounds
High resolution aerial imaging	• Need open ground • Problematic due to shadows • Miss mounds covered with and hidden by vegetation
Thermal imaging	• Only effective when mounds are active • Expensive
Plot searches/monitoring grids/sampling approach for tracks	• Only in suitable substrates • Not suitable following wind or rain
Walking	• Time consuming • Expensive • Labour intensive • Annual checks of known mounds likely to miss new mounds
LiDAR	• Most efficient and reliable method of mound detection over large and/or remote areas

LiDAR and its Application to Malleefowl

What is LiDAR?

Light Detection and Ranging (LiDAR), also known as 3D laser scanning, was conceived in the 1960s for submarine detection from aircraft. Most airborne LiDAR systems are made up of the LiDAR sensor, a GPS receiver, an inertial measurement unit (IMU) and onboard computer and data storage devices.

The LiDAR system pulses a laser beam towards the ground, typically from a fixed-winged aircraft but also from helicopters and more recently UAVs. The beam is scanned from side to side as the aircraft flies over the survey area, measuring up to 200,000 points per second. When the laser beam hits an object, it is reflected back to the sensor on the aircraft. The time interval between the pulse leaving the aircraft and its return to the LiDAR sensor is measured and stored. This data is then processed and the time intervals are converted and corrected in accordance with the other instruments (GPS coordinated, IMU etc.) to describe points in space where the object was detected. The LiDAR sensor collects a huge amount of data and a single survey can easily generate millions of points totalling several terabytes.

There are two broad categories of LiDAR systems based on the method of recording signals:

- discrete-return systems (Figure 6); and
- full waveform systems (Lefsky *et al.* 2002) (Figure 7).

Figure 6. Discrete return system.

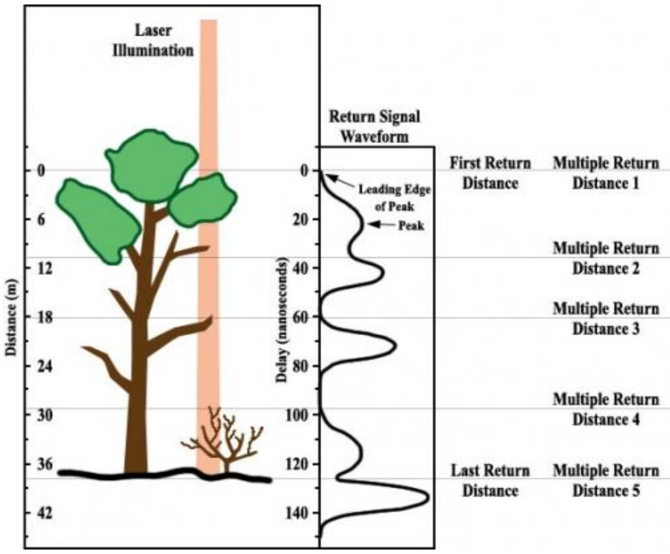

Figure 7. Full waveform system.

The discrete-return system only records a few (e.g. one to four) reflections per transmitted pulse, while the full wave-form system digitizes the entire return waveform at very high sampling frequencies (e.g. 1 GHz) and hence it is able to record up to around 80 samples per transmitted pulse. This allows significantly more data per pulse to be recorded and that provides a superior 3D representation of the subject area including canopy, sub-canopy structures, other infrastructure, ground cover and ground surface.

Aircraft typically fly along the length of the survey area, make precise turn-arounds, and fly the length in the opposite direction, with each tract called a swathe. These swathes are repeated until all parts of the survey area have been covered. The precision of the flight path is important; any overlaps between swathes can be accounted for during the analysis of the data.

To be able to detect near-ground features such as Malleefowl mounds, the LiDAR data has to be of sufficient density and accuracy, and then accurately classified as to whether it is ground, elevated ground or vegetation.

Formerly, the analysis of the large amount of data generated from a single survey was a time and energy consuming, laborious process requiring many hours and many computers. However, the Geospatial team at Umwelt has developed software, known as *Anditi* that has the ability to efficiently apply appropriate series of algorithms to the data that processes the information and provides detailed results in a timely manner.

The Problem

While the threats to Malleefowl have been recognised, the trend in Malleefowl populations generally is poorly known. The home range of the Malleefowl can be extensive ranging from over one to several kilometres in the course of a year (Benshemesh 2007). During the breeding season males spend most of the time in the vicinity of their mounds. Notwithstanding this, the elusiveness and great distances do not lend themselves to accurately determine the numbers of Malleefowl in any one area.
Given the difficulties in finding and counting individual birds, the occurrence of Malleefowl mounds has been typically used as a proxy for the bird's occurrence. However, finding Malleefowl mounds can be time consuming, labour intensive, expensive and may not be practical in large, remote areas. Typically, a line approach is used in which a number of suitably qualified surveyors stand in a line equidistant from each other and walk along pre-determined tracks searching for Malleefowl mounds. The distance between people is determined by the density of the vegetation with distances as close as five metres apart in dense vegetation, and greater distance in sparse vegetation. Similar to swathes, tracks are walked along the length of the survey area until the entire area has been surveyed. However, as tabled above (Table 3), a most efficient method of reliably detecting Malleefowl mounds over large and/or remote areas is with the use of LiDAR.

Umwelt's Solution

Umwelt ecologists and our geospatial team realised that the extensive datasets being collected or able to be collected in LiDAR runs would include information about Malleefowl mounds – they just needed to be able to discern mound 'signatures' within the billions of LiDAR points returned in a typical survey. To give a sense of how difficult this is, there are typically two million to five million LiDAR points in each 1 km^2 of data. A Malleefowl mound is typically represented by just ten points to twenty-five points and there may be vegetation covering the mound.

Umwelt has completed searches for potential Malleefowl mounds using LiDAR data in areas up to 1,000 km^2. Manually examining billions of LiDAR points in such a large area would not be feasible, so Umwelt has developed software to search through the data for mounds, even those covered by vegetation. An algorithm ranks mound-like objects, with the most likely mounds then presented visually to the user one by one, to enable suitably experienced ecologists to determine if the candidate mound is a Malleefowl mound. This software Umwelt has called *Anditi.*

Locations of the identified mounds are then placed in a GPS so that they can be visited in the field to confirm whether they are actually mounds or not. This approach provides substantial time saving when searching for Malleefowl mounds within large areas.

Umwelt's algorithm does not discriminate between recently active mounds and those that were last used several years ago. However, the software provides information on the height and diameter of each mound, plus an indication of whether a central 'pit' was present when the LiDAR was collected. The central 'pit' may be indicative of an active mound that has been opened up intermittently late in the season to allow solar energy to heat the eggs, an old mound where the central core is collapsing or a mound that has been predated and where the eggs have been excavated leaving a central 'pit'. This emphasises the importance of having experienced ecologists ground-truthing LiDAR results of potential mounds.

LiDAR data should ideally have at least two points per square metre to find Malleefowl mounds, although studies in heavily vegetated areas will benefit from higher resolutions to ensure the ground has been defined adequately by the laser. With good data, both megamounds and mounds as low as 0.1 m in height have been observed in LiDAR data.

The following figures provide examples of the various mound age classifications:
Figure 8 represents an active mound with both litter and many scratchings present;
Figure 9 represents an active mound within an old mound that has collapsed;
Figure 10 represents and old mound with a central pit and partially covered with vegetation; and
Figure 11 represents and old domed mound covered in vegetation with no central pit.

Figure 8. Active mound.

Figure 9. Active mound within collapsed mound.

Figure 10. Very old mound covered in vegetation with central pit.

Figure 11. Very old mound covered in vegetation.

Case Studies

In the case studies presented in this paper, LiDAR data had already been collected by the client and was presented to Umwelt for analysis. After initial receipt of the data, a range of quality control and data verification checks were conducted as the first stage of working with the data. The steps used to process spatial data included:

- data verification:
    - preliminary check of the data;
    - backup copy of the data;
    - load data into databases;
    - check vertical alignment of LiDAR swathes;
    - check horizontal alignment of images with LiDAR;
- correct data alignment where necessary;
- generate landform from ground points;
- undertake project-specific analysis from LiDAR and aerial imagery to identify potential Malleefowl mounds based on general profile characteristics of Malleefowl mounds;
- engage Umwelt's experienced ecologists to assist with the identification of potential mounds; and
- develop list of GPS coordinates for ground-truthing of candidate mounds.

Case study 1

Umwelt's first Malleefowl survey using LiDAR was conducted in 2011/2012 at a site approximately 175 kilometres (km) north-west of Kalgoorlie in the Yilgarn Craton, Western Australia.

The LiDAR data provided to Umwelt for analysis had already been collected at two points per square metre over 80,000 hectare (ha). Analysis of the data identified 102 potential candidate mounds (see Figure 12 for example of potential mound). Ground-truthing of these candidate mounds confirmed 99 out of the 102 mounds were actually Malleefowl mounds, giving a 97 per cent (%) chance that each candidate target was a Malleefowl mound.

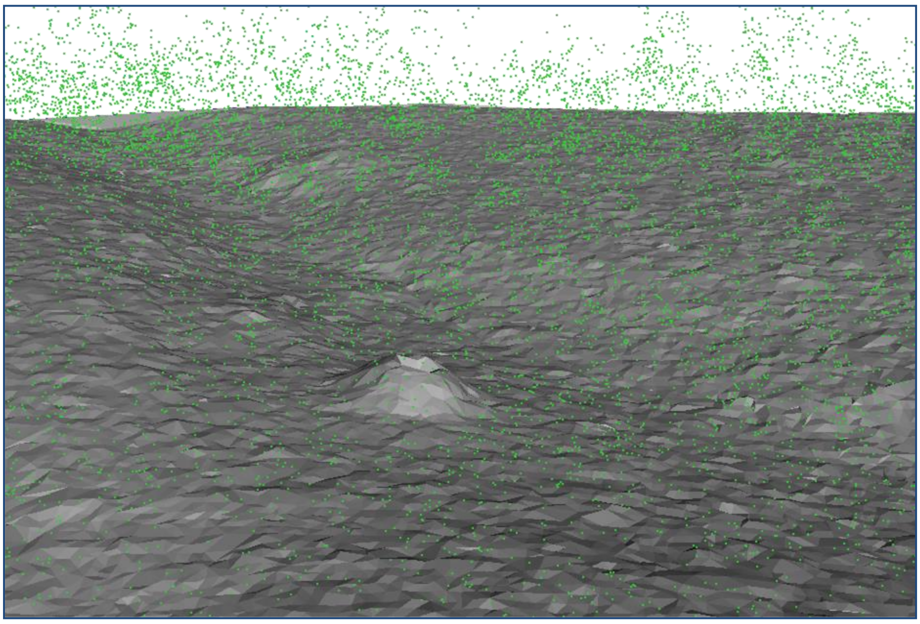

Figure 12. Analysis of LiDAR data depicting a potential Malleefowl mound surrounded by varying levels of vegetation.

Case study 2

A second case study was undertaken in 2012 at a mine site approximately 100 kilometres north-east of Southern Cross in the Yilgarn region of Western Australia. The Malleefowl survey was conducted to comply with a Ministerial Condition that required an annual search for Malleefowl mounds within a buffer area of 12,000 ha.

The LiDAR dataset provided to Umwelt for analysis was flown in April 2012 and had 0.5 points per square metre. A total of 144 potential mounds were identified from the dataset, with only 21 potential mounds within the survey area. Of these 21 potential mounds, 15 were confirmed to be Malleefowl mounds and six were either circular rocky outcrops (n = 3) (Figure 13) or circular areas of vegetation (n = 3) (Figure 14). Collectively this can be interpreted as a 71.4 % success rate of LiDAR data analysis.

Figure 13. Example of circular granite outcrop.

Figure 14. Example of circle of vegetation.

The lower success rate in identifying potential mounds in this study highlights the difference in the number of points fired per square metre, with more points (two points per square metre) providing greater accuracy (97%) compared with fewer points (0.5 points per square metre) resulting in lower success in identifying Malleefowl mounds (71.4%).

It is recognised that more points per square metre will provide more information from the data, with a concomitant higher success rate.

Summary of Specific and General Benefits

Specific benefits

Specific benefits of using LiDAR to assist in the identification of Malleefowl mounds include, but are not limited to, the following:

- The ability to survey large areas in remote locations before a far reduced team of ecologists (one or two) target ground-truthing of potential Malleefowl mounds in those locations.
- Reduced costs (time and money) of ecologists on the ground.
- Reduced on-site impacts.
- The ability to accurately determine ground levels and changes.
- The ability of LiDAR to 'see' through vegetation covering mounds.

LiDAR cannot replace the skills and experience of ecologists in the assessment of Malleefowl mounds. However, adding LiDAR to ecologists' toolbox of ecological and technical competencies will enable more targeted work for ecologists to be undertaken with much more accurate results. While the initial startup/analysis costs may be a disincentive in some cases, the results and medium to long term outcomes of the use of LiDAR will negate these. Further, the associated general benefits of capturing LiDAR may far outweigh these initial mobilisation and analyses costs.

General benefits

Raw and interpreted LiDAR data that are captured as part of Malleefowl mound detection campaigns can also be used for a range of other purposes. These can include:

- generating high resolution digital terrain models;
- contour information;
- vegetation structure and cover;
- forestry and silvicultural purposes including percentile tree counts and stem measurement, and identifying certain tree species/genera such as Cypress Pine and introduced pines;
- identifying vegetation communities including Threatened and Priority Ecological Communities;
- monitoring rehabilitation progress;
- generation of continuous topography for general/specific analyses;
- monitoring landform changes including stockpile and embankment details;
- erosion and deposition volumes;
- wide-area surveys for features;
- characterising site features to choose sites for environmental surveys;
- information on the built environment such as roads, buildings and other infrastructure;
- line of sight analysis to determine visual impacts;
- high resolution data for environmental modelling (air, noise, flood); and
- carbon accounting, fuel load assessment.

Conclusion

Given the conservation status of the Malleefowl and the uncertainty of determining population trends, any advance of the time-consuming, labour intensive line approach of surveying for Malleefowl mounds would be a welcome advance for ecologists. The use of LiDAR to detect Malleefowl mounds in remote areas and across vast landscapes has proven to be an innovative and feasible technique. The information gained through this technique can be used by ecologists to better predict Malleefowl populations and, thereby, make better informed decisions when reviewing management options for this iconic species.

The Authors

From digging up trapdoor spiders to detailed mapping large swathes of vegetation, and many more talents within the ecological spectrum, Vi and Travis collectively have nearly 50 years of experience.

Vi has principally worked in faunal ecology throughout Western Australia both in research and in the field, and has also worked briefly in New South Wales. Vi has conducted all Levels of fauna surveys in accordance with Guidelines and Position Statements issued by the Western Australian Environment Protection Authority and the Western Australian Department of Parks and Wildlife under the Western Australian *Environmental Protection Act* 1986 and *Wildlife Conservation Act* 1950, and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999.

Specifically, Vi has walked many, many miles conducting line approach Malleefowl surveys, worked together with the geospatial team fine-tuning the search criteria within the algorithm and conducted the first ground-truthing exercises, providing valuable feed-back to enhance the *Anditi*™ system.

Travis is Umwelt's Practice Leader Ecology, a role in which he conducts and oversees ecological studies and assessments across Australia by Umwelt's team of regionally-based Ecologists. His background is in the mapping and surveying of vegetation communities across bioregional landscapes, including vegetation community statistical classification and threatened ecological community management. Travis also has a background in threatened fauna surveying and management. In his current role he is primarily focussed on ecological impact assessments, biodiversity offsetting and ecological management plan preparation and monitoring, including major project approvals under state/territory and Commonwealth legislation.

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22. Motion-sensitive cameras for monitoring a range of animals in Malleefowl monitoring sites

Joe Benshemesh, La Trobe University, Vic; Member National Malleefowl Recovery Team

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Abstract

The national Malleefowl monitoring system provides essential information on trends in Malleefowl populations at over 100 sites across Australia. By relating these trends to other information, such as management actions and environmental conditions, we gain understanding of what influences Malleefowl populations. In particular, Malleefowl may be affected by the abundance of other animals, especially predators such as foxes and cats, pests such as rabbits and goats, and natives such as kangaroos. All of these animals may have an impact on Malleefowl, but obtaining reliable information on them is difficult.

In 2013 we trialled the use of motion-sensitive cameras at two monitoring sites in Victoria in order to collect information on a range of animals simultaneously. To be most efficient in terms of cost and labour, we envisaged a system in which cameras were semi-permanent and visited only once per year to download photos and check that cameras were working properly. Accordingly, cameras were set up with solar panels and batteries and scattered through the mallee (not at mounds) to monitor animals throughout the year. We devised a simple system for volunteers to sort photos which proved effective, accurate and popular. Once sorted, the data were easily extracted and transferred to a database in preparation for analysis. The ensuing data provide a detailed view on the abundance of a range of species that may affect Malleefowl. The techniques promise to deliver cost-effective and valuable information to the Malleefowl Adaptive Management Project, and more generally to land managers.

Introduction

Monitoring Malleefowl provides data on the trends in the species populations which is essential for informed management. This information is made meaningful by relating it to other factors that influence Malleefowl populations, such as rainfall, fire history, and landscape context (Benshemesh, Barker & MacFarlane 2007). However, many important factors can't be tracked so easily. For example, foxes are the main predators of Malleefowl but are elusive and difficult to monitor; previous studies have resorted to counting fox scats on mounds as a means of estimating fox trends and their effect on Malleefowl populations (Benshemesh, Barker & MacFarlane 2007, Walsh *et al.* 2012). Obtaining useful data on the abundance of other predators and competitors that may affect Malleefowl populations is even more difficult (Benshemesh 2007), yet this information is essential if we are to make sense of Malleefowl trends and identify the most effective management options. As Malleefowl monitoring moves from a passive activity to a dynamic interaction with management under the Adaptive Management Project (Benshemesh & Bode 2011, Hauser *et al.* 2014), information on trends of predators and competitors will become increasingly important.

Motion sensitive cameras provide an efficient means of gathering data on a range of medium to large sized animals simultaneously (Silveira, Jácomo & Diniz-Filho 2003, Vine *et al.* 2009, Claridge, Paull & Barry 2010). In regard to Malleefowl monitoring, cameras could provide quantitative data on the abundance of several animals of interest, including predators such as foxes, dogs and cats, and potential competitors such as kangaroos, goats, and rabbits. Cameras might also provide alternative information on Malleefowl abundance that cannot be obtained through the current monitoring practice which focusses on breeding birds. In particular, cameras may provide some information on non-breeding Malleefowl, and help identify years in which recruitment of young occurs into the adult population.

As monitoring sites are only visited annually, the ideal setup would involve cameras that require little maintenance and are able to collect photos over a 12 month period. In this ideal scenario, people doing the Malleefowl monitoring each year would simply swap the full memory cards of the cameras with empty cards.

In this study we assessed the utility of camera traps for the Malleefowl monitoring and adaptive management projects. Twenty-four cameras with solar panels and external batteries were placed in two monitoring sites and evaluated in terms of the suitability of the technology, the ease of processing the photos, the usefulness of the ensuing data, and the practicability of developing a larger program in which camera traps might be placed in the majority of Malleefowl monitoring sites and provide information on the abundance and trends of a number of species of interest.

In particular, we were interested in the performance of the cameras and how best to set them up for continuous field operation. For example, should the cameras take multiple photos whenever triggered? Should they be made insensitive between trigger events or capture every trigger event?

Funding for this study was provided by the Iluka Malleefowl Management Fund, and on-ground support was provided by the Victorian Malleefowl Recovery Group and the Mid-Murray Field Naturalists. The work was carried out under permit from DEPI (#10006879) and we thank Parks Victoria and the Menzies family for their support. We especially wish to thank the volunteers who sorted photos for us: June Brown, Jess Gardner, Felix and Bonnie Gelman, Vicki Natt, Liz and Gil Hopkins, Iestyn Hosking, Judy Irvin, Bob Jones, Rod Lingard, Rob Lucas, Greg and Marg Davis, Annette Robertson, Rosemary Thompson, Graeme Tonkin, Keith and Cynthia Willis and Ron Wiseman.

Methods

Faunatech (www.faunatech.com.au) supplied 25 cameras (KeepGuard KG-680v) and provided each with an SD card (4GB), battery (6V, 12Ah lead-acid dry-cell) and solar panel. Faunatech also supplied all necessary wiring and attachment brackets for the solar panels.

Twenty-four cameras systems were installed in neighbouring Malleefowl monitoring sites separated by 1km of agricultural cleared land: 16 camera systems in Wandown (area about 18 km^2) and eight in Menzies (area about 3.4 km^2). Cameras were placed 100-200m off tracks to facilitate access while keeping them out of sight from passers-by and were typically strapped to the base of mallee trees). Orientation was usually southerly to minimise glare from the sun, and care was taken to select a site and orientation that avoided vegetation that might move in the wind and trigger the camera. The battery was wrapped in plastic bags and covered with sticks or triodia clumps to reduce interference from animals. Solar panels were attached to a mallee stem 1.5 – 2.0 metres above the ground and orientated to the north.

Cameras were revisited by VMRG members who checked its condition, removed and replaced the SD cards, and restarted the camera. These people had no prior experience with the cameras, but were provided with each camera's GPS location and instructions that detailed the reading process.

The 24 cameras captured 29,494 photos over the first period (55 days: 24 March to 18 May 2014) and 84,854 photos over the second period (171 days: 18 May to 5 November 2014). All photos were in JPG format.

The data on the 24 SD cards was transferred to a PC and then copied to two 300GB hard drives for security, one of which was prepared for analysis. A separate folder was created for each camera, and photos were renamed with the camera number followed by the photo number using Ant Renamer, a Windows program designed to rename collections of files. Subfolders were created for eight species of interest: Malleefowl, Fox, Cat, Emu, Kangaroo, Pig, Rabbit/Hare, Echidna (rabbit and hare were combined as they were relatively rare).

We used Windows Explorer opened in two separate windows, or (preferably) FastStone Image Viewer (FastStone Soft) to scan through the photos rapidly and move them to the appropriate folders, and ExPrint (JD Design) to write the contents of the directory that included the photos to a spreadsheet (Microsoft Excel) and a database (Microsoft Access), including the file path and the Exif date/time.

All cameras were set to take two photos in rapid succession whenever the infrared trigger was activated, however inspection of the photos showed that there was no advantage in this as animals were usually readily identified from the first photo. In quantitative analyses, these second photos were ignored.

The photos from the first period were sorted by one of us (JB). The second set of photos was divided into eight batches of about 5,000 photos and sent to 15 volunteers who sorted them. People were asked to use the first 1,000 photos to become familiar with the task, and to time the sorting of subsequent groups of 1,000 photos.

During this assessment, all cameras were set to take a photo whenever they detected movement. However, the cameras can be set to enter an insensitive or 'rest' period after a photo is triggered. This minimises repeated photos of the same animal or other trigger event, but risks missing interesting animals that might pass while the camera is insensitive. To simulate different time interval settings on photo-sets that would eventuate from setting the cameras to be insensitive for 1 - 60 minutes after a photo was taken, we manipulated the data in Excel and Access to mimic insensitive intervals (i.e. photos were ignored if they were taken within a nominated insensitive period since the last trigger event).

Results

Installation of cameras took 10 - 20 minutes and exchanging the SD cards and checking the systems took less than five minutes, even for inexperienced volunteers. System failures occurred but were not common: one camera system failed to take photos during the first (54 day) period due to incorrect setup, and none failed in the second period. A few cameras developed an internal error that rendered daytime photos in monochrome pink but these nonetheless provided adequate detail to identify target animals.

Ten percent of photos were of target animals and the remainder were regarded as nulls without recognisable animals in them. Most likely these were triggered by moving vegetation or shadows. However, nulls also included photos of various bird species, especially white-winged choughs and magpies, as well as occasional photos of yellow throated miner, ravens, chestnut quail-thrush, tawny frogmouth, and a wedge-tailed eagle.

Target animals were photographed by every camera, averaging about 1.1 target-animal photos/camera/day. The proportion of photos that were of target animals averaged 20% across cameras, but this varied considerably between cameras from less than 1% to 64% due to some cameras at which a very high number of nulls occurred. Nulls were also recorded at every camera.

Camera rest periods

The **proportion of target animal species** detected by the cameras was not sensitive to the simulated rest periods after a trigger event (Figure 1). If a species was detected at a camera when there was no rest period, then it was generally also detected even if the insensitive rest period was up to 60 minutes. There were some exceptions, but changes were minor: Malleefowl were detected at 19 of the 24 cameras when there was no rest period, but at only 18 cameras when the rest period was one minute or greater. Rabbits/hares were detected at 22 cameras consistently until the rest interval was increased to 60 minutes, when it was not detected at one of the cameras. Non-target birds (XBird) were similarly detected at all 24 cameras until the interval was increased to 10 minutes and more when they were detected by 23 cameras. Foxes and kangaroos were the most ubiquitous animals and were detected at all cameras regardless of interval.

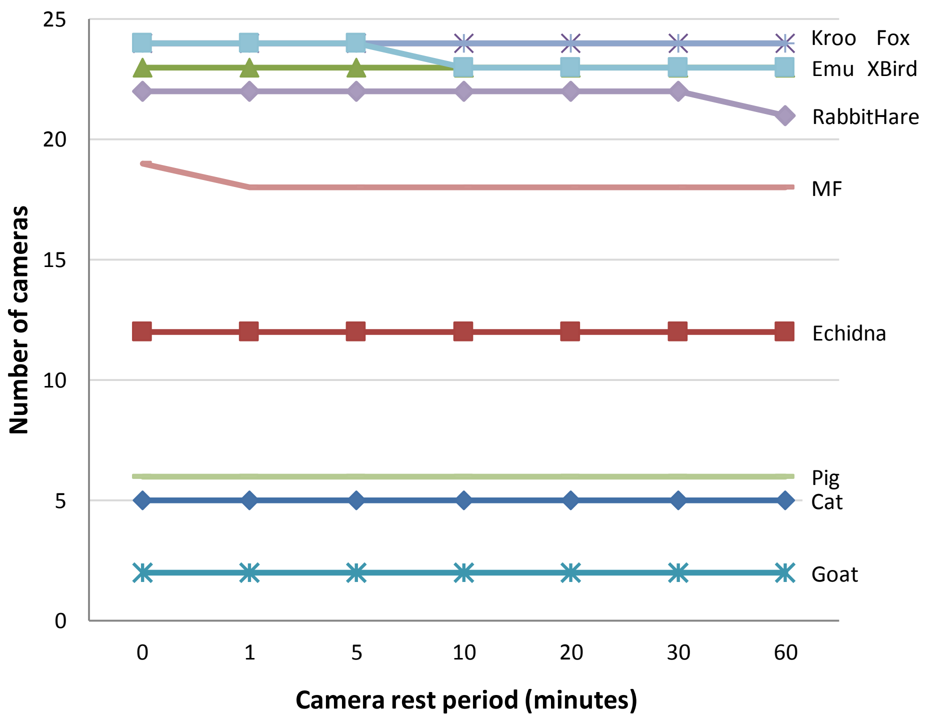


Figure 1. Number of cameras that detected target animal species for different photo intervals (24 cameras in total over 224 days).

While the proportion of cameras that detected each species was relatively constant in relation to camera rest intervals, the **number of photos of each target animal was greatly affected by rest length**. The number of nulls was greatly reduced when rest intervals increased: a one minute interval between successive photos reduced the number of nulls by 38%, a five minute interval by 65%, and a 60 minute interval by 87% (Figure 2). Similarly, the number of animal photos was reduced by 39%, 52% and 59% for one, five and 60 minute intervals respectively. The reduction in the number of nulls was greater than that of target animals, and consequently the proportion of animal photos increased with increasing intervals (Figure 2).

Target species responded differently to varying the interval length between photos. Kangaroos were the most commonly photographed animals, averaging 113 photos per camera in the original dataset, but this dropped to 50 photos per camera with a one minute rest interval, and to 29 photos per camera with a five minute interval. Thereafter, declines were slight (Figure 3). Emu and, to some extent, pig captures also followed this pattern of substantial reductions in captures with the introduction of camera rest periods, followed by only small changes with increasing rest interval. In contrast, foxes averaged 63 photos per camera in the original dataset, and this dropped less radically to 56 photos per camera with a one minute rest interval, and to 54 photos per camera with a five minute interval; thus fox became the most frequently captured species once a rest period of one minute or more was simulated, and with a ten minute or greater rest interval, were recorded at least twice as frequently as Kangaroo. The number of photo captures of Malleefowl, cats, rabbit/hare and echidna changed little with different interval length. In general, there was little change in the average number of photos per camera for target species with intervals greater than five to ten minutes (Figure 3). These data are represented in terms the proportional contribution of each species' photos for camera rest interval in Figure 4 where the contrast between capture patterns of kangaroos and foxes is particularly evident.

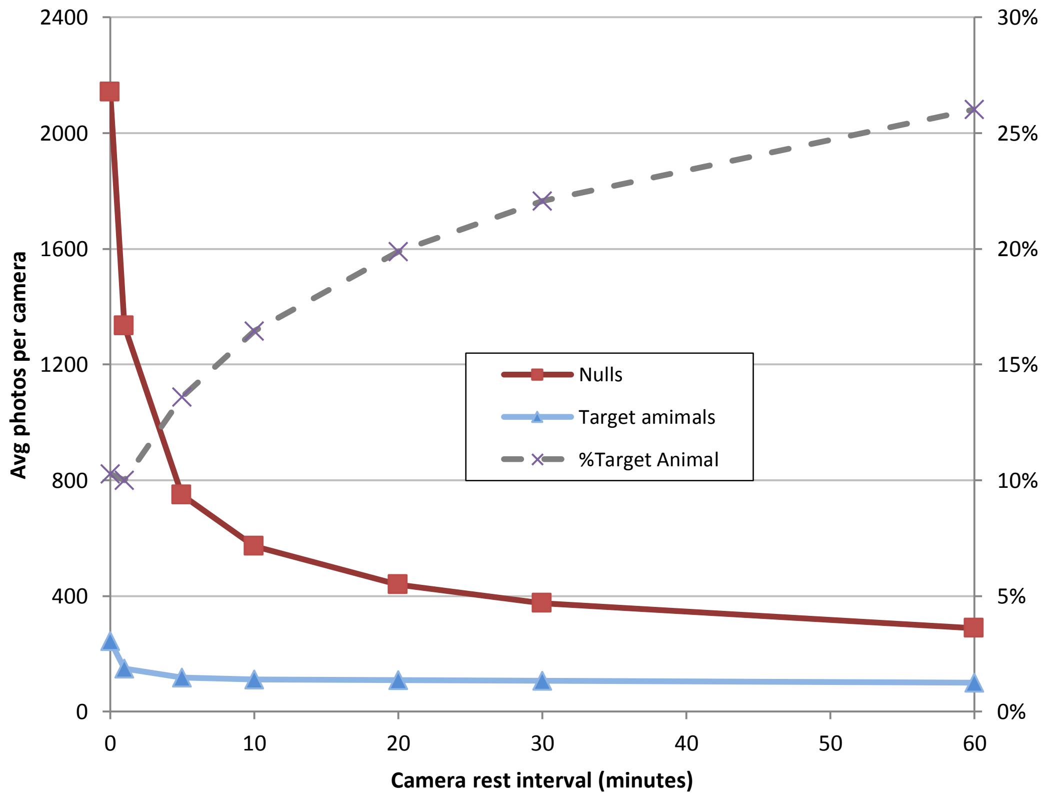
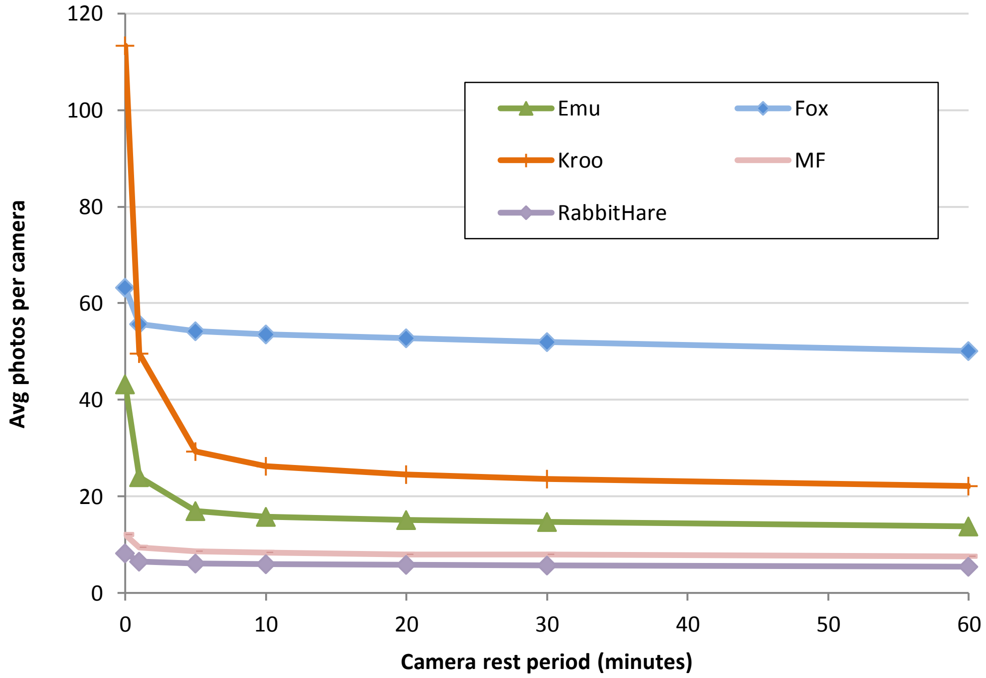


Figure 2. Average number of null and target animal photos per camera, and proportion of photos that were of target animals, in relation to camera rest intervals.

Species captures at Wandown and Menzies

Simulated numbers of photos with a ten minute rest interval were used to examine differences in the abundance of target animals at Menzies and Wandown (Figure 5). Kangaroos, emu and Malleefowl were more commonly photographed at Wandown and Menzies. Fox and rabbit/hare were photographed a similar rates at the two sites, whereas cat, pig and echidna were rarely photographed at either site.

a)



b)

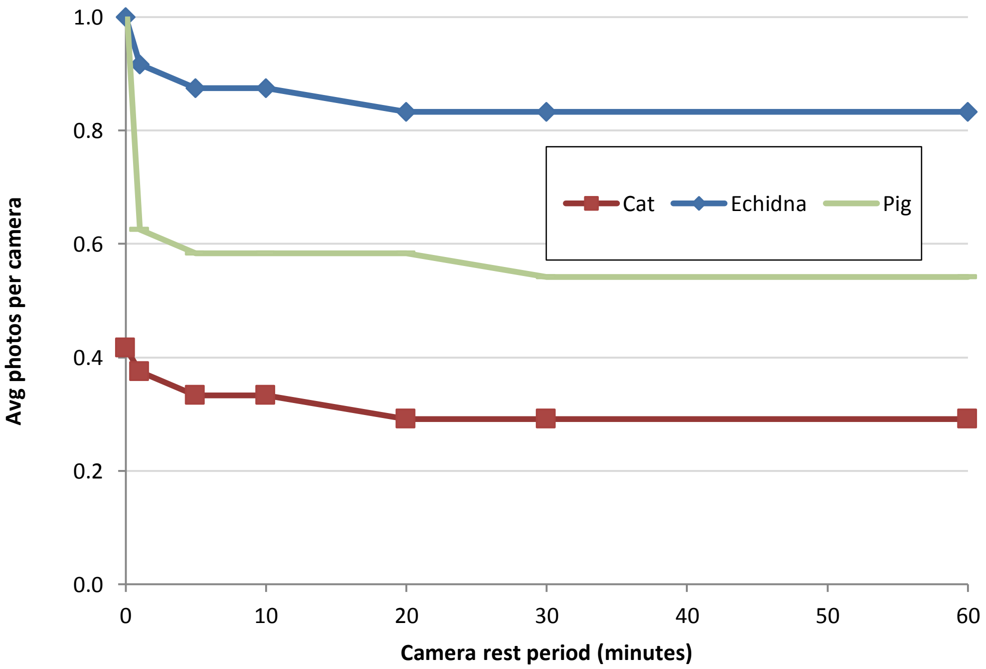


Figure 3. Average number of photos of target species per camera over the 224 day study period for different camera rest intervals between photos: **a)** most common species (more than 1 detection/camera); **b)** less common species (less than 1 detections/camera).

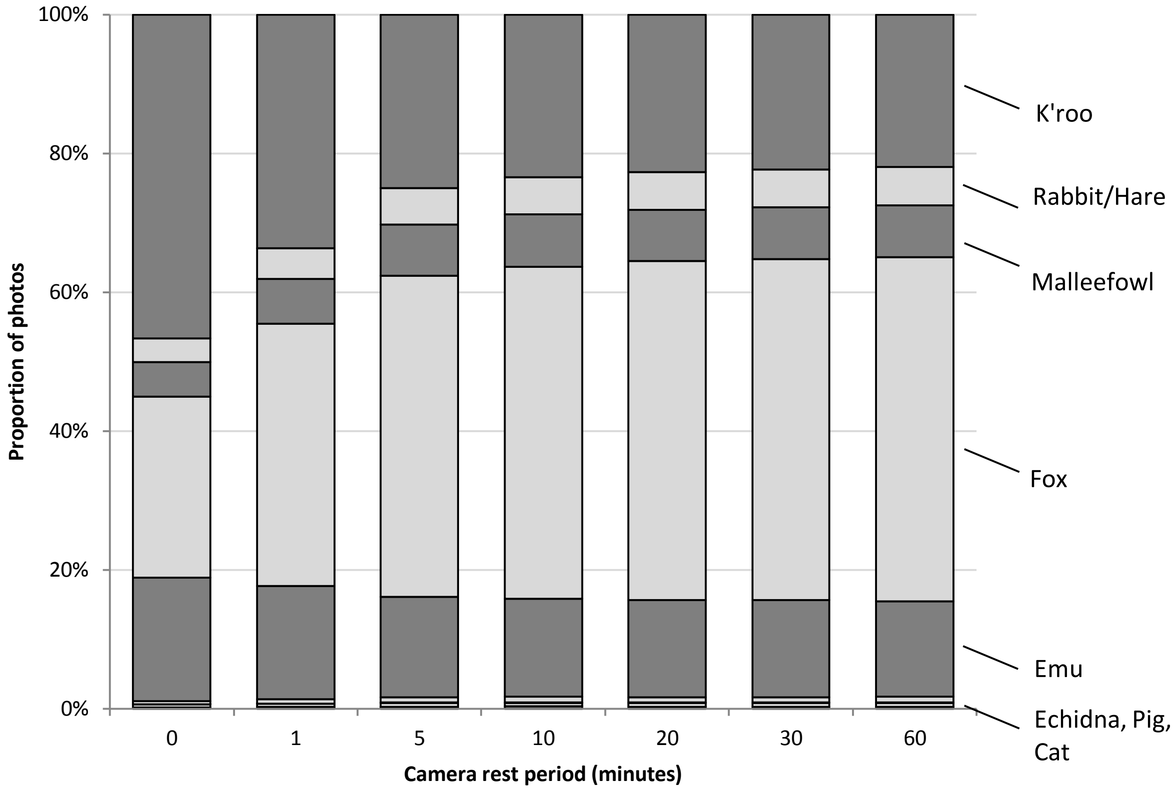


Figure 4. Proportion of photos of target species for different intervals between photos.

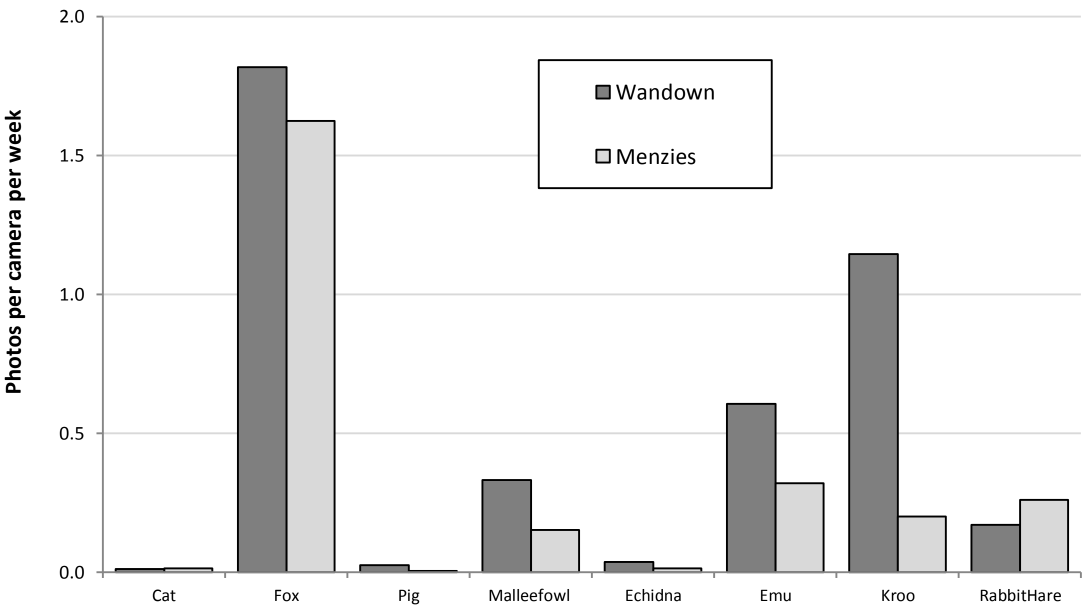


Figure 5. Number of photos of target species per camera per week at Wandown (dark grey) and Menzies (light grey) with a 10 minute interval between photos.

Sorting photos by inexperienced volunteers

Fifteen of the 16 people who volunteered for the task, returned a disk with sorted photos. Responses were overwhelming positive: all responders said they enjoyed the process, all said they would do it again, and all but one said they were prepared to sort three times as many photos each year if we were able to purchase more cameras (the only responder who was unsure was using a Mac computer and sorting was very slow).

The median time for volunteers to sort 1,000 photos was about 40 minutes. Times varied greatly from eight to 120 minutes per thousand photos (Figure 6). The variation in sorting rate probably reflected the nature of the photos being sorted; where there were many successive nulls or repeated photos of particular animals (especially kangaroos), sorting was faster because many photos could be dragged to the appropriate folder in a single action. Another source of variation was the computers that people worked with: the slowest volunteer was unable to use the recommended software and progress was very slow, estimated at 129 minutes for each thousand photos. It was also apparent that some people were simply faster than others. However, volunteers became faster at sorting with increasing experience: the 2nd thousand photos took a median of 50 minutes, the 5th thousand photos took only 35 minutes and the experienced sorter took only 28 minutes to sort one thousand photos (Figure 6).

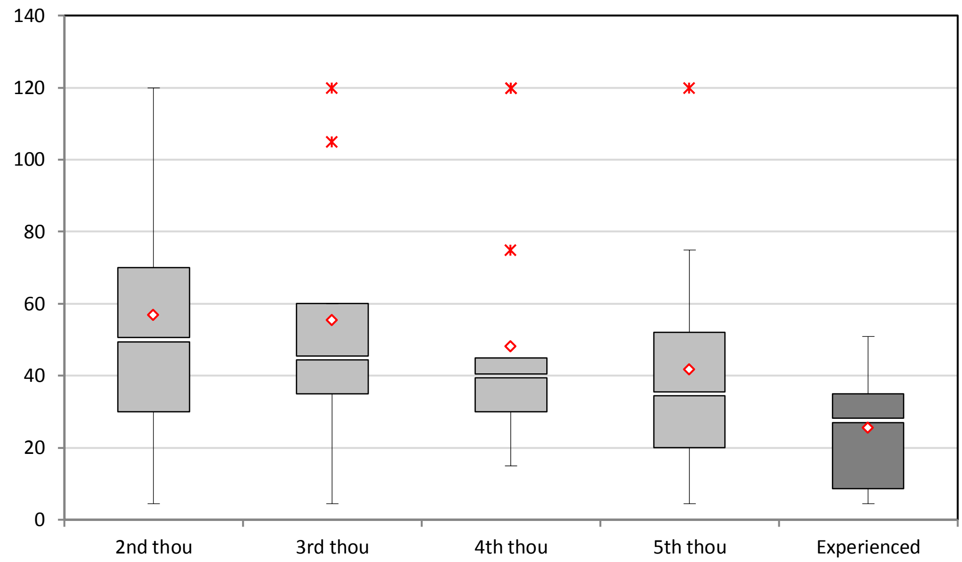


Figure 6. Boxplot showing the time to sort 1,000 photos in relation to experience. The central 50% of observations in each data set is shown as boxes divided in two by the median and bounded below by the first quartile and above by the third quartile. The whiskers (error bars) extend to 1.5 times the box height. Values outside the whiskers are considered to be outliers. Means are indicated by the diamonds.

Discussion

This study focussed on three issues that are critical to determining the feasibility of using motion sensitive camera to obtaining information of relevance to the Malleefowl monitoring program. The first of these concerned the technology. All of the cameras appeared to perform adequately provided they were set up correctly and the battery and solar panel arrangement also worked well.

The second feasibility issue concerns the practicability of running a program involving several cameras at numerous monitoring sites, potentially collecting hundreds of thousands of photos each year. Given the scale of project and difficulty of obtaining sustainable funding, we were particularly interested in whether volunteers would be capable and interested in taking a camera monitoring project on, as an addition to the regular mound monitoring. It was for this reason that we enlisted the help of volunteers in this study. The involvement of citizen scientist volunteers is necessary where appropriate resources to do the monitoring can't be obtained, but volunteers also provide the longevity that is necessary for an effective program; a program run by volunteers is relatively immune from interference and the vagaries of funding decisions, and can thus be maintained in the long-term with a degree of certainty. However, a wide scale camera trapping project would require another large commitment by volunteers and may not be sustainable long term if it was labour intensive.

In this study, volunteers installed half of the camera systems without technical assistance after being shown how, and another team of volunteers revisited the cameras and retrieved the photos with only written instructions and a GPS. Both operations were simple and straightforward and were successfully accomplished.

A bigger issue is the initial identification of photos, counting the animal detections and processing of information onto a database. Each camera is capable of taking tens of thousands of photos and processing these from many cameras could become a huge undertaking. However, in this study the processing of photos was found to be surprisingly fast and easy, and the most time consuming part, the sorting of photos, was well within the capabilities of volunteers. Set to trigger a photo at least five minutes after the last trigger, we estimate that an average of about 1,500 photo captures would be expected per year; sorting these photos is likely to take only about an hour (assuming the median sorting speed in this study). Supposing six to ten cameras would be needed at each site to provide information on trends in various animals, sorting the photos for a site could feasibly be done by one person in one or two days. In short, the labour requirement for processing a full year of photos does not seem excessive, especially as the effort could be spread out over many days or weeks.

Will citizen scientist volunteers be interested in taking on a camera monitoring project in addition to their mound monitoring? The indications are that they would be and we have been approached by a number of people offering their services. Viewing and sorting the photos is an inherently interesting task that is both informative and addictive. There is a high degree of site fidelity amongst volunteers involved in the Malleefowl monitoring, and people who monitor sites are likely to be very interested to see what other animals are recorded at the site. There has also been a great deal of interest in the motion camera project from volunteers who are unable to meet the physical demands of monitoring, which involves many hours of walking in remote regions, but who are nonetheless keen to help with less arduous activities.

The third feasibility issue concerns the usefulness of the data. In this study, a wide range of species that may impact on Malleefowl were detected, including foxes, cats, pigs, kangaroos, rabbits/hares and Malleefowl. Goats, sheep and deer are unlikely to occur at Wandown and Menzies, but are animals of great concern at other monitoring sites and would be easy targets for camera traps. Information on the abundance and trends in these animals is of great relevance to Malleefowl management and conservation, especially given the current emphasis on the development of a formal adaptive management program to guide management.

It seems clear that the camera trap results have the capacity to describe differences between sites and monitor species trends over time. In the current study, there were apparent differences between Wandown and Menzies: kangaroos, emus and Malleefowl were captured by cameras more often at Wandown than Menzies, whereas other species were captured at relatively similar frequencies. This result conforms to expectations as Menzies is a much smaller and disturbed isolate than Wandown, and also to our collective experience of these sites.

Camera traps as trialled in this study have clear advantages over alternative methods for monitoring the diverse set of animals of interest to Malleefowl conservation. The camera traps provide the ability to count the number of times a species of interest passes the camera every day and night for an entire year. These data provide a means of monitoring trends in a variety of species, and also provide information on when species are active, data that may be critical for understanding potential interactions. For example, the 24-hour patterns of foxes and Malleefowl show that while foxes (Figure 7) were generally much more commonly recorded than Malleefowl, foxes were largely nocturnal while Malleefowl were diurnal. Nonetheless, foxes were sometimes out and about during the day and at these times the frequency of recording them was similar to Malleefowl: Malleefowl may encounter foxes as frequently as encountering their own species.

In brief, the camera traps provide a relatively cheap, logistically simple and highly efficient means of collecting data on species of interest to Malleefowl conservation. Maintenance and data management requirements also appear to be low, especially considering the number of species that are monitored and the quantity and quality of ensuing data.

In this study we also examined the effect of different intervals between photos from the practical rather than statistical point of view. Short intervals between photos had the effect of increasing the proportional representation of kangaroos and resulted in a large numbers of redundant photos that would inflate the time needed for processing the photos and quickly fill up the SD cards. Part of the reason for this redundancy is that kangaroos tended to hang around an area for long periods, especially during the day when they were resting, and are social animals that occur in groups. Other animals that travel in groups (pig, emus) showed the same but less extreme patterns. The proportional abundance of different animals appeared to stabilise with intervals greater than five minutes, and intervals of five minutes also resulted in a manageable expected number of photos per year. Accordingly, setting the cameras to become insensitive to triggers for an interval of five minutes after each photo would seem advisable. Increasing the interval more than this would further reduce the number of photos that need to be processed, but would also increase the likelihood of missing rarer animals (such as juvenile Malleefowl). While these practical issues are of great importance, they should not be confused with the statistical issue of autocorrelation (i.e. the similarity of observations at successive times) which will need to be dealt with in any statistical analysis of the data. A related and more urgent statistical issue concerns the number of camera traps needed to adequately determine the abundance and trends of species at each monitoring site, a subject that Rosanna van Hespen (Melbourne University) will be examining in 2015 using the data described in this report.

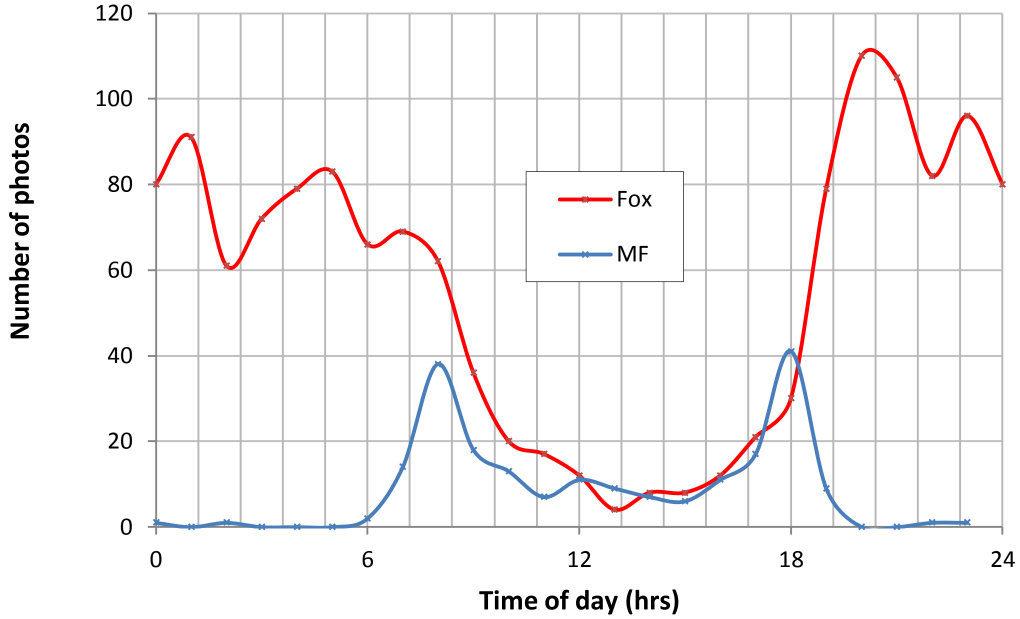


Figure 7. Diurnal activity patterns of Malleefowl and Foxes in relation to time of day. Fox abundance was highest through the night, but they nonetheless occurred during the day with similar frequency of photos as Malleefowl. Data based on five minute intervals between photos from 24 cameras at Wandown and Menzies monitoring sites between March and November 2013.

Conclusions

We made a lot of mistakes in this study, but in the process we have learnt lessons about how to achieve our objective of developing a manageable camera surveillance system for animals at monitoring sites. We know now that we should attach cameras to stakes rather than trees (because the movement of trees in the wind triggers photos), that a five minute rest interval is a good way of limiting the number of photos and increasing the proportion of target species photos without much loss in detecting uncommon species.

Over the period of this study the motion sensitive cameras proved to be reliable and successful at detecting a range of animals of interest to Malleefowl conservation, including Malleefowl themselves. The system (cameras, battery and panels) was adequate for the task and simple to install. Field labour requirements were low as the cameras need only be visited once per year during the monitoring, and an efficient way was developed of processing the large number of photos and entering the data onto a database. Sorting the photos was the most labour intensive part of the process but is within volunteer capabilities and is estimated to take only a day or two per monitoring site per year (assuming six to ten cameras per site). There is a high level of interest by the Victorian Malleefowl monitoring community in the project and we expect this will increase in time as it is inherently fascinating to see what animals pass the cameras, day and night, at sites where Malleefowl are monitored. Amid the drudgery of sorting thousands of photos there is an element of fun, surprise and learning that will increase its appeal and promote the sustainability over many years.

Given these results, expanding the project to include more Malleefowl monitoring sites would seem a worthwhile investment in Malleefowl conservation. Camera monitoring would greatly enhance the existing mound monitoring program by providing critical information on the abundance and trends of a range of animals that may impact on Malleefowl. In addition, Malleefowl are often detected by the cameras and these data are likely to prove very useful in determining trends in the abundance of adults and young. The information provided by the motion sensitive cameras will be of great value in analyses of the factors related to Malleefowl trends. This is particularly the case for the Adaptive Management Project where camera capture data would enable the effects of management actions, such as reducing fox abundance, to be directly measured.

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23. Using high definition aerial photography to search for Malleefowl mounds – A case study for Mount Gibson's Extension Hill

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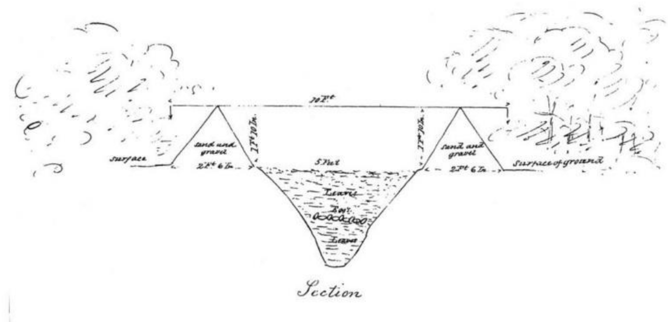
Abstract

This presentation will provide the results of a case study on the use of very high definition aerial photography to search for Malleefowl mounds at Mount Gibson Mining's Extension Hill mine in the midwest of Western Australia. An aerial survey captured approximately 7,000ha with a ground sample distance (GSD) was 4cm and horizontal accuracy of 0.08m. This very high definition photography was post-processed to produce stereo images that were searched using 3D Vision Glasses. The survey recorded 237 mounds in total. Of the 108 Malleefowl mounds (i.e. active and inactive) known from earlier on-ground surveys, 91 (84.3%) were recorded during the aerial searches. Mounds not found were all old and weathered, and many barely above ground level and some with vegetation growing in the centre of the crater. Approximately 11.4% of the mounds identified from the aerial photography that we considered 'confidently mounds', were false positives, and approximately 64.2% of the mounds identified in the aerial photography that were considered to be a 'potential mounds' were indeed mounds. Twenty-two of the newly discovered mounds were either recently active or currently being worked. The cost of searching for Malleefowl mounds using high definition aerial photography and subsequently examining these areas on the ground is appreciably cheaper than on-the-ground grid searches. Based on this case study the use of high definition aerial photography to search for Malleefowl mounds is cost effective.

Preface



The nest was described and sketched. *Leipoa ocellata*, *Malleefowl*. 'gnow, gnow-ow, knowow, Know-ow (sic), native pheasant'. Sanford's claim that the nest is 'probably new to naturalists, as far as the detail is concerned' is incorrect. Sanford was evidently unaware of Roe's description of October 1836, Gilbert's description of September 1842, and the sketch made in December 1842 by George Grey. The information collected by Gilbert and Grey was published by Gould in 1840. Handwritten annotation: "Thicket around Cowcowing, 12 miles N. of Poison Rock – and in thickets on the Murchison below the great bend."

Introduction

Malleefowl (*Leipoa ocellata*) are listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and as a Schedule 1 (Fauna that is rare or is likely to become extinct) under the WA Wildlife Conservation Act 1950. The geographic distribution of Malleefowl includes much of the southern half of Australia from the Great Dividing Range to the west coast (Blakers *et al.* 1984), and originally as far north as the Tanami Desert (Kimber 1985). Its geographic range has contracted in recent years, particularly in arid areas and around the periphery of its distribution (Benshemesh 2000). This is mostly attributed to clearing of habitat (Benshemesh 2007). Figure 1 shows the recorded location of Malleefowl in the Department of Parks and Wildlife NatureMap database since 2000.

Figure 1. Malleefowl records reported since 2000 in the Department of Parks and Wildlife NatureMap.

With the contraction of the geographic distribution of Malleefowl over the last century (Parsons *et al.* 2008), in Western Australia they are now mostly found in areas of dense vegetation as this provides the best protection against potential predators, with the fox (*Vulpes vulpes*) being one of the most significant predators (Priddel and Wheeler 1996, Priddel *et al.* 2007).

There are a multitude of mines and potential mines in the known current geographic distribution of Malleefowl (Figure 1). Prior to submitting a Native Vegetation Clearing Permit application or an Environmental Impact Assessment (EIA) for an expansion of an existing mine or a new development a Malleefowl survey is required. Surveying for this species is complicated by the fact that Malleefowl are relatively cryptic, mobile and spend a considerable amount of time during the day on the ground, making them difficult to find and count. The presence of active mounds is used as a proxy for their presence and relative abundance in a particular area (Brickhill 1985, Benshemesh and Emison 1996, Priddel and Wheeler 2003, 2005). Any area that could potentially support Malleefowl must be searched to determine presence/absence, and if present, indicate relative abundance and the location of all recently active mounds. A more cost-effective solution to assessing potential impacts of developments on Malleefowl is very relevant to the mining industry in Western Australia where this work was undertaken, and elsewhere in Australia.

Mount Gibson Mining Limited currently operated the Extension Hill Hematite Operation – an iron ore mine in the Mt Gibson Range, approximately 350km north east of Perth, where mining commenced in late 2010. A number of grid searches were conducted in the project area in 2004/2005 to establish baseline data, prior to the commencement of mining activities and regular monitoring of the known mounds is conducted, pursuant to the project Malleefowl Management Plan. In 2013, the requirement to re-search the project area was recognised and an effective and efficient methodology to achieve this using aerial imagery was developed.

Typical Malleefowl country in the mid-west of Western Australia.

Finding Malleefowl!

Existing survey techniques

The detection of active Malleefowl mounds in an area is generally used as a proxy for their presence (Brickhill 1985, Benshemesh and Emison 1996, Priddel and Wheeler 2003, 2005). This is a relevant proxy to confirm their presence in an area and provides a very rough estimate of the number of Malleefowl in the area, as it directly relates to the number of reproductively active birds in the area, which can be a useful indicator of survival of the local population, although the number of Malleefowl that breed each year varies which reduces its usefulness.

Traditionally, Malleefowl mounds have been located by grid searching suitable habitat on the ground. This means a group of people walk in a line, spaced at a distance so that they can see all of the land between two adjacent searchers. Typically, groups of four to ten people are used.

The National Manual for Malleefowl Monitoring (Hopkins ed.) suggested two search procedures: a) grid searching an area on foot, and b) aerial surveys. The Commonwealth Government Guidelines (Department of Sustainability, Environment, Water, Population and Communities 2010) suggested that in semi-arid and agricultural areas searches in suitable habitat for active mounds, tracks and sightings is the best method of detection. They also indicate that aerial surveys may be useful in extensive areas of relatively open habitat. These guidelines also indicate that in arid regions transect searches for footprints in sandy areas are most effective.

Benshemesh and Emison (1996) reported on the usefulness of airborne thermal scanners to identify active Malleefowl mounds. Their methodology successfully detected up to 36% of active mounds on cloudy mornings in mid-October and 25% of active mounds in mid-November and about 15% in mid-summer. They suggested that repeated scans would have substantially increased detection rates. They concluded that the methodology was feasible, cost-effective and capable of covering vast areas, although further development was required for broad-scale application. Since then the technology has improved, and may have the potential to record active mounds over a significant area (e.g. mine site, control and adjacent areas). Thompson and Thompson (2008) used more recent technology and explained how thermal imaging could be used to record active mounds. This more recent technology consisted of a tri-camera system of an ultraviolet sensitive camera, infrared long wave radiometric camera and a hi-res digital video camera working in unison. This system worked well when mounds were open and there was a significant heat differential between the centre of the mound and the adjacent area. Thermal imaging is only successful in identifying active mounds when they are open, and is not useful for inactive, and in particular, disused and old mounds.

Aerial photography

In this case study very high definition aerial photography was used to search an area around Mount Gibson Iron's Extension Hill mine in the mid-west of Western Australia (Figure 2). This area is central to the presence of Malleefowl in Western Australia (Figure 1) and had been searched on multiple occasions and the location of many of the Malleefowl mounds is known (ATA Environmental 2005). This example therefore provides an opportunity to compare the results from aerial photography with previous ground transect searches.

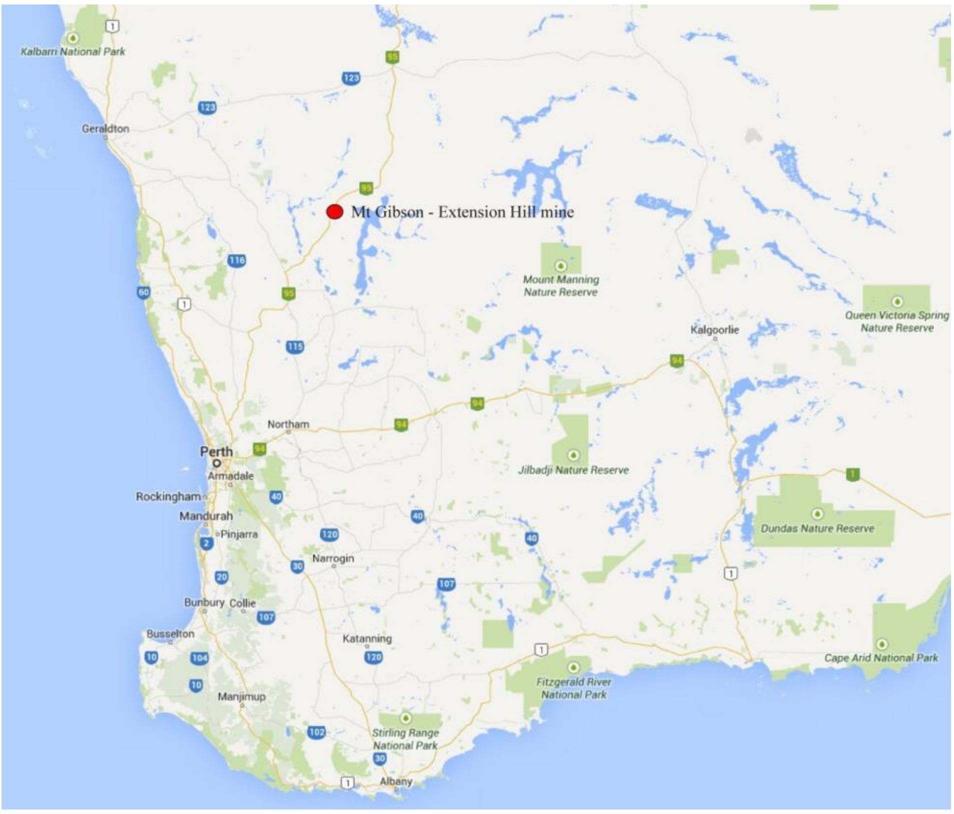


Figure 2. Location of the Extension Hill mine site and project area.

Methods

During 8-16 March 2004 a vertebrate fauna survey was undertaken around the proposed Extension Hill mine and areas were incidentally searched for Malleefowl and their mounds (ATA Environmental 2005). Then during 20-24 September 2004 and 13-21 January 2005 eight people walked parallel lines through an area of vegetation (Figure 3) searching for Malleefowl and Malleefowl mounds. The distance between each observer varied depending on vegetation density but ranged between 5 and 50m. Malleefowl mounds in open areas were easily located, however; those in dense vegetation were often cryptic and difficult to see, particularly those that were weathered over a period of many years. The status (i.e. active or inactive) and a GPS location were recorded for each Malleefowl mound.

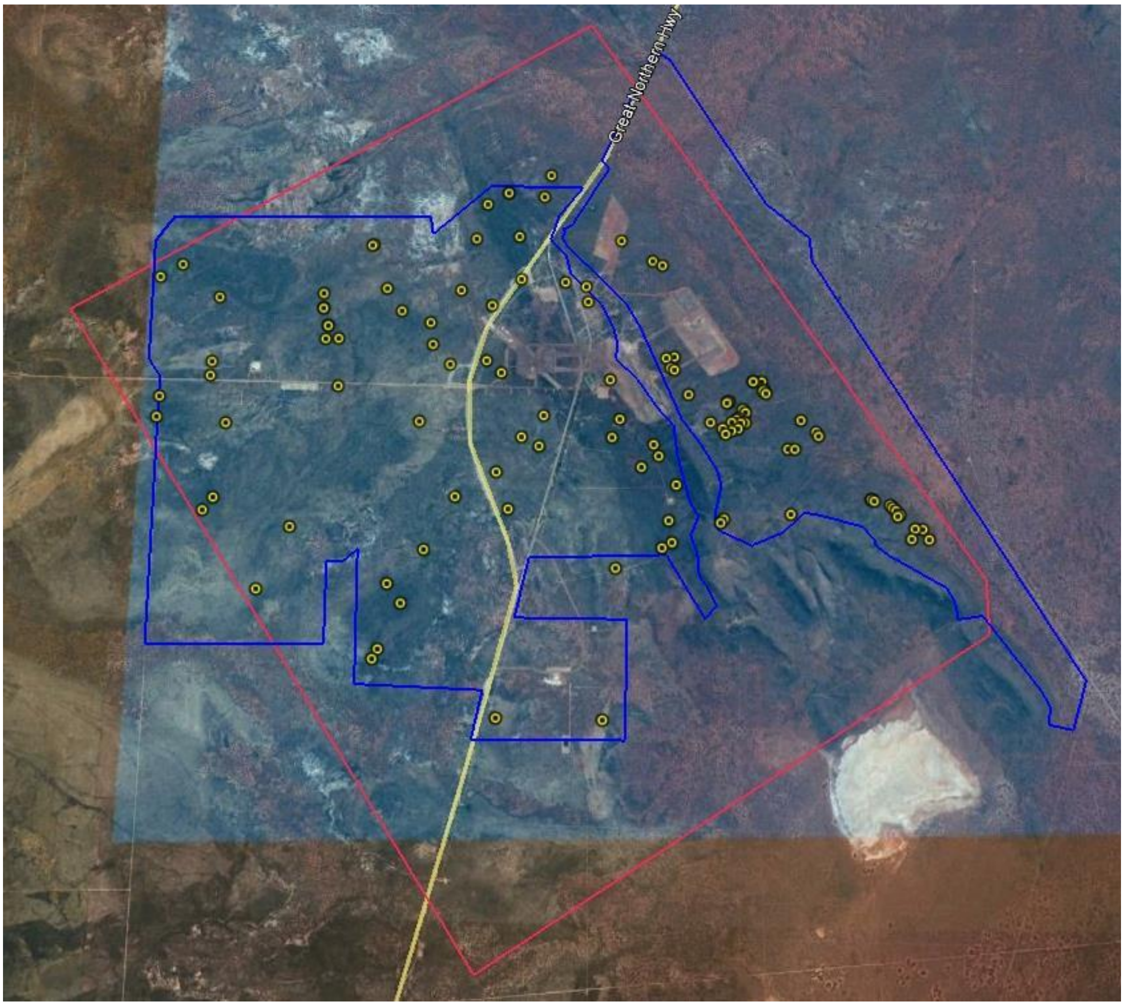


Figure 3. On ground and aerial photography search areas.
NOTE: Blue lines enclose on the ground search areas during 2004-05, red lines enclose the 2013 aerial search area and yellow dots are mounds known from on-ground searches.

In October 2013 Aerometrex flew an area of approximately 7x10km (7,014ha; Figure 3) using a Microsoft Ultracam D large format camera mounted in a Shrike Aero Commander 500 to capture the area. Aerometrex used a forward overlap of 70% and a side overlap of 60% to provide stereo imagery suitable for searching in 3D on the computer. Cross strips were added to the flight paths to aid in determining vertical accuracy (Figure 4). The resolution of the imagery was 4cm GSD (ground sample distance = pixel size).

Figure 4. Flight path with 70% front to back overlap and 60% sidelap.

Aerial photography was then post-processed and aerotriangulated with photogrammetric block adjustment to provide images able to be searched on a computer and then loaded and examined in DTMaster (INPHO). Stereo images were examined using NVIDIA 3D Vision Glasses. Drs Graham and Scott Thompson of Terrestrial Ecosystems spent two days in the Aerometrex laboratory examining the aerial photography and developing a search procedure for detecting Malleefowl mounds. The location of mounds known from previous on-the-ground searches were examined so that a 'search image' of a mound could be developed by the viewer, then areas were searched that contained mounds to determine whether they could be found. This procedure was repeated on multiple occasions using both black and white and colour aerial photography, and various distances above the ground (i.e. scaling).

Coloured images were superior to black and white images. Lines running north-south that were 40m apart on the ground were overlain on the aerial photography, the height above the ground was then adjusted so that these lines were the width of a 23" screen providing a scaling of 1:80. The aerial images were then systematically moved vertically down the screen to search each 40m wide strip until the entire 7,014ha had been searched (Figure 5). These parallel lines ensured the aerial photography was moved vertically and all areas were searched.

All potential identified mounds were rated as: 'confident it was a mound' and 'potentially a mound'.

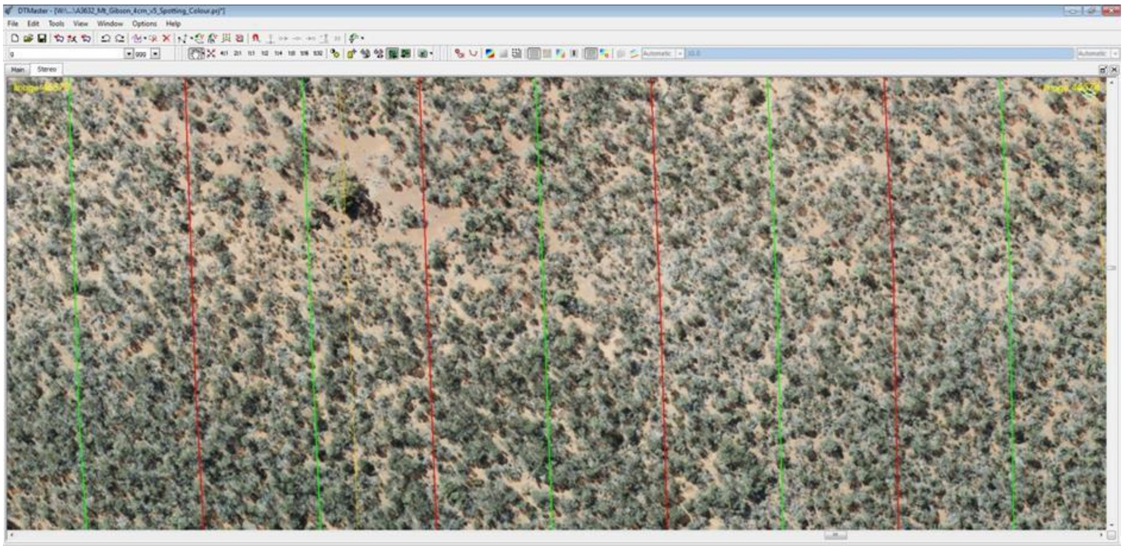


Figure 5. Screen grab of the parallel lines developed for the computer search.

Results

Habitat

Areas searched for Malleefowl mounds included woodlands, mallee and sand plain vegetation communities. Bennett Environmental Consulting (2000) identified five woodland communities, four mallee communities, 12 thicket communities and two heath communities within the Mt Gibson mining leases. Typically, the area below the banded ironstone formation (BIF) was *Acacia* thickets with emergent *Eucalyptus* spp. and *Callitris glaucophylla*. The most common *Eucalyptus* sp. was *E. loxophleba* (York Gum) and *E. brachycorys* which grew on the flat and along the gullies of the hillsides. *Callitris glaucophylla* was the dominant tree on the sandy soil but was often associated with *Ecdeicolea monostachya*. Vegetation on the top of the BIFs varied considerably and the dominant species on the hill slopes were *Allocasuarina acutivalvis*, *Melaleuca nematophylla* and *Grevillea obliquistigma*.

Coverage of on-ground and aerial searches

Sections of the areas searched in 2004-05 were outside the area covered by the aerial photography and parts of the area covered by the aerial photograph were not searched on the ground in 2004-05 (Figure 3). However, all of the Malleefowl mounds located during on-ground searches in 2004-05 were within the aerial search area. Some of the Malleefowl mounds identified in 2004-05 have been subsequently cleared for mining infrastructure and the mining pit.

Mounds located by aerial survey

All 24 mounds known to have been recently active (i.e. they were found or checked in March/September 2005, November 2008, January 2010, November 2010 and December 2012) were found in the search of the aerial photography. In addition, five more active mounds that were not recorded in ATA Environmental (2005) and subsequent surveys were recorded. Of the 108 mounds known from previous on ground searches, 94 (87 %) were recorded during searches of the aerial photography. The 14 mounds not identified by aerial photography were old and weathered, and many were barely above ground level and some had vegetation growing in the crater. The average height of mounds not found was 7.64 cm (se ±1.460; range 1-20 cm). The average height all mounds measured was 26.27 cm (se ±1.952; range 1-110cm).

Mount Gibson Mining has completed ground truthing the mounds by searching the GPS positions provided on the ground and photographing the located mounds. Of the 207 mounds recorded as 'confident mounds' during the search of the aerial photography, 94 were previously known and 100 were previously unrecorded mounds; thus 93.7% of the areas recorded as 'confident mounds' were actual mounds and there were 6.3% false positives. Most false positives were small cleared areas that had a substrate of pebbles or rock in an area that was surrounded by vegetation, or were piles of sand/organic matter created by machinery. Of the 123 areas recorded as 'potential mounds', 80 (65%) were actual mounds and 35% were false positives.

Mt Gibson Extension Hill Project	**2004–12 Ground Searches**	**2013 Aerial Search**
Area searched	4941 ha	7014 ha
Previous Active mounds found	24	24+5 = 29
Number of previously known mounds	108	94 (87%)
Previously unrecorded mounds		65
Average height of mounds measured		26.27 cm
Average height of mounds not found		7.64 cm
Aerial photography search ratings*		
Total number of 'confident' mounds identified		207
Number of 'confident' mounds confirmed by ground truthing and comparison with existing data		194 (93.7%)
Total number of 'potential' mounds identified		123
Number of 'potential' mounds confirmed by ground truthing and comparison with existing data		80 (65%)
Costs		
Cost – paying all the costs	$21.36/ha	$9.55/ha
Cost – using aerial photography flown for another purpose		$6.70/ha

**All areas identified as possible Malleefowl mounds were rated as either 'confident' (i.e. it was a mound) or 'potential' (i.e. it was possibly a mound).*

Aerial photography search protocol

The two days spent developing an effective protocol for searching the aerial photography resulted in a methodology that was demonstrated to be effective. We took a very conservative approach and tended to record false positives instead of failing to record a mound. The task of searching aerial photography can be tedious for most people, with the consequence that many people will lose concentration and then miss recording Malleefowl mounds. It is our experience that this process requires a particular type of person to maintain the required level of concentration for an extended period in order that all mounds are located.

Innovation

This is the first occasion where high definition aerial photography has been used to search for Malleefowl mounds. Data provided above indicate that this method is able to record all recently active mounds and a majority of the inactive mounds. This new and innovative methodology is able to achieve the objectives for an EIA, specifically it can determine presence/absence, and if present, indicate relative abundance and the location of all recently active mounds.

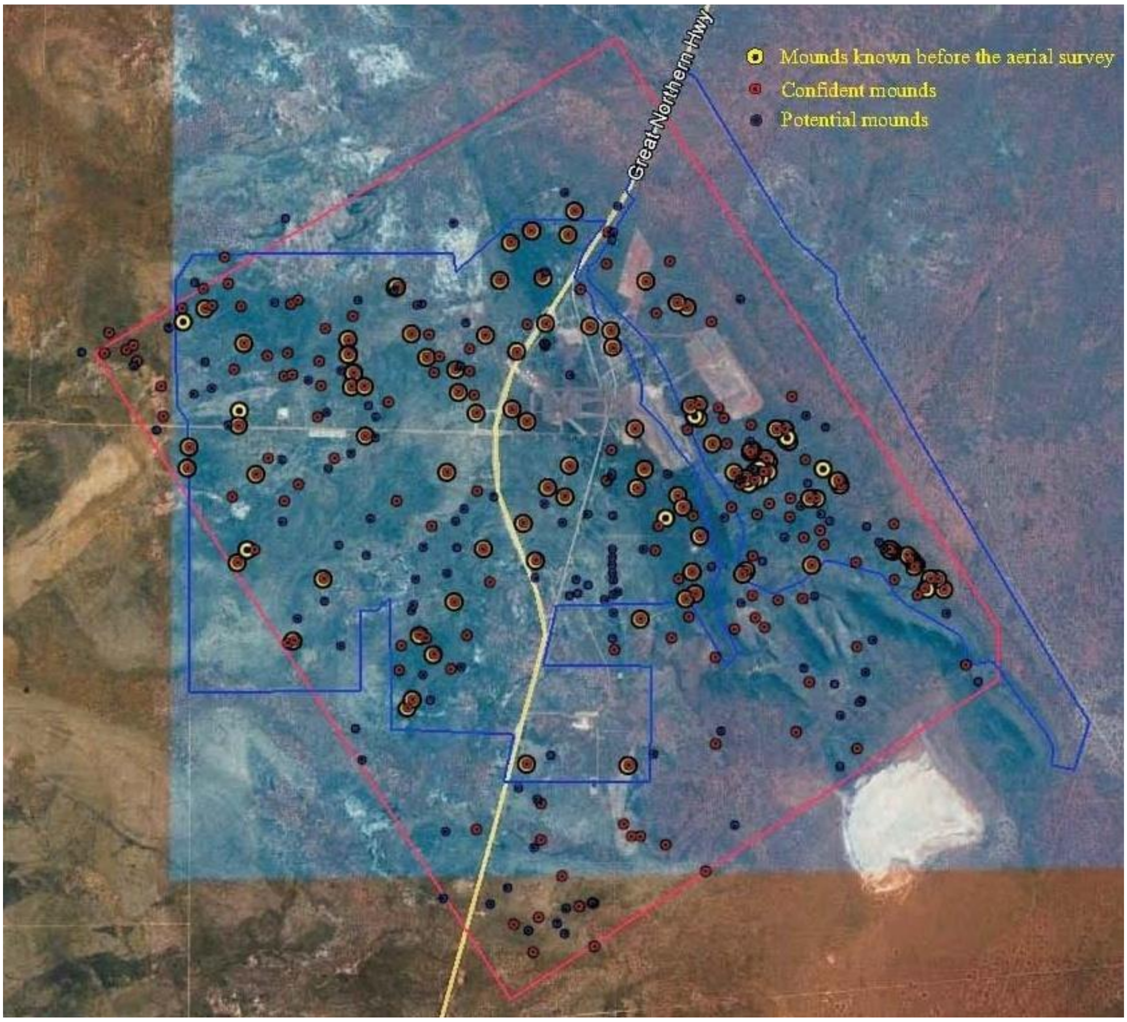


Figure 6. Malleefowl mounds recorded during on-ground and searches of aerial photography. Areas bounded by blue lines were searched on-ground in 2004-2005 and the area bounded by red lines was searched using aerial photography in 2013. Yellow circles with a black centre are known mounds from the on- ground searches (see Figure 3), red dots with a black centre are areas recorded as 'confident mounds' and dark blue dots are areas recorded as 'potential mounds' during a search of the aerial photography).

Costs

Cost savings are a significant benefit of the application of the technology. In the 2004-05 search approximately 100 person days were spent conducting ground searches for Malleefowl mounds in an area of interest of 4,941 hectares (ha) at a cost of approximately $105,000 or $21.36 per ha (calculated using 2014 figures) with the mine providing all food and accommodation. In comparison, the 2013-14 search, took 90 hours to search 7,014 ha of aerial photography. The total cost for the capture and the searching of the aerial photography was approximately $47,000 plus $20,000 if environmental consultants were engaged to ground-truth the identified mounds giving a total of $67,000 or $9.55 per ha.

There is an additional significant saving if the environment survey can be combined with aerial photography flown for another purpose such as end of quarter volumes with only one plane mobilisation and shared triangulation costs. Reporting costs have been excluded.

To put these costs into perspective cheaper and better methods of searching for Malleefowl mounds have been explored by Brickhill (1985), Benshemesh and Emison (1996) and Thompson and Thompson (2008). Brickhill (1985) undertook an aerial survey using an Aerospatiale Gazelle 341G helicopter flown at about 76m above ground at about 90kmh-1 over 20,800 ha of the Round Hill Nature Reserve in New South Wales and the adjoining land. Search transects were about 400m apart followed by a similar pattern at right angles. The search area was relatively flat country with mallee growing to 5-6m high. Most of the surveyed area had been burnt in 1957 and the aerial surveys were undertaken between August 1977 and January 1984. Four of the nine surveys were flown in August, the time when active mounds are piled high with litter in preparation for breeding and where therefore likely to be more visible. Brickhill (1985) concluded that even with a relatively slow flying speed, the ground survey showed that many transects were necessary before half of the mounds were found.

Benshemesh and Emison (1996) examined the feasibility of using thermal scanning during aerial surveys with subsequent ground-truthing to detect active Malleefowl mounds. Four areas were flown in Victoria with sites between 300 and 500 ha in size. These four areas contained 39 active mounds during the trial. Survey sites were characterised by a relatively thick canopy of mallee and variable understorey of shrubs. A Daedalus 1240/60 thermal scanner mounted in a Queenair plane was flown at about 250kmh^{-1} at an altitude of 305m above ground level. The thermal scanning technique recorded between 14 and 60% of active mounds. Thompson and Thompson (2008) examined the possible use of a tri-camera system (i.e. ultraviolet sensitive camera, infrared long wave radiometric camera and a hi-resolution digital video camera working in unison) to detect active mounds, but this approach was also limited to mounds that were open during the survey. The use of thermal imaging is limited to active mounds and when mounds are open (i.e. when the centre of the mound had a higher thermal footprint than the surrounds) when surveyed.

Malleefowl frequently use already constructed mounds instead of building a new mound each year (Priddel and Wheeler 2003). In the mid-west breeding activity is influenced by winter rainfall (Firth 1959) and in the occasional years when winter rainfall is very low, breeding activity can be non-existent or very low. Insufficient rain results in the organic matter in the centre of the mound not decomposing at a rate sufficient to generate enough heat to incubate the eggs (Firth 1956). The use of thermal imagery is therefore limited to identifying active mounds during the breeding season and is predicated on appropriate decomposition rates, heat generated in the mound and therefore the frequency it is opened. Thermal imagery is therefore not a suitable methodology for searching for Malleefowl mounds for the purposes of an EIA.

Safety and Convenience

Historically, habitat potentially supporting Malleefowl is grid searched by environmental consultants in areas for future development. In relatively open areas, searchers can be up to 50m apart, but in areas of dense vegetation the distance between searchers can be reduced to 5m. It is the experience of Terrestrial Ecosystems, the environmental consultant on the Mount Gibson project that Malleefowl in the mid-west and the goldfields of Western Australia are more likely to be found in areas of dense vegetation. Grid searching dense vegetation is difficult, time consuming and expensive. Because of the denseness of the vegetation, searchers are continually protecting their faces and eyes from branches, twigs and leaves as they push their way through the vegetation. Often the head is lowered to force your way through particular thickets and mounds can be missed in these searches. Unused mounds progressively weather over many years, with very old mounds often having a bare circular shape perhaps with a shallow depression in the centre. Old weathered mounds can also support vegetation growth with the consequence that they are easily missed in searches.

The task of searching aerial photography can be extremely tedious for many people, with the consequence that they will lose concentration and then miss recording Malleefowl mounds. The Aerometrex innovation largely minimises the risk of human error/lack of concentration experienced in photo-interpretation by allowing for the data to be methodically searched by any number of people over any period of time. However there is still an advantage in using skilled and experienced photo-interpreters who are accustomed to maintaining the required level of concentration for an extended period in order that all mounds are located.

Conclusion

This innovation in searching very high-definition aerial photography is able to record all recently active mounds. About 13% of all mounds were not detected, but most of these were old and weathered and unlikely to provide useful information in the context of an EIA, other than the area once supported Malleefowl. A minor drawback of this approach is the number of false positives recorded.

Approximately 6% of areas that were rated as a confident mound were not mounds, and about 65% of the areas rated as 'potential mounds' were actually a mound. In almost all cases a false positive was a cleared area 3 - 5m wide in a vegetated area that often contained gravel or rock substrate, a substrate of a different colour to the surrounds or another human disturbance.

It is therefore important that all possible mounds are recorded in the search of the aerial photography, and each potential mound identified is subsequently ground-truthed. Ground truthing is necessary to determine whether each area recorded is an actual mound, whether the mound has been recently used and to collect other data in accordance with the National Malleefowl monitoring protocol.

Based on this first example, searching high-definition aerial photography for Malleefowl is an effective method of recording recently used Malleefowl mounds in relatively densely vegetated areas on sand plain and thickets in undulating areas.

The cost of aerial searches and the subsequent ground-truthing of each of the mounds located is cheaper than grid searching the entire area. If there is another purpose for preparing the aerial photography and this can be used to off-set the cost, then the cost of aerial searches for Malleefowl mounds is appreciably cheaper than on-the-ground grid searching. Because of the cost of aircraft mobilization and post-data analysis, there are economies of scale that can further reduce the costs.

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24. Comparison of three survey techniques for locating Malleefowl mounds

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Abstract

Accurate and cost effective location of nesting mounds underpins most monitoring and management activities for the nationally threatened Malleefowl. Mounds are often concealed in dense vegetation that is difficult to walk through and survey methodically. We compared mound detection rates in three 1 sq. km grids of mallee woodland on north-eastern Eyre Peninsula in South Australia.

Grids were surveyed using three different techniques: 1) two spotters in a helicopter, 2) by a team of people walking a grid on the ground, and 3) by canopy piercing Airborne LiDAR (Light Detection and Ranging) laser scanning from an aircraft. The relative cost-effectiveness of each survey technique was compared, along with the percentage of false positive and false negative records of purported Malleefowl mounds. Commentary is provided on the most appropriate and cost-effective search techniques for different purposes and suggestions for how to improve the precision and cost-effectiveness of LiDAR surveys for Malleefowl mounds.

Introduction

Malleefowl (*Leipoa ocellata*) are nationally threatened birds that inhabit much of the semiarid and southern arid regions of Australia. Due to their listing under the national *Environment Protection and Biodiversity Conservation Act* 1999, Malleefowl typically feature in biological survey, monitoring and environmental offset programs for industrial development throughout their potential range. Malleefowl construct large mounds, typically four to six metres in diameter and up to 90cm high in which they incubate their eggs. Due to their cryptic nature but dependence upon these fixed mounds for nesting, Malleefowl populations are most efficiently monitored by regular assessment of the activity of mounds. Disused mounds can persist in the environment for many decades, with historic mounds distinguished from more recently used mounds by increasing crusting of lichen or moss with age of the mounds. Inspection of mounds in a specified area over time can therefore facilitate appraisals of whether nesting densities have increased (low percentage of historic mounds) or decreased (high percentage of historic mounds) in recent decades.

Strategic and representative monitoring of mound activity is dependent upon comprehensive understanding of the distribution of mounds. Malleefowl mounds are commonly surveyed using ground-based foot searches over grids, often two to four square km in area (ref National Malleefowl Monitoring guidelines). Lines of walkers, spaced sufficiently to sight mounds between adjacent observers, are used to traverse the grids. In recent times alternative methods of searching for mounds have developed, including tracking Malleefowl tracks to their mounds, aerial surveys via helicopter, and remote sensing tools using infrared, high definition photography and Light Detection and Ranging (LiDAR).

Over 150 Malleefowl mounds had been located through opportunistic foot-based surveys from 2008-2013 within a 50,000 hectare area of the Middleback Alliance region of north-eastern Eyre Peninsula, South Australia. However, this count is likely to represent only a fraction of the mounds in the study area, as less than 20% of the region has been traversed. Determining the most accurate and cost effective technique for locating Malleefowl mounds in dense mallee vegetation will enhance the ability to monitor, and perhaps manage, populations of this nationally threatened species.

This study compared the relative efficacy of walking grids, helicopter based visual surveys and LiDAR transects at detecting Malleefowl mounds in the mallee of the Middleback Alliance region.

Methods

Study Site

Middleback Alliance region encompasses three conservation parks (Lake Gilles, Sheoak Hill and Ironstone Hill), one private nature reserve (Secret Rocks) and numerous Heritage Agreements and pastoral leases. The habitats vary from open mallee woodland to chenopod shrubland with granite rock outcrops and *Triodia* sand dunes. The majority of the Malleefowl mounds are found within sandy mallee sections of the region covering approximately 100,000 hectares Five grids, each measuring approximately 1km x 1km were selected in areas considered to be favourable for Malleefowl for detailed survey.

Helicopter surveys

Helicopter-based aerial surveys were conducted from a helicopter flying at approximately 150 metres above ground level over five x 1 km^2 search grids in April 2013. Three grids were established on Secret Rocks Nature Reserve and two on Ironstone Hill Conservation Park. Each grid was surveyed by six to eight passes, approximately 100 metres apart. When a suspected mound was spotted, the helicopter would circle or hover above the mound to confirm the observation and record an accurate location on a handheld GPS. The helicopter travelled at a speed that the spotter was comfortable with and would enable a thorough survey, with the pilot asked to slow down if necessary. Surveys were conducted in the Shirrocoe east, Shirrocoe west and Sandy grids between 14:30 and 15:15 on April 30, 2013 and on the Powerline and Bluey grids 11:00-11:40 on May 2, 2013.

Ground surveys

Strategic ground-based walking surveys were conducted in November 2013 throughout the same five x 1 km^2 grids that had been surveyed by the helicopter. Four to five walkers traversed the grid at a spacing of approximately 20m where they were comfortable they could sight their neighbouring walkers' feet. The outside walkers on each transect marked their trail on a handheld GPS to set the course for subsequent transects and ensure adequate coverage. When any walker observed a mound the line stopped whilst the mound location was recorded before the line resumed the search. This method closely followed that outlined in the National Malleefowl Monitoring guidelines.

LiDAR surveys

LiDAR technology was utilised during a survey of Malleefowl mounds within two 500m wide transects through the Middleback Alliance area as part of an environmental assessment for a proposed high voltage powerline. One of these LiDAR transects traversed two of the Malleefowl mound grids surveyed by helicopter and ground searches.

A Bell 206B-3 JetRanger (C20J Turbine) aircraft flown at 325m above ground level and 60 knots, equipped with an Optech Orion LiDAR Sensor, using nominal point density of 20+ points / m^2, was flown over the transects between 30 November and 2 December 2013. A relative system accuracy of 2 cm on both horizontal and vertical scales was achieved. A DiMAC 51 mm image sensor captured imagery at a resolution of 4 cm. Orthophotography was provided at a resolution of 10cm pixel size with a horizontal accuracy of 10cm. Data analysis and modelling was conducted from 16 December 2013 to 26 February 2014.

By exaggerating the vertical scale of the surface created by the LiDAR ground points most mounds were clearly visible (Figure 1) and a 3D point was manually placed by operators in the centre of objects of similar size and shape to Malleefowl mounds. A total of 253 objects were identified but cross-checking with orthorectified photos suggested that a percentage of these objects were not Malleefowl mounds. To eliminate most of these false positives an algorithm was created to eliminate all objects with an arbitrary height lower than 25cm above the surrounding plain, which eliminated 80 of the identified objects. The remaining 173 objects (from both transects) were reviewed using the LiDAR ground points and the orthorectified imagery to differentiate between objects with a concave apex and those with a domed apex. This process differentiated 81 'confirmed' mounds (Figure 1) with a concave shape and 92 'possible' mounds which were flat or domed.

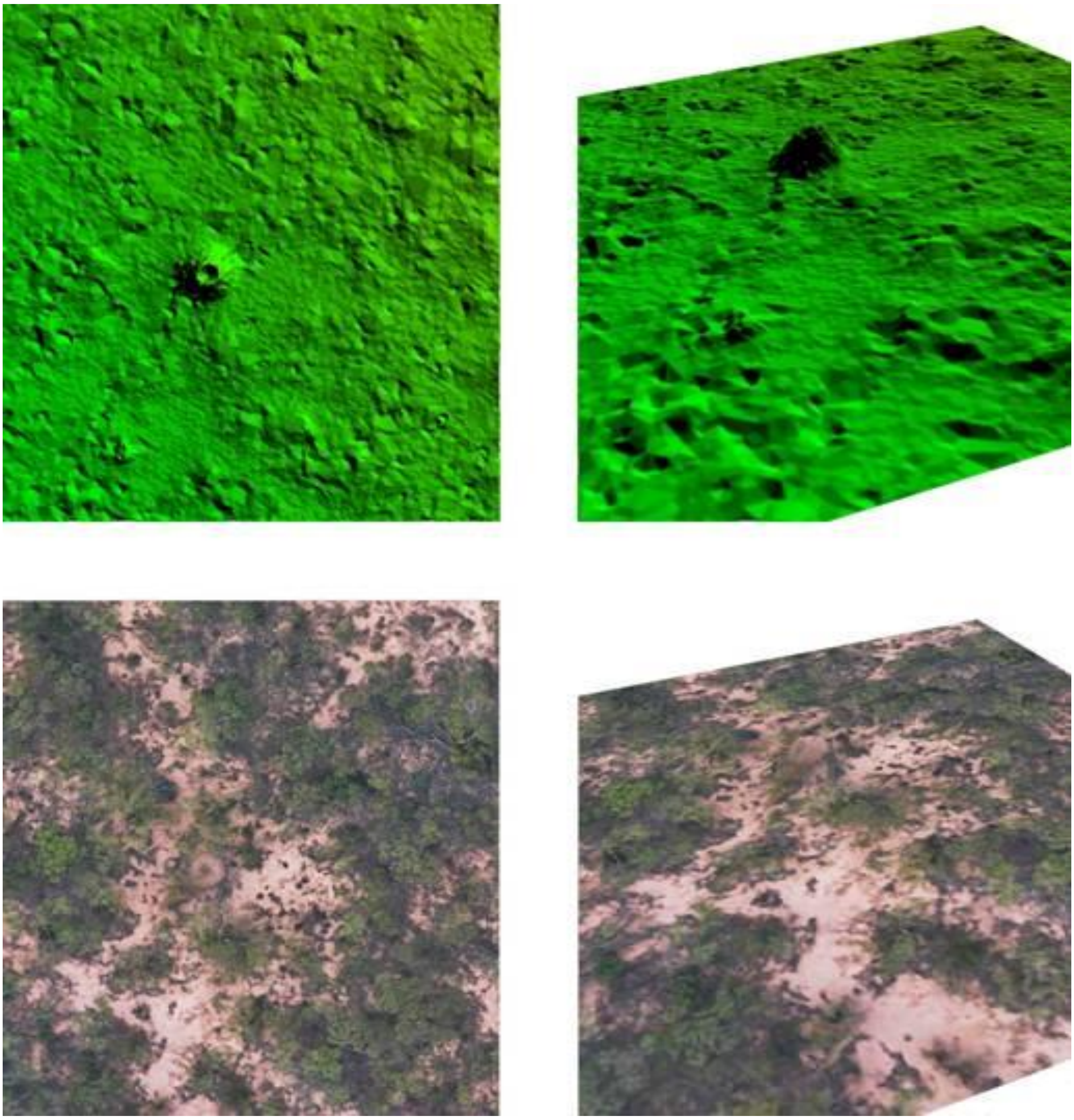

Figure 1. Examples of LiDAR (top row) and aerial photography (bottom row) (used to ‘confirm’ mounds) for Malleefowl mound MA78.

Validation and comparison of techniques

The accuracy of the LiDAR detections was assessed by ground truthing 137 of the 173 identified mounds, comprising 67 (83%) of the 81 'confirmed' and 70 (76%) of the 92 'possible' mounds. Ground truthing was conducted by John Read of Ecological Horizons in March and April 2014. The dimensions and characteristics of all visited mounds were scored using standard National Malleefowl Mound Monitoring guidelines. 'Historic' mounds were distinguished from more recently active mounds by moss or lichen (Figure 2). Incidentally, several earthen mounds, presumably created during the powerline construction, exhibited similar degrees of crusting as these historic mounds. Additionally, by overlapping the flight path of the helicopter, the walking path of the ground surveys and the LiDAR corridor for two of the five survey grids, the location of mounds recorded by each technique could be compared to assess each technique's relative efficacy.

Figure 2. Old Malleefowl eggshell, moss and lichen on a historic Malleefowl mound (C056).

Costings

For the purposes of comparing the costs of the different techniques the following rates were used to determine costs per square kilometre:

- Field work time for ground surveys 20hr @ $50/hr = $1,000 per km^2
- Helicopter time 10 mins @ $950/hr = $158 per km^2
- LiDAR costs (see table 2) = $ 311 km^2

No mobilisation costs were incorporated into any of the estimates and these will obviously vary considerably depending on access to aircraft and field personnel. The LiDAR estimate is only for 'confirmed' mounds and does not include ground truthing. Likewise the helicopter survey did not include ground truthing, as all mounds identified by helicopter were also independently located by the ground-based survey.

Results

Grid searches

A total of 35 mounds were detected from the five grids surveyed by helicopter, LiDAR and ground-based searches. Plotting of the exact routes of the helicopter and walkers revealed slight disparities in the area of each grid covered, which explains the different total mound counts on two of the five grids (Table 1). The LiDAR transect only intersected part of the Shirrocoe E and Bluey grids. The total mounds detected on grids using all three techniques were assumed to represent the total mounds present on each grid. Ground-based searches detected all but two (94%) of the total mounds known to be present. The two mounds not located by the ground searches were in the very densely vegetated Bluey grid (Table 1). These additional mounds were detected (and subsequently confirmed on the ground) by LiDAR on one of the two grids traversed by LiDAR and hence it is possible that other mounds were also missed by the ground-based surveys. Eleven mounds were detected by the helicopter survey, with nine of the 14 mounds present detected from the three grids surveyed in the afternoon and two of the 15 mounds detected from the grids surveyed in the late morning, with a mean detection frequency of 37% of the mounds located by this technique (Table 1). The LiDAR survey located six of the ten mounds on grids that it traversed but two of the 'missed' mounds were calculated to be within ten metres of the far edge of the LiDAR transect and may have been inadvertently not included in the transect (Table 1).

Because the helicopter hovered low over any mounds before they were recorded, all mounds recorded from this technique were subsequently confirmed to be mounds.

Table 1. Ratio of mounds recorded by the three techniques and relative cost per mound recorded of helicopter and foot based surveys.

Grid ID	**Helicopter**		**Foot**		**LiDAR**
	Ratio found	**$ per mound**	**Ratio found**	**$ per mound**	**Ratio found**
Shirrocoe W	3/5	$53	5/5	$200	na
Shirrocoe E	4/4	$40	7/7	$142	3/5 *
Sandy	2/6	$79	6/6	$167	na
Bluey	1/9	$158	9/11	$111	3/5
Powerline	1/6	$158	6/6	$167	na
Total	**11/30**	**$72**	**33/35**	**$151**	**6/10**

* Two undetected mounds were within 10m of edge of LiDAR strip

Table 2. Cost breakdown for this LiDAR survey and cost savings with potential modifications.

	Unit cost	**Total cost**	**Cost km^2**	**Cost per mound**
Helicopter	2h @ $2400	$4800		
LiDAR equip & operation	2h @ $850	$1700		
Processing & quality check	50h @ $150	$7500		
Total this survey		**$14000**	**$311**	**$181 ('confirmed')**
Fixed wing	1h @ $1200	$1200		
LiDAR equip & operation	1h @ $850	$850		
Processing	22.5hr @ $150	$3375		
Total simplified survey		**$5425**	**$120**	**$70 ('unconfirmed)**

NOTE: These estimates do not include mobilization and standby fees and should be seen as ballpark figures. There are economies of scale that will have an influence on cost; usually the bigger the area the lower the per sq. km rate.

LiDAR transects

Seventy confirmed mounds were detected by the LiDAR survey, bringing the known count of Malleefowl mounds in the Middleback Alliance area to 245.

In total, 95% (64 of 67) of the 'confirmed' objects identified by LiDAR were found to be Malleefowl mounds by ground truthing. The other three false positive objects were circular earthen mounds created by earthmoving equipment. By contrast, only 8.5% (six of 70) of the 'possible' objects were confirmed to be Malleefowl mounds. Several of these false positives were the elevated lignotubers of mallee trees (Figure 3) although most were piles of soil left by the creation of firebreaks or the construction of a powerline and access track. Of the 66 mounds identified by the LiDAR search and confirmed by ground truthing, the average depth of the central cone was 34.8cm (range 5 - 90cm), the average height of the mound rim above the ground surface was 24.4cm (range 2 - 47mm) and the average differential height between the rim and the bottom of the cone was 59.2cm (range 10 - 125cm) (Figure 4).

Sections of the LiDAR transects included areas of cleared land or unsuitable chenopod shrubland habitat, leaving 65.8km considered to traverse potentially suitable Malleefowl habitat. Together these data suggest a density of 2.6 mounds per square kilometre throughout the region, which is considerably less than the average of seven mounds per square kilometre detected from the five grids selected in prime Malleefowl habitat (Table 1).

The only two mounds identified by LiDAR that were likely to have been active in the previous summer were considered to be 'possible' rather than 'confirmed' mounds. Active mounds may alter from having a concave shape to a domed shape over the course of a day (Fig. 3), and it is likely that these mounds were indeed mounded and active when the LiDAR was flown. Improvements in the algorithm used to distinguish mounds from LiDAR data to include these convex mounds, would likely improve the percentage of active mounds correctly assigned as 'confirmed' and possibly decrease the number of mounds not detected (false negatives) by the LiDAR. Furthermore, incorporation of the differential height (from rim crest to the central low point of the mound) into the LiDAR algorithm may further increase detectability and also allow mounds of different profile to be distinguished.

Figure 3. P89 is an example of a potential mound that was in fact the elevated lignotubers around a mallee stump.

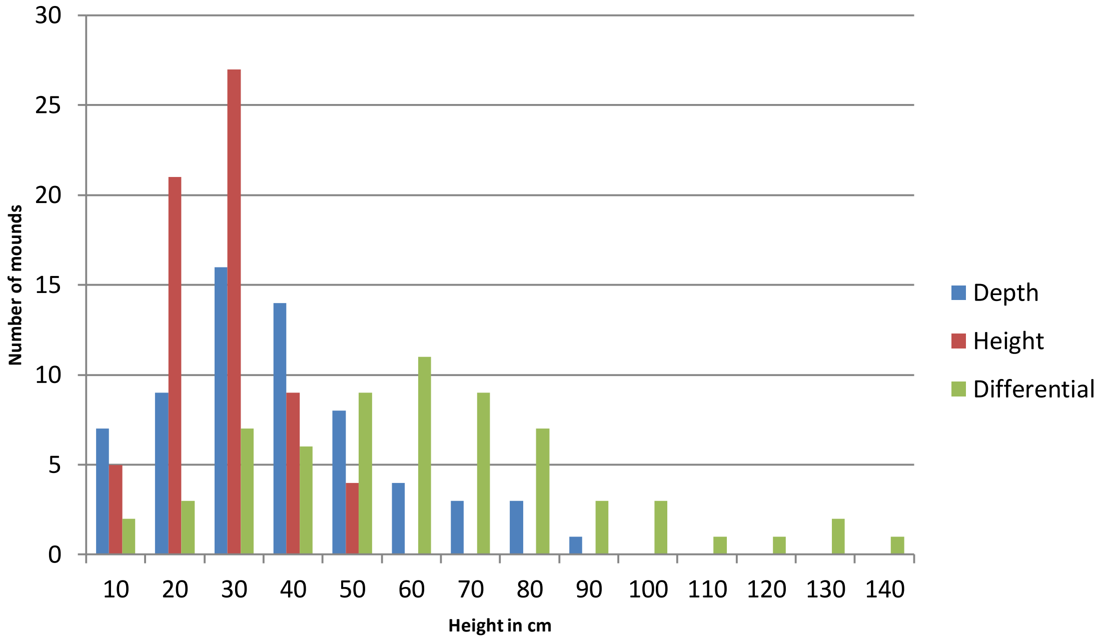

Figure 4. Depth and height dimensions of the 65 mounds detected by LiDAR in the Middleback region and the differential height between the rim of the mound and the bottom of the central cone.

<u>LiDAR false negatives</u>

Four mounds confirmed by ground searches along the LiDAR transects were not identified by the LiDAR survey. One of these, MA108, was identified by the LiDAR operators but discarded because, like the other three false negatives, its height above ground level was lower than the arbitrary 25cm cut-off. Two of these undetected mounds had previously been located in the 1 km^2 grids methodically surveyed by helicopter and on the ground.

Low percentages of active nests (two from 70, 2.9%) along LiDAR transects and the surveyed grids recorded in this survey was consistent with low nesting success recorded by the Middleback Alliance monitoring program in 2013, when only 2 of 127 monitored mounds (1.6%) were recorded as active in the same region. This low nesting effort is believed to be related to environmental conditions and contrasts markedly with activity levels of 12.9%, 22.3% and 24.7% in the years 2011, 2012 and 2013 respectively.

<u>Costs</u>

The helicopter costs of $900 per hour did not include mobilisation costs of $6,300 because the Malleefowl search was conducted whilst the helicopter was based locally for feral goat control operations. Mobilisations costs would need to be factored into the costings if the Malleefowl mound surveys required separate mobilisation.

Each of the walking grids took an average of five people a full day to conduct by the time they were briefed and transported to and from their sites from the base camp. Fuel and food reimbursement for this weekend campout amounted to $2,400, or $480 per 1$km^2$ grid.

The LiDAR transect was flown as part of a broader contract including other deliverables for an electricity supply company, which meant that mobilization costs and the greater expense incurred by high density LiDAR were covered independently from the Malleefowl mound survey.

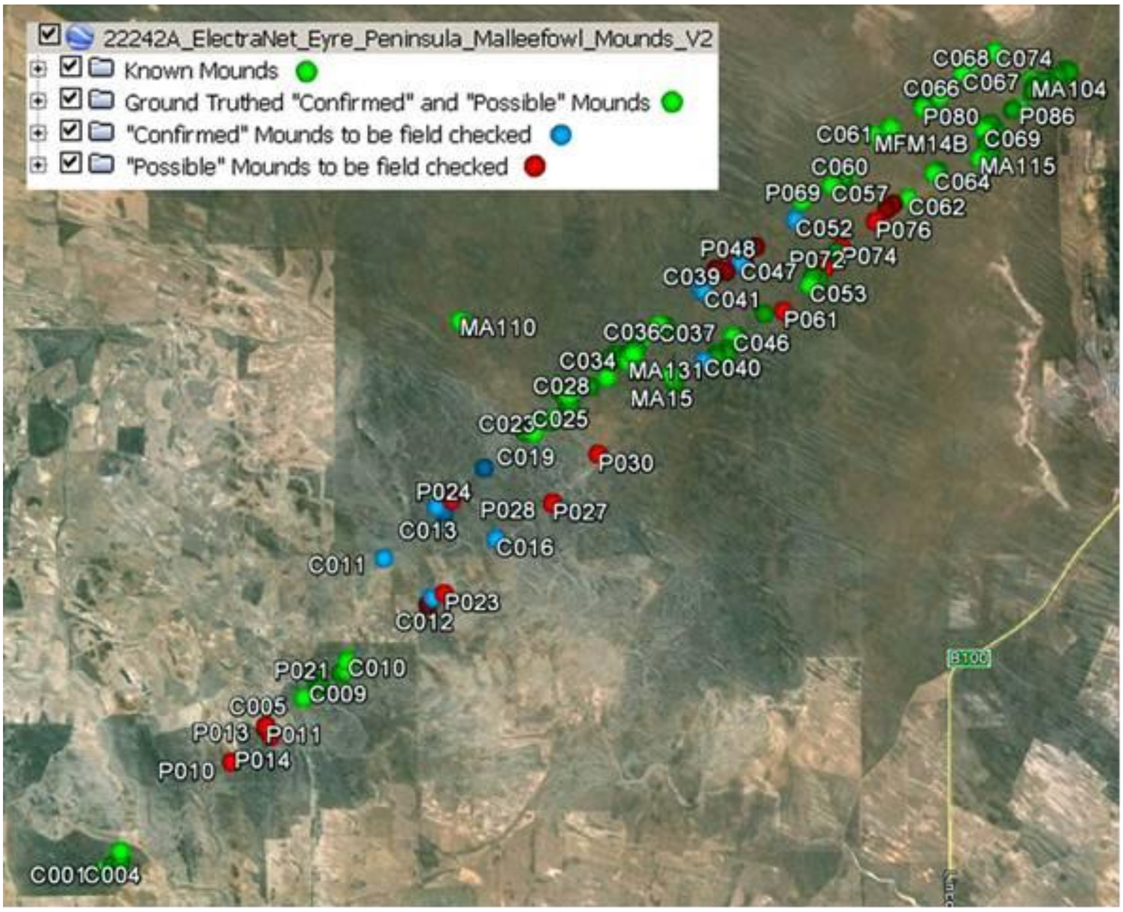

Figure 5. Green dots: confirmed (ground-truthed) Malleefowl mounds; blue dots: not ground-truthed but 95% likely based on confirmed percentage of ‘confirmed’ objects; red dots: not ground-truthed but 8.5% likely (based on confirmed percentage of ‘possible’ objects).

Discussion

This survey revealed average Malleefowl mound density of 2.6 mounds per km^2 throughout the intact mallee vegetation in the Middleback Alliance region of NE Eyre Peninsula. This density is approximately one third of the median mound density for Malleefowl sites in South Australia but relatively high for an arid region (J. Benshemesh pers. comm.). Less arid areas with high density mounds are typically restricted to smaller isolated remnants suggesting that the Middleback Alliance region, whilst supporting lower mound density, is supporting a significant Malleefowl population due to the large area of intact habitat.

The LiDAR survey was the most widespread and accurate Malleefowl mound survey technique used in this survey. On the basis of the false negative records verified by ground searches, those mounds identified by LiDAR are assumed to constitute 69-72% of the mounds within the transect. A high percentage of the mounds not identified by LiDAR were historic low mounds that did not protrude more than 25cm above the surrounding ground surface. These mounds are of relatively low importance to the management and monitoring of Malleefowl populations compared with the active or recently active mounds.

Confirmation of false positives identified by LiDAR was straightforward because identified objects could be ground-truthed. However determining the percentage of false negatives, or mounds that were not detected by LiDAR, was compromised by difficulty in determining the exact boundaries of the LiDAR transect. Uncertainty about the precise extent of the LiDAR survey area is best managed by including a slightly wider strip, or overlapping strips over the area of interest.

The Middleback Alliance study suggests that although conventional ground based surveys are the most accurate and informative technique for surveying Malleefowl mounds, LiDAR offers a valuable tool to search for Malleefowl mounds, particularly in dense scrub that is difficult to walk through. Given that the quality assurance provided by cross checking LiDAR identified objects with photographs cost in excess of $3,000 but was not able to reliably identify active mounds, savings could be generated by providing the unverified positions of objects identified by the LiDAR algorithm without this office-based quality assurance.

Helicopter-based surveys may be beneficial in rapid detection of Malleefowl mounds, especially where ground access is difficult. However our experience is that these aerial surveys located only about a third of the mounds, with many concealed by shadows or shielding vegetation. Therefore, whilst allowing rapid location of mounds for monitoring purposes, we would not advocate helicopter based surveys when the location of most mounds in an area is required.

Optimal Malleefowl mound survey techniques depend upon the required precision and relative costs of ground based surveys or ground truthing in the search area. LiDAR costs would be reduced by approximately 200% through use of a fixed wing aircraft, especially if mobilisation costs can be minimised, together with reduced precision (from 20 to 4 points per m^2) and reducing the quality assurance process through comparisons with aerial photographs rather than ground truthing all mounds.

Aerial techniques such as LiDAR and helicopter surveys obviously benefit from economies of scale whereby the per-hectare or per-mound costs reduce with increasing size of the search area.

In extensive areas that are difficult to access on the ground or if accurate locations of mounds are required urgently, we recommend use of detailed LiDAR assessment combined with office-based quality assurance using orthorectified aerial photography, that was used in this trial.

Where ground-based verification or detailed measurements are necessary we suggest that less precise LiDAR (e.g. 4 points per m^2) combined with automated ID and removal of objects less than 25cm high would be more economical. This less precise technique will generate more false positives and hence require greater field verification.

25. The Mallee Hawkeye Project: assessing most suitable habitat for threatened mallee birds using predictive fire history mapping

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Abstract

The Mallee Hawkeye Project is a collaborative research project between the Department of Environment and Primary Industries, La Trobe University and Deakin University, begun in 2011. It seeks to further understand factors affecting the response of species to fire, and to assess the impact of prescribed burning on biodiversity values. This presentation will provide an overview of the project's objectives and significant findings, with a special emphasis on our current research into the impact of prescribed burning on threatened mallee birds.

Fire has shaped the distribution of suitable habitat for many mallee bird species and inappropriate fire regimes may significantly threaten several endangered and iconic species such as the Malleefowl, Mallee Emu-wren, and Black-eared Miner. However, past research and management of threatened bird species in the Murray Mallee region has been constrained by scarce records and incomplete mapping of fire histories across political boundaries. There is urgent need to understand the effects of fire on this group of rare and declining species because current land management policy recommends historically unprecedented levels of fuel reduction burning. We collated a comprehensive dataset of species' occurrence for twelve key rare and threatened species in the region, including the Malleefowl, and used recent developments in fire history mapping to determine the extent to which their occurrences were driven by fire. We then assessed the regional distributions and identified areas of critical habitat for each species. These distribution models were then projected onto long-term future burning scenarios to evaluate how the extent of habitat was affected by proposed prescribed burning.

Part 1 – Distribution of threatened mallee birds with relation to post-fire age

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Introduction

Fire is a major component of disturbance regimes and shapes the distribution of suitable habitat for many species worldwide (e.g. Barro and Conard 1991, Woinarski and Recher 1997). Human-induced changes have altered historical fire regimes in a diversity of ecosystems including forests (e.g. Weber and Flannigan 1997, Gill 2012), shrublands (e.g. Conard and Weise 1998) and grasslands (e.g. van Wilgen, Govender *et al.* 2004). In Australia, inappropriate fire regimes, characterised by changes to the frequency, intensity, scale and seasonality of fire occurrence at a landscape level, have been identified as a major threat to the persistence of fifty-one terrestrial bird species (Woinarski and Recher 1997), and already responsible for the extinction of up to five (including three subspecies). In fire-prone regions, the effects of climate change are predicted to result in increased frequency and size of fires (Liu, Stanturf *et al.* 2010, Moritz, Parisien *et al.* 2012, Enright and Fontaine 2014) which will only exacerbate this risk. Ongoing fragmentation and loss of habitat have largely restricted many species to public reserve networks, further compounding the susceptibility of populations to both bushfire and planned burning management actions (Sandell, Tolhurst *et al.* 2006, Brown, Clarke *et al.* 2009).

Despite the need for urgent action, in many ecosystems knowledge of species' fire responses and even the nature of the historical fire regime itself are limited at best (e.g. Bradstock, Bedward *et al.* 2005, Driscoll, Lindenmayer *et al.* 2010). In the semi-arid mallee shrub environments of southeast Australia, there is a growing body of knowledge of both the landscape's fire history (Clarke, Avitabile *et al.* 2010, Avitabile, Callister *et al.* 2013, Callister, Griffioen *et al.* in prep.) and the association of birds with post-fire vegetation (e.g. Clarke 2005, Clarke, Boulton *et al*. 2005, Brown, Clarke *et al.* 2009). Novel landscape-scale studies have significantly advanced prior site-based understanding of those relationships (Taylor, Watson *et al.* 2012, Watson, Taylor *et al.* 2012). In spite of this, the capacity to investigate the effects of fire, at a landscape scale, on declining threatened and rare endemic bird species has been constrained by a scarcity of records and by the limited extent of reliable fire mapping to approximately forty years post-fire (Callister, Griffioen *et al.* in prep.). Yet it is many of these species, like the Malleefowl (*Leipoa ocellata*) and Black-eared Miner (*Manorina melanotis*), that are in fact considered most susceptible to altered fire regimes (Woinarski and Recher 1997) and that are believed to require long unburnt vegetation (Benshemesh 1990, Bradstock and Cohn 2002, Clarke 2005, Taylor, Watson *et al.* 2012). Thus, it is this suite of species that most urgently demand investigation.

The field of species distribution modelling has developed rapidly in recent years (Elith and Leathwick 2009). As better spatial layers have become more readily available due to advancements in satellite imaging technology, and as modelling capabilities have strengthened, it offers increasing application to species conservation management worldwide (e.g. Wintle, Elith *et al.* 2005, Addison, Rumpff *et al.* 2013). Within this field, Maxent is a widely used modelling method (Phillips, Anderson *et al.* 2006, Phillips and Dudík 2008) which is able to robustly predict species distributions at the landscape scale using presence-only datasets (e.g. Hernandez, Graham *et al.* 2006, Kaliontzopoulou, Brito *et al.* 2008, Kuemmerle, Perzanowski *et al.* 2010). This can lead to a significant expansion in the understanding of the requirements and distribution patterns of rare species. It has been found to perform favourably against a suite of established species distribution models including both presence-only and presence-absence methods (Hernandez, Graham *et al.* 2006, Phillips, Anderson *et al.* 2006, Dormann, Elith *et al.* 2013).

Critical to further informed study of threatened mallee bird distributions, predictive fire history mapping capable of differentiating old post-fire patches (Callister, Griffioen *et al.* in prep.) and predictive vegetation mapping (Haslem, Callister *et al.* 2010) that provides a uniform classification system have recently been developed for the Murray Mallee region. These predictive modelling tools provided the unique opportunity to obtain an understanding of the extent and location of suitable habitat available to threatened bird species across reserve and jurisdictional boundaries, and to determine to what extent their patterns of occurrence were driven by an association with fire.

We collated the most comprehensive presence-only historical datasets to date for twelve threatened and declining bird species of the region – the Malleefowl, Major Mitchell's Cockatoo (*Lophochroa leadbeateri*), Regent Parrot (*Polytelis anthopeplus*), Mallee Emu-wren (*Stipiturus mallee*), Striated Grass-wren (*Amytornis striatus*), Shy Heath-wren (*Calamanthus cautus*), Black-eared Miner, Southern Scrub-robin (*Drymodes brunniopygia*), Chestnut Quail-thrush (*Cinclosoma castanotum*), Red-lored Whistler (*Pachycephala rufogularis*), and Gilbert's Whistler (*Pachycephala inornata*). These datasets were used to develop species distribution models with Maxent, with the following objectives: (a) to determine to what extent species' occurrences were driven by post-fire vegetation age; (b) of those species with an association to post-fire vegetation age, to determine the nature of their response; (c) to predict the regional Murray Mallee distributions of all threatened bird species and identify where the most suitable habitat available to them was located; and (d) to identify whether any of these species were considered highly restricted within the region.

As discussed in the Malleefowl Forum presentation, models for the Malleefowl were not strong enough to discriminate areas of preferred habitat well, and so are not discussed further in this paper. Nonetheless, the approach and our findings have relevance within the wider context of threatened mallee bird species management, and presented here are results for those bird species for which strong models were developed.

Methods

Study area

Species distribution models were developed for the Murray Mallee study region which encompasses approximately 104,000 km^2 and covers areas of South Australia, New South Wales and Victoria.
Historical bird data

Distribution models were constructed for all threatened bird species occurring in the Murray Mallee region. This included all species identified under the Flora and Fauna Guarantee listed Victorian Mallee Bird Community: the Malleefowl, Mallee Emu-wren, Striated Grass-wren, Shy Heath-wren, Black-eared Miner, Southern Scrub-robin, Chestnut Quail-thrush, Red-lored Whistler, and Gilbert's Whistler. In addition, the following species were included: the Major Mitchell's Cockatoo, (listed as Threatened under Victorian legislation), Regent Parrot (listed as Threatened under Victorian legislation, and Vulnerable under Federal legislation), and Crested Bellbird (listed as Threatened under Victorian legislation).

All historical records for these species from 1999 to October 2010 were sought for the study region. Records were obtained from the New South Wales, South Australian and Victorian state agency databases, the Birds Australia Atlas, and data collected by Deakin, La Trobe and Monash University research groups. A presence-only record format was used for modelling, as the collection of datasets had comprised a range of methods including standardised transect and point count surveys, targeted threatened bird surveys with call playback and incidental records, which provided an incomplete record of absences.

Use of Maxent to develop species distribution models

Maximum entropy modelling, or Maxent, is a species distribution modelling (SDM) tool that operates within a defined area divided into a series of gridded cells, in which occurrence records for a focal species are compared with environmental variables at those localities to identify the species' distribution relative to those variables (Phillips, Anderson *et al*. 2006, Phillips and Dudík 2008). This information is used to build a model of species occurrence, as explained by those predictors found to be relevant. Maxent projects the predicted species occurrence to un-sampled cells within the defined area, based on the values of environmental predictors at those cells. Thus it generates a spatially explicit simulation of the species' predicted distribution in a given geographic space. Values of environmental predictor variables are compared between the occurrence localities for the given species and random 'background' points in the study region (where species presence is unknown). Maxent was chosen for this study because of its ability to robustly predict species distributions using presence-only datasets, and small sample datasets; typical of rare species (e.g. Phillips, Anderson *et al.* 2006, Anderson and Gonzalez Jr 2011).

Environmental variables

<u>Post-fire age class and vegetation type variables</u>

Our primary aim was to determine the distribution of threatened species with regard to seral class; accordingly, fire age class and vegetation type were selected as environmental predictor variables. Predictive vegetation class and fire-age class models developed by the Mallee Fire & Biodiversity Project (Watson, Taylor *et al*. 2012) were used because they represented the best spatially explicit knowledge available for the region. We amalgamated known fire scars with the distribution map of predictive post-fire vegetation age developed by Callister, Griffioen *et al.* (in prep.) for sites burnt prior to 1972 for the Murray Mallee region (Figure 1). Threatened bird records were assigned post-fire ages relevant to the year in which they were recorded. Age class intervals were assigned post-analysis and are defined by the following categories – very young (1-10 years), young (11-20 years), intermediate (21-40 years), late intermediate (41-50 years), old (51-70 years) and very old (71+ years).

The regional distribution of vegetation types was obtained from the predictive model developed by Haslem, Callister et al. (2010) (Figure 2). This model identified four distinct vegetation types - *Triodia*, chenopod, heathy and shrubby mallee. Species distribution models were developed only for those areas identified as either *Triodia* or chenopod mallee, because threatened bird sampling was not conducted across an adequate distribution of age classes within either heathy or shrubby mallee to permit their inclusion.

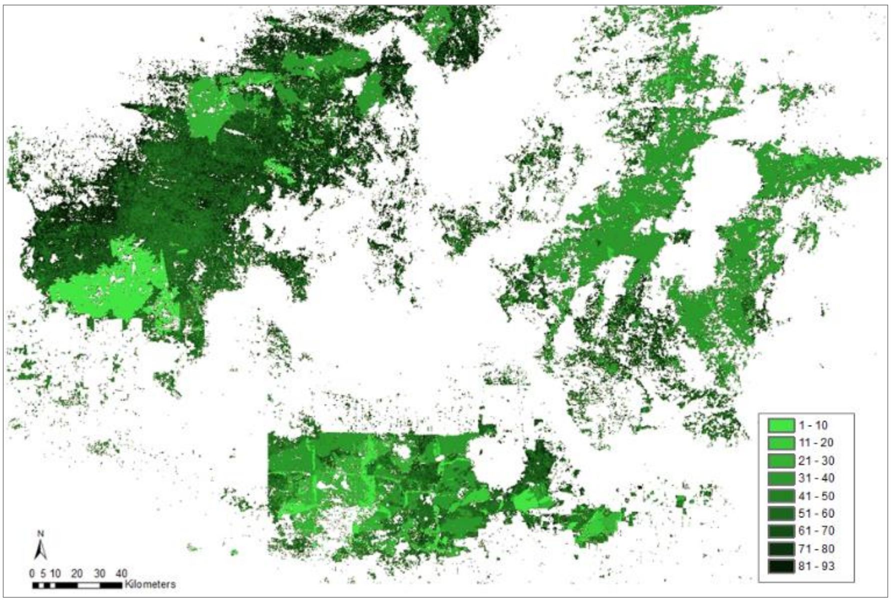

Figure 1. Distribution of post-fire age classes for mallee vegetation at 2011, Murray Mallee region.

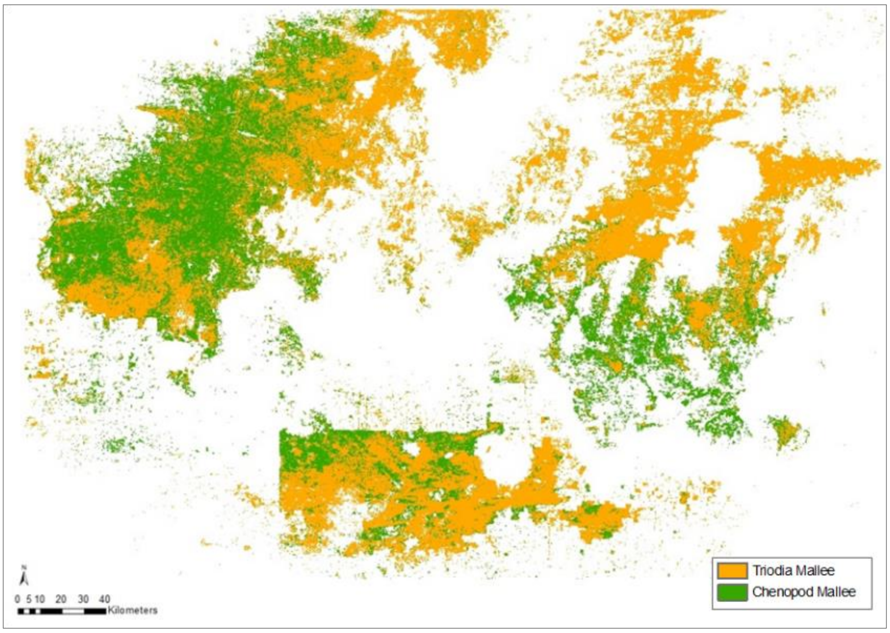

Figure 2. Distribution of Triodia and chenopod mallee vegetation classes across the Murray Mallee region.

Climatic zone variables

Rainfall and temperature gradients exist across the region and accordingly, the following predictor variables were considered biologically relevant to species distributions and included for contention in all species distribution models: variables relating to climatic zone (mean annual maximum and minimum temperatures and mean annual precipitation) and variables relating to climatic extremes (mean maximum temperature of the hottest month, January, and mean minimum temperature of the coldest month, July, and mean precipitation of the driest and wettest months, April and October respectively). Climatic spatial layers were obtained for the region from the Bureau of Meteorology (2014). Long-term data averages were calculated from records for the thirty year period 1961 – 1990 and depict regional climatic zones.

Estimation of sampling bias

We used target group sampling (Phillips and Dudík 2008) to contend with sampling biases likely to be present in our historical datasets. However, this was unable to negate the effect of biased sampling effort in intermediate post-fire age classes (20-60 years, Figure 3), with the greatest scarcity of records in very old age classes (>80 years) relative to their prevalence in the landscape at 2011. Given the perceived importance of older mallee to many of these threatened species (Clarke 2005, Watson, Taylor *et al.* 2012, Taylor, Watson *et al.* 2013), we remain cautious in providing any valuation of this age class beyond 80 years. Thus, individual species responses to post-fire age class were prepared for the age class distribution of 1-80 years only.

Model selection

For each species, outlier records were removed according to the protocol specified by Van Selst and Jolicoeur (1994), and raw models were then run using the full set of environmental predictors. Predictors were tested, by species, for collinearity using the Pearson's correlation coefficient. Any pairs of predictor variables with a coefficient $\geq$0.7 were deemed collinear (Dormann, Elith *et al.* 2013). The predictor of the pair found to have a lower explanatory effect on the test dataset gain was removed from the model (as done by Kuemmerle, Perzanowski *et al.* 2010). Models were then successively re-run until all predictors shown to detract from or contribute ~0% to model predictive performance and test gain were removed. This variable subset formed the final model.

Final models were screened and accepted for analysis on the basis of area under the curve, or AUC, performance. Models are typically evaluated using the strength of the AUC value (0-1) which is a rank-based statistic that provides a measure of model discrimination, or ability to rank cells in terms of predicted presences and background points (Yackulic, Chandler *et al.* 2013). Evaluation using the AUC provides a reliable ranking of areas in terms of relative habitat value (Wintle, Elith *et al.* 2005). Broadly, an AUC of $\leq$0.5 indicates a discriminatory ability of no better than random, 0.5-0.7 indicates some discriminatory ability, 0.7-0.9 indicates reasonable discrimination, and >0.9 indicates strong discrimination (Pearce and Ferrier 2000). Only models with AUCs >0.75 were accepted (Anderson, Dudík *et al.* 2006, Reside, VanDerWal *et al.* 2012), resulting in the exclusion of models developed for the Malleefowl, Major Mitchell's Cockatoo and Crested Bellbird.

Final species distribution models of relative predicted habitat suitability were projected onto the Murray Mallee study region as at 2011.

Results

Maxent distribution models with high performance (AUC values $\geq$0.75) were developed for nine of twelve threatened bird species (Table 1), but did not include the Malleefowl. Results for other species are discussed here.

Post-fire vegetation age was retained by all nine models and was a strong predictor for many species. Vegetation type showed relatively minor predictive power, and was retained in models for only three species. Nevertheless, its importance in predicting the occurrence of those three species was high, being the highest ranking predictor for the Mallee Emu-wren and the third highest ranked predictor for the Striated Grasswren and Red-lored Whistler.

Table 1. Final Maxent species distribution models with AUC ≥0.75, listing percent contributions of all predictors.

Species	Final Model AUC	Standard Deviation	Predictor 1	Predictor 1 contribution	Predictor 2	Predictor 2 contribution	Predictor 3	Predictor 3 contribution	Predictor 4	Predictor 4 contribution
Regent Parrot	0.844	0.039	Mean annual max temp	39.5	Highest temp hottest month	30.3	Post fire age	23.4	Mean annual min temp	5.4
Mallee Emu-wren	0.832	0.044	Vegetation type	36.2	Post fire age	35.9	Mean precip highest month	22.9	Mean annual total precip	5.1
Striated Grasswren	0.849	0.017	Mean precip driest month	31.7	Post fire age	24.8	Vegetation type	23.3	Mean annual total precip	12.6
Shy Heathwren	0.845	0.024	Mean annual min temp	41.4	Post fire age	32.0	Mean precip lowest month	13.1	Mean precip highest month	8.4
Black-eared Miner	0.873	0.025	Mean precip driest month	71.8	Post fire age	11.4	Mean annual max temp	9.9	Lowest temp coldest month	6.9
Southern Scrub-robin	0.806	0.024	Post fire age	30.6	Mean annual total precip	24.6	Mean precip lowest month	16.8	Mean annual min temp	15.2
Chestnut Quail-thrush	0.773	0.022	Mean annual min temp	42.3	Post fire age	38.2	Highest temp hottest month	7.6	Lowest temp coldest month	6.4
Red-lored Whistler	0.920	0.014	Post fire age class	41.0	Mean precip lowest month	39.0	Vegetation type	10.7	Mean annual max temp	9.3
Gilbert's Whistler	0.784	0.031	Mean annual total precip	45.9	Post fire age	29.8	Mean annual min temp	14.5	Mean precip lowest month	9.8

Species	Predictor 5	Predictor 5 contribution	Predictor 6	Predictor 6 contribution
Regent Parrot	Lowest temp coldest month	1.4	-	
Mallee Emu-wren	-		-	
Striated Grasswren	Mean annual min temp	7.5	-	
Shy Heathwren	Lowest temp coldest month	2.9	Mean annual max temp	2.3
Black-eared Miner	-		-	
Southern Scrub-robin	Lowest temp coldest month	12.8	-	
Chestnut Quail-thrush	Mean precip highest month	5.6	-	
Red-lored Whistler	-		-	
Gilbert's Whistler	-		-	

Variables relating to climatic zone provided high predictive power across all models; in particular measures of precipitation ranked highly. Whilst predictor variables relating to temperature were retained by a majority of models, most made only a small percent contribution.

Species predominantly showed maximum occurrence within intermediate, late intermediate and old post-fire vegetation classes (Figure 4). Maximum occurrence was highest in old post-fire age classes for the Striated Grass-wren (41-60 years), Black-eared Miner (41-60 years) and Gilbert's Whistler (41-60 years), highest in intermediate and late intermediate for the Regent Parrot (21-50 years), and highest in intermediate for the remaining species – Mallee Emu-wren (21-30 years), Shy Heathwren (21-40 years), Southern Scrub-robin (31-40 years), Chestnut Quail-thrush (31-40 years), and Red-lored Whistler (21-40 years). For all species except the Shy Heathwren, lowest occurrence was found in very young post-fire vegetation (1-10 years); young post-fire vegetation (11-20 years) similarly had lowest occurrence for all species except the Mallee Emu-wren. However, this species was not found to occupy any sites of <18 years post fire. Association with post-fire ages beyond 80 years remained undefined.

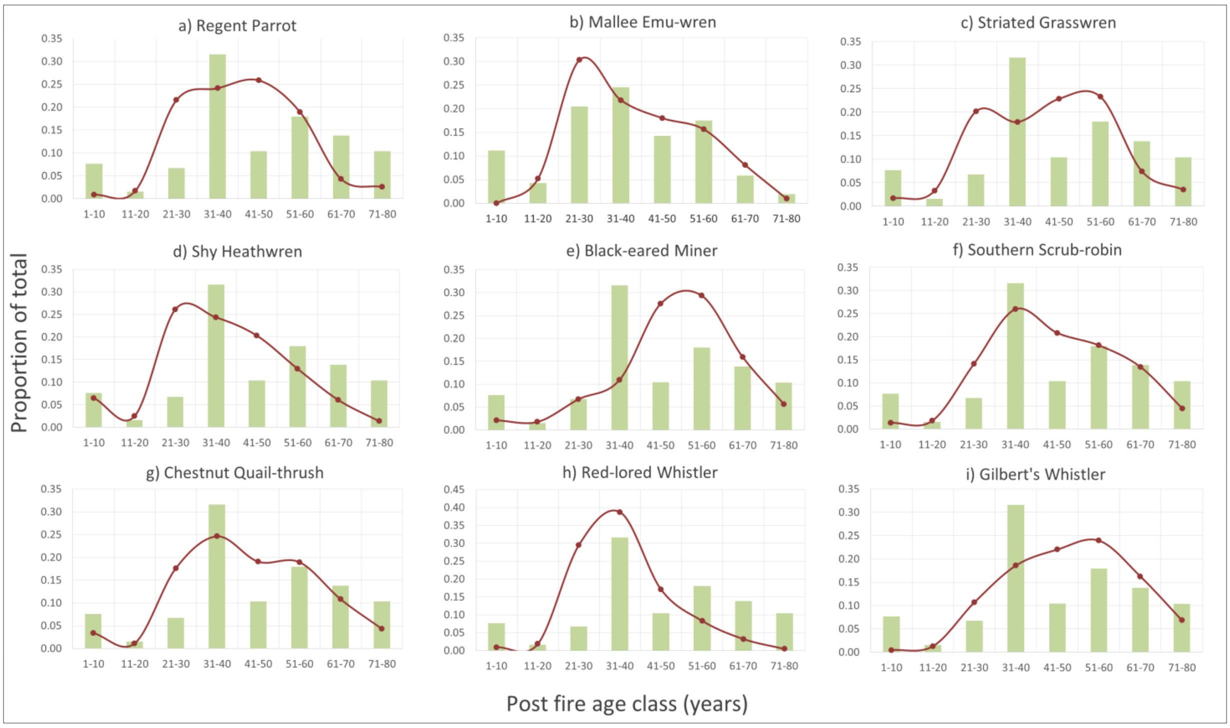

Figure 4. Proportion of total occurrence records for each species in each post-fire vegetation age class (red line), and available post-fire vegetation age classes as at 2011 for the Murray Mallee region (expressed as a proportion of total, green bars).

Of those three species which retained vegetation type as a predictor, response type was uniform; the Mallee Emu-wren, Red-lored Whistler and Striated Grasswren all demonstrated a strong preference for *Triodia* mallee (Figure 5).

Regional distribution of most suitable habitat differed between species, both in total patch extent and its configuration. Distribution models for many species predicted small and isolated patches, both within and off reserve, as highly suitable. Distribution of most suitable habitat was highly restricted within the study region for the Red-lored Whistler and Mallee Emu-wren (Figure 6). Small zones of suitable habitat were chiefly restricted to small areas within one or several connecting public reserves. Most suitable habitat for the Mallee Emu-wren was restricted *a priori* to the southeast of the study region, and here it was strongly associated with *Triodia* mallee, located in small, discontinuous patches of intermediate age vegetation located in the Hattah Kulkyne, Annuello and eastern Murray-Sunset Victorian reserves. Suitable habitat for the Red-lored Whistler was predominantly restricted to the southeast of the study region, and was located in a mostly connected series of small patches in the west of the Murray-Sunset

Victorian reserve, likewise chiefly in *Triodia* mallee. In contrast, only minor distinction in relative habitat suitability was seen across the region for both the Chestnut Quail-thrush and Gilbert's Whistler.

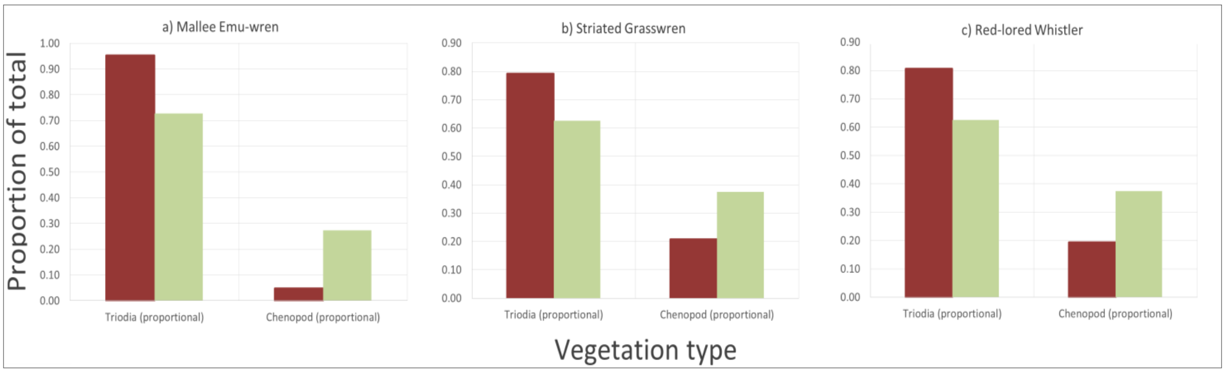

Figure 5. Proportion of total occurrence records for each species in each vegetation type (red column), and available vegetation types (expressed as a proportion of total, green bars; Mallee Emu-wren – for the Victorian mallee only, and Striated Grasswren, Red-lored Whistler - for the Murray Mallee region).

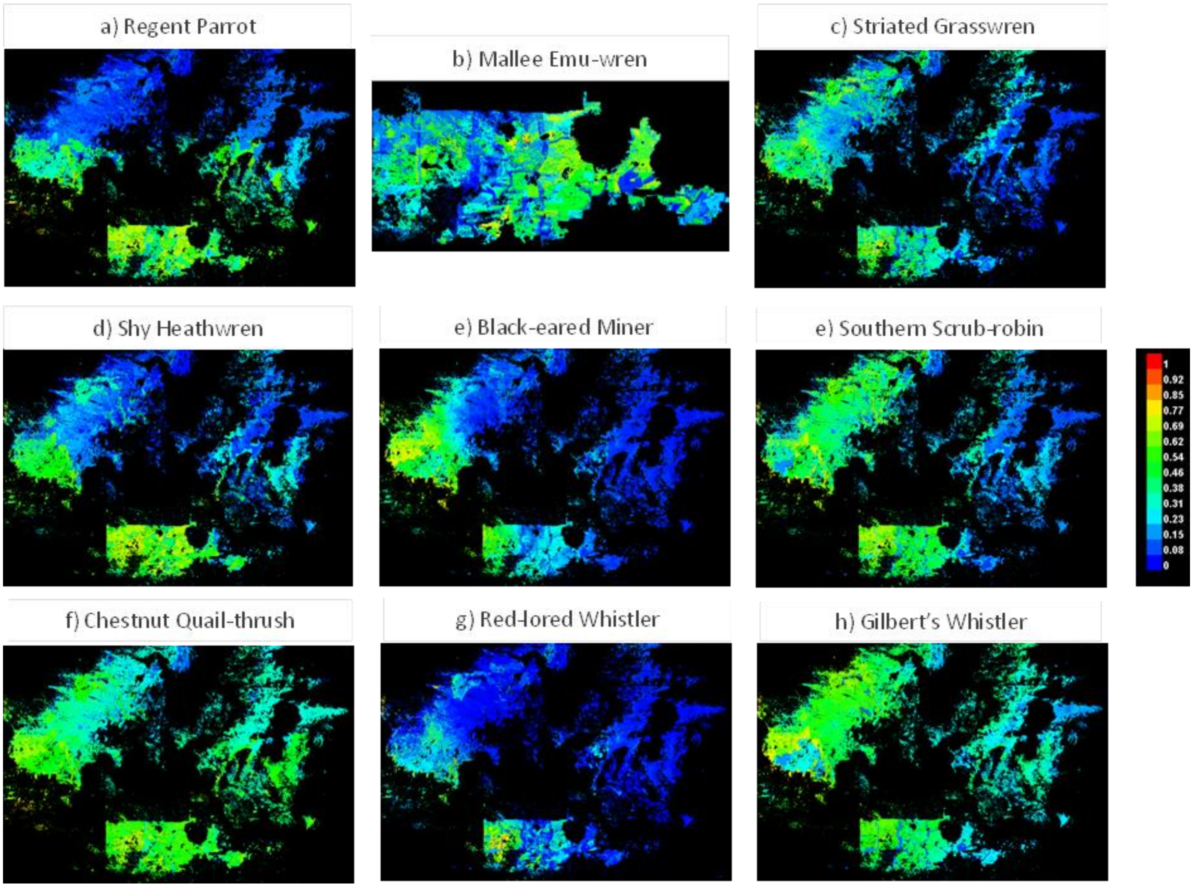

Figure 6. Maxent model distribution maps for the Murray Mallee region at 2011. Pixels of highest relative predicted occurrence (approaching 1) are indicated by red, intermediate (~0.5) green, and lowest (approaching 0) blue.

Discussion

These findings significantly advance our knowledge of the extent and distribution of suitable habitat available to declining mallee bird species, as we were able to associate historical threatened bird occurrences with the first spatially explicit distributions for both post fire age class (Callister, Griffioen *et al.* in prep.) and vegetation (Haslem, Callister *et al.* 2010), portrayed on a common scale across jurisdictional boundaries. Species' association with post fire age classes and vegetation types were broadly consistent with prior modelling (Clarke 2005, e.g. Clarke, Boulton *et al.* 2005, Brown, Clarke *et al.* 2009, Watson, Taylor *et al.* 2012). Our work identified that under prevalent conditions of low rainfall, all nine species for which strong predictive models were able to be developed showed an association with post-fire age class. Distinctly, almost all species showed a disproportionate association with vegetation >20 years. A number of species showed peaks of occurrence in intermediate age classes (21-40 years) which subsequently declined, likely to be affiliated with their requirements for structural elements and habitat resources shown to decline with time (Haslem, Kelly *et al.* 2011). Analogous to prior work, the Mallee Emu-wren, Red-lored Whistler and Striated Grasswren were found to be strongly associated with *Triodia* mallee. These species are widely recognised as *Triodia* specialists (Higgins and Peter 2002, Clarke 2005, Brown, Clarke *et al.* 2009). The Mallee Emu-wren for example utilises *Triodia* hummocks for nesting and refuge purposes (Brown, Clarke *et al.* 2009) and these begin to senesce approximately 40 years post fire (Haslem, Kelly *et al.* 2011), consistent with the birds' decline in occurrence. The Striated Grasswren, Black-eared Miner and Gilbert's Whistler were most strongly associated with late intermediate (41-50 years) and old (51-70 years) vegetation, consistent with prior studies (McLaughlin 1990, Clarke 2005, Clarke, Boulton *et al.* 2005, Watson, Taylor *et al.* 2012).

Clarke (2005) remarked that upper limits to preferred age class ranges for this suite of species had been identified by few studies due to the restrictions of satellite imagery (Callister, Griffioen *et al.* in prep.), which was limited to assigning anything above 35 years to 'old' (Clarke, Avitabile *et al.* 2010, Avitabile, Callister *et al.* 2013). Our work has more than doubled the length of 'known age' post fire age classes to 80 years. However, due to the scarcity of records available for very old post-fire age classes (>80 years), and constrained by our use of historical presence-only data, species use and requirement for resources affiliated with those still older age classes remain inconclusive. However, response curves developed by Watson, Taylor *et al.* (2012) using presence-absence data suggest that for species like the Gilbert's Whistler and Southern Scrub-robin, occurrence in very old vegetation (>70 years) continues to incline to at least 100 years post-fire. Evidence from prior studies indicates such older post-fire age classes are unequivocally important for the breeding requirements of species like the Black-eared Miner (Higgins, Peter *et al.* 2001) and others unable to be strongly modelled here, like the Major Mitchell's Cockatoo and Malleefowl (Benshemesh 1990). The Major Mitchell's Cockatoo, for example, requires hollows for breeding and has been found to occupy those of >15cm in dimension (Higgins 1999). These do not begin to develop in live stems until approximately 60 years post fire, and would require still many more decades for a tree to develop hollows large enough to accommodate this species (Higgins 1999, Haslem, Kelly *et al.* 2011). Thus, it must be emphasised that these distribution models may in fact underestimate the suitability of very old vegetation across the landscape.

Notably, limited preference for very young and young age classes (1-20 years) was exhibited. Only the Shy Heathwren showed any association with youngest vegetation (1-10 years), consistent with its habitat association with shrubs and the shrub-like coppicing of *Eucalyptus* spp. which occurs in early successional stages following fire (Higgins and Peter 2002).

Models showed an uneven distribution of most suitable habitat for species across reserve and regional boundaries. The highly restricted extent of suitable habitat identified for the Mallee Emu-wren and Red-lored Whistler reflect evidence from contracting occurrence records for these species in recent decades (Higgins, Peter *et al.* 2001, Clarke 2005, Brown, Clarke *et al.* 2009). For mallee endemics like these and the Black-eared Miner, these Murray Mallee distributions represent a significant extent, if not the entirety, of their global distributions and emphasise their vulnerability to stochastic events and land management actions at a single reserve scale (Brown, Clarke *et al.* 2009). This has been highlighted by recent population losses of the Mallee Emu-wren following bushfire events at Ngarkat Conservation Park and Bronzewing Flora and Fauna Reserve in January 2014.

Identification of suitable habitat by these distribution models is constrained by species requirements for minimum patch size and by their dispersal abilities, not just between reserves, but between suitable habitat patches within reserves. Firstly, we doubt off-reserve isolates (identified as highly suitable for several species, including the Black-eared Miner and Chestnut Quail-thrush by Maxent modelling) are of significant value for the species. The likelihood of species occupation and sustained use of such isolated or small fragments is unlikely (Luck, Possingham *et al.* 1999, Ford, Barrett *et al.* 2001) but remains to be examined. Secondly, within reserves there is an urgent need to better understand the effects of species dispersal capacity and minimum patch size needed to sustain both viable meta- and sub-populations. Radford and Bennett (2004) and Radford and Bennett (2006), for example, identified that the White-browed Treecreeper (*Climacteris affinis*) displayed evidence of a patch occupancy threshold, where it was limited in its ability to disperse between patches of no more than three kilometres apart. This threshold was exhibited even between suitable patches separated within natural vegetation matrices, although the threshold extended to eight kilometres. Such evidence of dispersal limitations highlights that ostensibly suitable habitat is not a guarantee of occupation. Similarly, minimum patch size requirements for a species are likely to render much purported suitable habitat to be of little use. Taylor, Watson *et al.* (2012) remarked that the response of species to fire-mediated spatial properties of landscapes (e.g. the size and configuration of patches) remains virtually unknown (Bradstock, Bedward *et al.* 2005, Driscoll, Lindenmayer *et al.* 2010), including for most of those species studied here. Preliminary assessments by Clarke, Boulton *et al.* (2005) speculated that greater than 13,000ha was required to sustain a viable Black-eared Miner population, and further analysis showed the species was positively associated with a low diversity of age classes (Taylor, Watson *et al.* 2013). Such findings would indicate that smaller and patchy pockets of suitable habitat identified by Maxent, like those in southeast South Australia, are in fact of little real use for the species. We require a better understanding of how such limiting factors affect these species to better interpret the spatial connectivity, and their likely use, of habitat.

These cautionary comments highlight that that use of species distribution models for conservation assessment purposes poses the danger of "adding up pixels", whereby artificially high estimates of the extent of suitable habitat are generated which might not provide an immediate basis for registering concern. Nevertheless, to date ecological management of key species has chiefly been limited to the use of historical occurrence records to obtain an understanding of their distributions. However, catering for species' needs must take into consideration the transient nature of post-fire vegetation age by managing for future age class distributions and ensuring its spatial connectivity over time to enable re-colonisation by species. These models significantly advance our understanding of threatened species relationships to fire age class and subsequent patterns of distribution at a landscape scale, thus providing a much greater capacity to do that.

Part 2 – Predicting the impact of future planned burning on a suite of threatened mallee bird species

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Introduction

Worldwide, fire-prone ecosystems are increasingly exposed to altered fire regimes resulting from changed land use practices (e.g. Westerling, Hidalgo *et al.* 2006, Liu, Stanturf *et al.* 2010, Keeley, Bond *et al.* 2012). Continued human population expansion at the wildland-urban interface generates increasing risk of such bushfires threatening human life and built assets (Gill and Stephens 2009, Penman, Bradstock *et al.* 2014). In response, planned fire has increasingly been employed as a management tool. Its objectives are two-fold – it is used widely in attempt to reduce the risk of bushfire causing loss to life and property (Reinhardt, Keane *et al.* 2008, Penman, Bradstock *et al.* 2014), and to better manage the ecological processes and values within remnant ecosystems (Morrison, Buckney *et al.* 1996, Burrows 2008, Penman, Christie *et al.* 2011). To marry these potentially conflicting goals is highly challenging. Questions remain both about the effectiveness of planned burns in mitigating the rate of spread and intensity of bushfire (Fernandes and Botelho 2003, Boer, Sadler *et al.* 2009, Penman, Bradstock *et al.* 2014), and how best to burn in order to maintain and promote ecological values (Driscoll, Lindenmayer *et al.* 2010, Pastro, Dickman *et al*. 2011). Increasing the capacity for fire management actions to prevent landscape scale bushfires is, however, often a key aim of both objectives (Penman, Bradstock *et al.* 2014).

Adequate knowledge of species' fire requirements is critical for their effective conservation management, but in many Australian systems such knowledge about historical disturbance regimes remains limited at best (Parr and Andersen 2006, Clarke 2008, Driscoll, Lindenmayer *et al.* 2010). In densely populated and fire-prone south-eastern Australia, state policy employs the use of ecological traits of plants to identify appropriate thresholds within which to apply planned burns to ecosystems (Cheal 2010, Cheal 2012). This assumes that by allowing for regeneration of key fire-sensitive plant species, the subsequent provision of a range of post-fire age classes in the landscape will be adequate for associated fauna. Faunal associations with post-fire age class suggest a much more complex range of responses even within single ecosystems. Landscape scale studies conducted in the semi-arid mallee (Taylor, Watson *et al.* 2012, Taylor, Watson *et al.* 2013) and work in other fire prone environments (Bradstock and Cohn 2002, Pastro, Dickman *et al.* 2011) has shown that there is no universal approach to fire management that is likely to benefit all species. Given this challenge, Pastro, Dickman *et al.* (2011) suggest that it would be most useful to focus fire management on those high priority, fire-sensitive species or species groups.

In the aftermath of recent bushfire disasters in southeast Australia, and with worsening climate change projected to significantly increase fire risk (Liu, Stanturf *et al.* 2010, Moritz, Parisien *et al.* 2012), the imperative to effectively manage fuel loads intensifies (Enright and Fontaine 2014). Following a Royal Commission into the Black Saturday fires of 2009, Victorian state land management policy now recommends a significant increase to the amount of planned burning on public land to facilitate protection of life and property (Teague, McLeod *et al.* 2010). This represents an historically unprecedented level of burning for ecosystems such as the semi-arid mallee in north western Victoria (Watson, Taylor *et al.* 2012, Avitabile, Callister *et al.* 2013). Planned fire acts in a similar manner to bushfire in this ecosystem, whereby mallee eucalypts stands die and stands are replaced by regenerating lignotubers. This allows the likely impact of planned fire on biota to be evaluated using our understanding of typical post-fire responses. Taylor, Watson *et al.* (2012) and Taylor, Watson *et al.* (2013) evaluated a range of likely fire management strategies for the region using landscape-scale fire mosaics and found a higher species richness of both common and rare birds in vegetation that had not been burnt for at least 35 years. Such evidence suggests increased fire frequency would be likely to jeopardise the status of some of its already threatened and endemic biota.

We recently identified the fire-responses and spatial distributions of a range of declining and fire-sensitive mallee bird species, including several endemics, across the Murray Mallee region. This suite of species has previously been recognised as most at-risk to inappropriate fire regimes (Woinarski and Recher 1997), and our models confirmed prior work showing that most exhibited preference for older post-fire vegetation (ranging from 20-60 years; Bradstock and Cohn 2002, Clarke 2005, Clarke, Boulton *et al.* 2005, Brown, Clarke *et al.* 2009, Watson, Taylor *et al.* 2012). This provided us with the unique opportunity to employ a spatially explicit approach to assess how the long term application of varying levels of planned burning would affect both bushfire occurrence and species persistence at a landscape scale, utilising a Victorian mallee Landscape Management Unit (LMU) as a case study. In doing this we sought to identify whether a maximum threshold to the extent of planned burning in this landscape could be determined, above which available habitat declined. Our objectives were: a) to develop a series of realistic, spatially explicit future planned burning scenarios, spanning two decades, which depicted varying levels of burning per annum (0, 1.5, 3 and 5%) and incorporated large wildfire events; b) to demonstrate changes to the distribution of post-fire age classes in the reserve, following application of these future planned burning scenarios for two decades; c) to quantitatively show how the extent of most suitable habitat available to those threatened species differed between scenarios and changed over the course of time, and d) from this, to identify those species most likely to be negatively impacted by planned burning management actions.

Methods

Study design

The semi-arid Victorian Mallee Landscape Management Unit (LMU), comprising Annuello Flora and Fauna Reserve, Hattah-Kulkyne and Murray-Sunset National Parks (excluding riverine vegetation and the Taparoo Grassland respectively), was selected as a case study region. Twenty-one years of spatially explicit planned burning scenarios were prepared for analysis to allow the cumulative, long-term impact of four different burning strategies to be assessed.

Development of pseudo-Fire Operations Plans

Staff from the Department of Environment and Primary Industries (DEPI) and Parks Victoria (PV) prepared the planned burning scenarios in a format consistent with current departmental protocol, to ensure they were of value for informing management approaches. The Fire Operations Plan (FOP) is the method currently employed to formulate the location, size and timing of planned burn treatments on Victorian public land (DEPI 2014). The twenty-one years of planned burn scenarios were prepared as spatially explicit 'pseudo' Fire Operation Plans (FOPs) for the LMU. Consistent with workplace FOPs, each plan was of three years' length which required the preparation of seven FOP scenarios for each treatment of planned burning, spanning twenty-one years in total (2011-13, 2014-16, 2017-19, 2020-22, 2023-25, 2026-28, 2029-31). Plans were prepared using predominantly a strategic corridor burning approach; repeated treatment of areas at short intervals was not employed. Rules governing the design of the planned burning scenarios were consistent with those already used by DEPI and PV for planning planned burns in the Victorian Mallee Fire District (Department of Sustainability and Environment 2008).

The pseudo-FOP scenarios were built upon the real fire history of the LMU as at 2011 using DEPI mapping records for the region. The preparation of pseudo-FOPs was led by the PV Fire and Environment Program Officer, Kathryn Schneider, with development carried out by the Mallee District planned burning team comprising both PV and DEPI staff, whilst the digitisation of pseudo-FOPs and application of burn coverage was performed by the DEPI Hawkeye Project Officer, Natasha Schedvin.

Burn percentage comparisons

Four levels of planned burning treatments per year were prepared, each of twenty-one years in scope. These were: no planned burning in the LMU (bushfires only, at levels simulating average area burnt *p.a.* over the past 35 years); 1.5% of planned burning *p.a.*; this approximates the long-term average of annual burning (bushfire plus planned burning) in the Murray Mallee over the last thirty years (Watson, Taylor *et al.* 2012, Avitabile, Callister *et al.* 2013); 3% of planned burning *p.a.* to represent a potential compromise target for this ecosystem, and which was consistent with the Victorian Mallee District target for 2011; and 5% planned burning *p.a.* which was consistent with the recommendation of the Victorian Bushfire Royal Commission from 2012 and onwards (Teague, McLeod *et al.* 2010).

Generation of simulated bushfires

It was considered imperative to incorporate stochastic and potentially significant events such as bushfire into the scenarios. The Victorian mallee is a fire-prone environment subjected to regular lightning ignited bushfires; large bushfires (of greater than 10,000 ha) have occurred approximately every ten years since the onset of satellite imagery in 1972 (Avitabile, Callister *et al.* 2013). Whilst fires of small size occur in any given year, large fire events are responsible for the majority of area burned by bushfire and substantially affect vegetation age-class distributions. Inclusion of simulated bushfires above a lower size limit was considered necessary to enable more relevant inferences to be made about the future suitability of species habitat following the two-decade projection.

The average historical size of large fires for the Victorian mallee was used to inform simulated fire size (36,000 ha for Murray-Sunset National Park, Avitabile *et al.* 2013). The bushfire simulation program *Phoenix Rapidfire V3.9.0.0* (developed by Tolhurst, Shields *et al.* 2008) was used to incorporate simulated bushfires into the pseudo-FOP scenarios. This program was developed in Victoria and is used by DEPI to model complex fire behaviour. The program is operated in a simulated environment which replicates the topographic features and fuel loads of a defined, real landscape. Spatially explicit simulations of bushfire direction of spread and extent are generated using fire behaviour models based on ignition location, fuel parameters and input of weather conditions. Simulated bushfires respond to changes in weather and fuel parameters as time progresses. Operation of Phoenix software was performed by the PV Fire and Environment Program Officer, who also undertakes the fire behaviour analyst role during bushfire suppression events.

Species distribution models

Maxent threatened bird species distribution models developed for the Murray Mallee region were projected onto the Victorian LMU future planned burning scenarios. Only species for which strong models (AUC $\geq$ 0.75) could be generated and which exhibited a strong response to post-fire age class were included in analyses. Distribution models for the Regent Parrot (*Polytelis anthopeplus*), Mallee Emu-wren (*Stipiturus mallee*), Striated Grass-wren (*Amytornis striatus*), Shy Heathwren (*Calamanthus cautus*), Black-eared Miner (*Manorina melanotis*), Southern Scrub-robin (*Drymodes brunniopygia*), Chestnut Quail-thrush (*Cinclosoma castanotum*), Red-lored Whistler (*Pachycephala rufogularis*) and Gilbert's Whistler (*Pachycephala inornata*) were projected onto scenarios.

Changes to extent of suitable habitat for each species were measured following the application of each three year planned burning treatment (0, 1.5, 3 and 5% *p.a.*), from 2011 to 2032. The application of a binary, non-species specific threshold using predicted occurrence rate to delineate species presence and absence was not considered suitable as it would likely mask potential loss or gain of suitable habitat for rare species, which have lower occurrence rates (Nenzén and Araújo 2011, Warren, Wright *et al.* 2014). The upper 20th percentile of a species' predicted occurrence rate was used instead. This index identifies those areas of the LMU in which the predicted occurrence rate was equal to or greater than the top 20th percentile of the predicted occurrence rates for that particular species in 2011. One could then examine how the availability (in hectares) of this most suitable habitat changed in extent and location under various burning scenarios. Being percentile based, this had the advantage of identifying occurrence rates specific to each species.

Results

True distribution of fire age classes in the Victorian reserve as at 2011 showed an approximately normal distribution, with spikes in the youngest and intermediate-older age classes (Figure 1). By 2032, following 21 years without planned burning the simulated landscape showed a considerable increase in the amount of very old vegetation. Bushfire events in each decade converted a small portion of the total reserve to the youngest age class (1-10 years). Application of 1.5% planned burning *p.a.* plus bushfire events resulted in a bimodal distribution by 2032. Application of 3% planned burning *p.a.* to 2032 plus bushfire events resulted in an age class distribution strongly dominated by vegetation of twenty years of age or less which comprised almost two-thirds of total reserve area. Application of 5% planned burning *p.a.* to 2032 plus bushfire events saw a rapid conversion of over eighty percent of the reserve to vegetation of 20 years of age or less. All older age classes lost substantial area to burning treatments. Under 3 and 5% *p.a.,* remaining remnant patches of very old vegetation were small and highly fragmented (Figure 2).

Simulated bushfire events in each decade made progressively smaller contributions to the total amount of vegetation in the youngest age class in 0, 1.5, 3 and 5% *p.a.* planned burning treatments (Figures 3, 4). However, despite the mitigating effect of higher planned burning on bushfire size (Figure 3), with increased planned burning the total extent of recently burnt vegetation in the reserve increased.

The amount of planned burning over two decades had a varied impact on the extent of most suitable habitat available in the reserve for each species. Following two decades of projections, a higher amount of planned burning was associated with substantial reductions in the extent of most suitable habitat for two of nine species, the Mallee Emu-wren and Black-eared Miner. The Mallee Emu-wren was one of few species to show any increase in total extent available relative to 2011, under any treatment type; in this case no planned burning resulted in a two percent expansion of most suitable habitat. Under 5% and 3% *p.a.* extent was thirteen and eight percent less, respectively, than extent available under no planned burning. Additionally, most suitable habitat for the Mallee Emu-wren was widely dispersed under all planned burning treatments. The configuration of most suitable habitat under 5% *p.a.* in particular comprised very small and isolated patches (Figure 6). For the Black-eared Miner a similar considerable decline was exhibited following higher amount of burning, where under 5 and 3% *p.a.,* extent of most suitable habitat was reduced by ten and eight percent relative to the extent available under no planned burning.

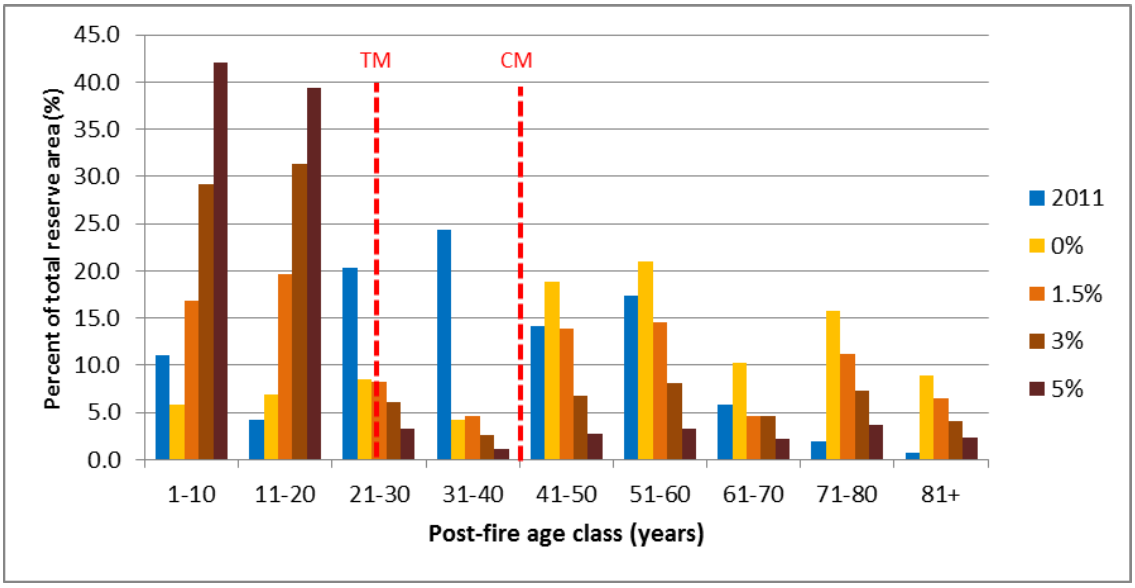


Figure 1. Post-fire age class distribution of reserve in 2032, following 21 years of planned burning (at 0% *p.a.* with bushfires only, and 1.5, 3, and 5% *p.a.* with bushfire). Blue indicates the 2011 distribution. Red dotted lines indicate the minimum tolerable fire interval for *Triodia* (TM, 25 years) and chenopod (CM 40 years) mallee.

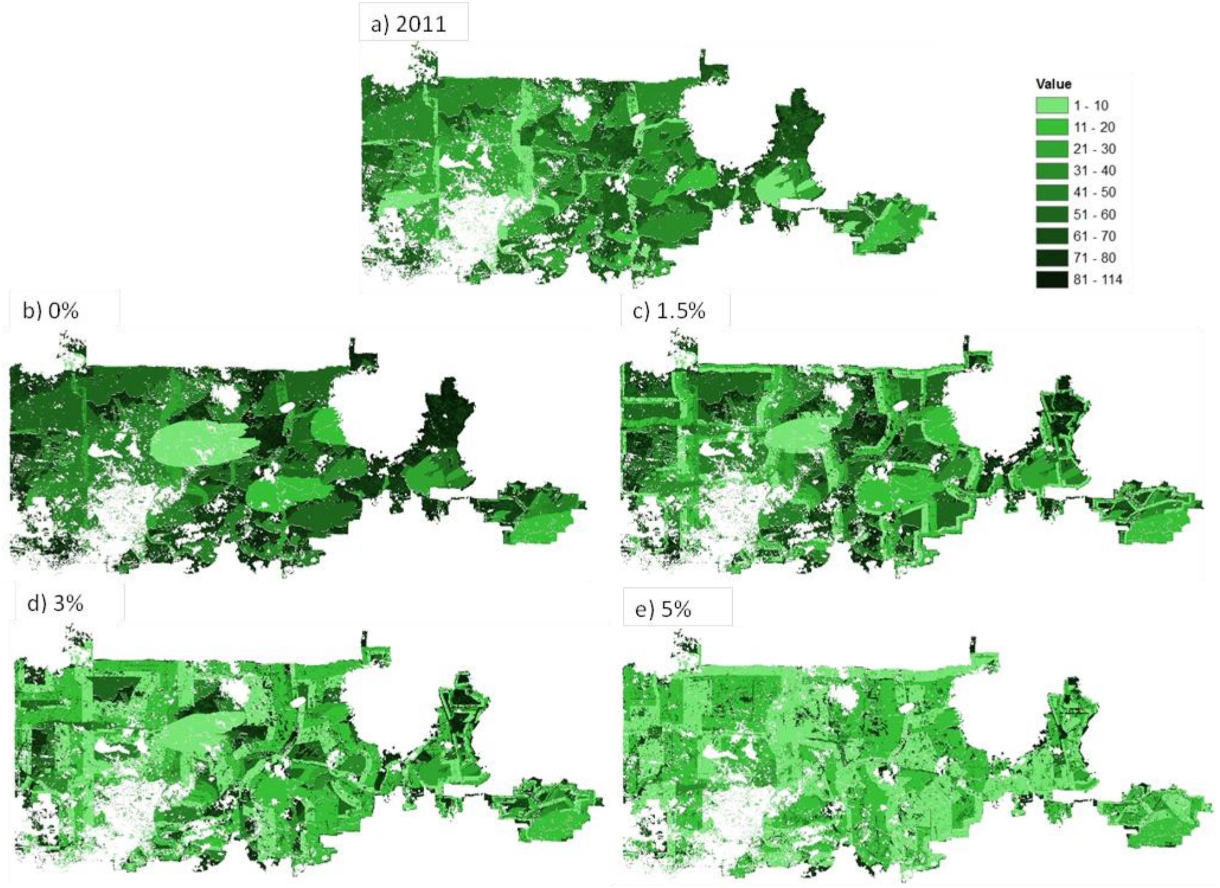


Figure 2. Post-fire age class distribution of Victorian reserve at 2011, and planned burning scenarios (0, 1.5, 3 and 5% *p.a.* plus bushfire) at 2032.

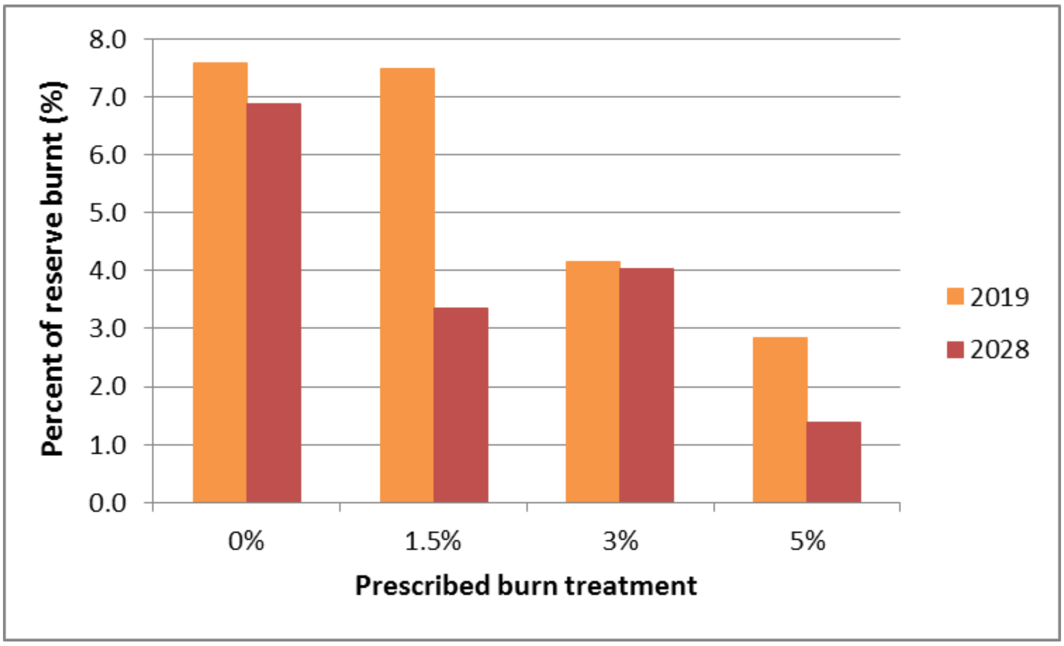


Figure 3. Bushfire complex size across treatments (0, 1.5, 3 and 5% *p.a.*), at 2019 and 2028.

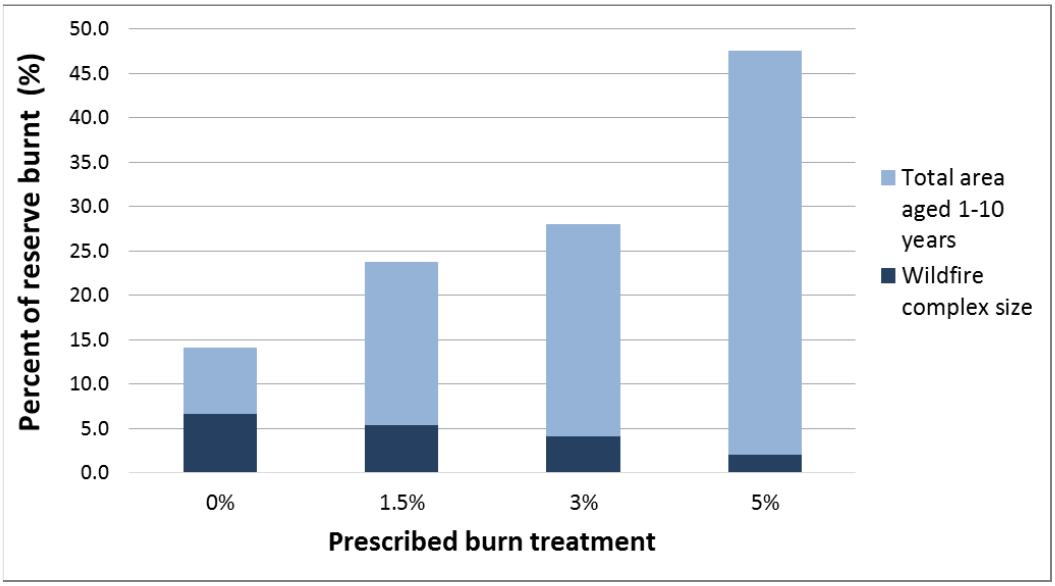


Figure 4. The average contribution of each bushfire complex (2018 and 2028) to the average total area burnt per decade (all vegetation aged 1-10 years, as at 2020 and 2032), per treatment (0, 1.5, 3 and 5% *p.a.*).

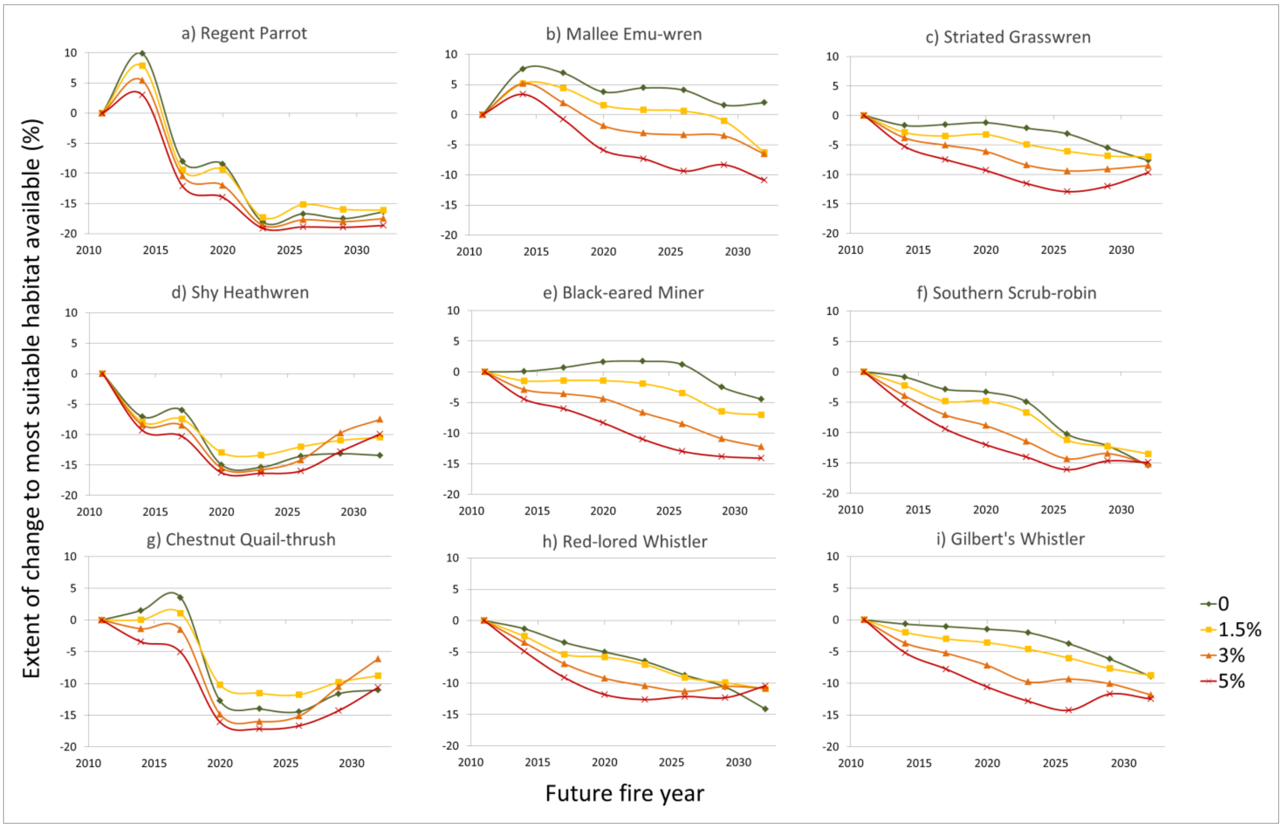
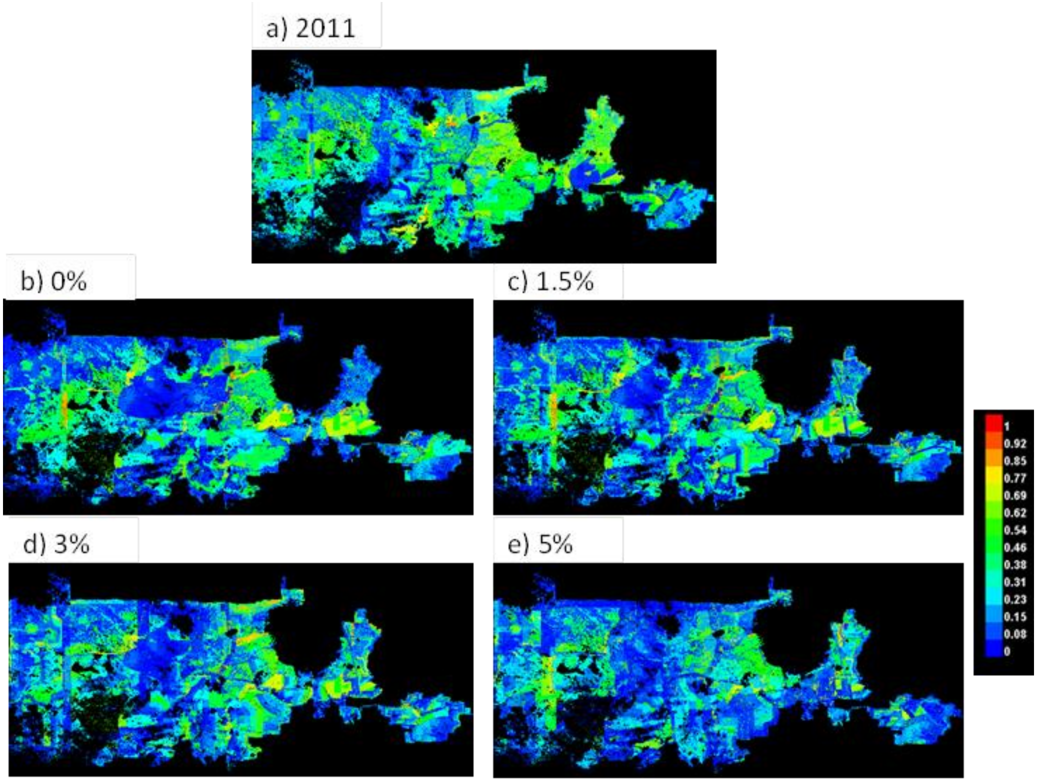
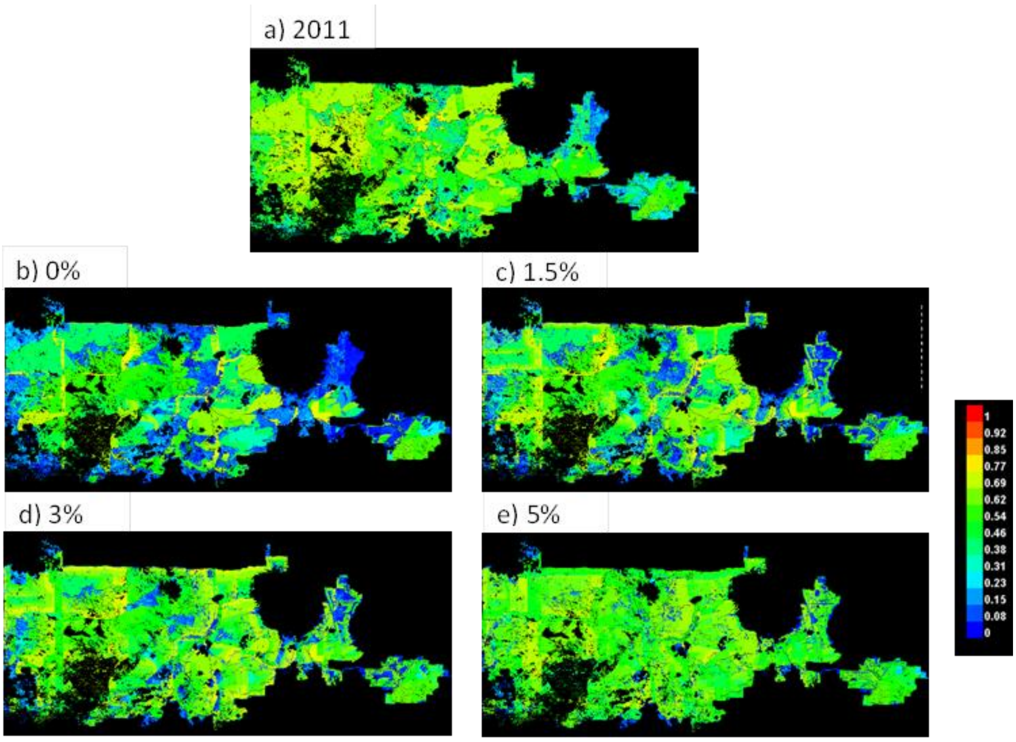


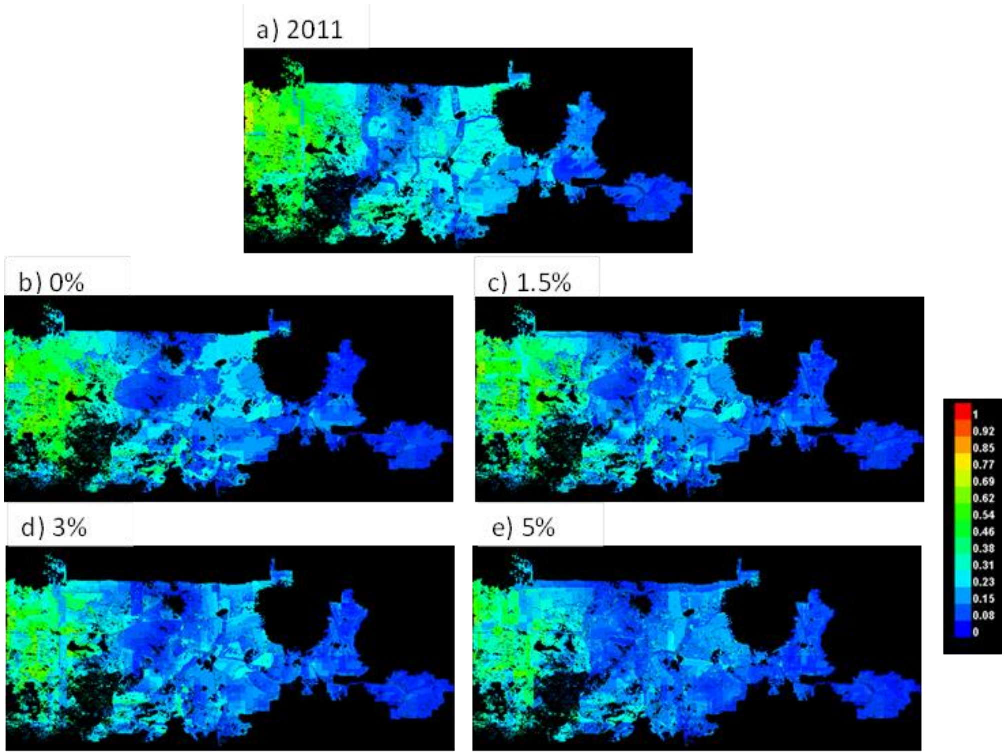
Figure 5. Changes to the extent of 'most suitable habitat' within the reserve over 21 years subjected to 0% (i.e. no planned burning but including bushfires), 1.5%, 3% and 5% *p.a.* planned burning. 'Most suitable habitat' is defined as those areas in which the predicted occurrence rate was estimated to be equal to or greater than the top 20th percentile of the predicted occurrence rates for each particular species in 2011. Changes are expressed relative to the total area of 'most suitable habitat' in 2011 in the reserve.



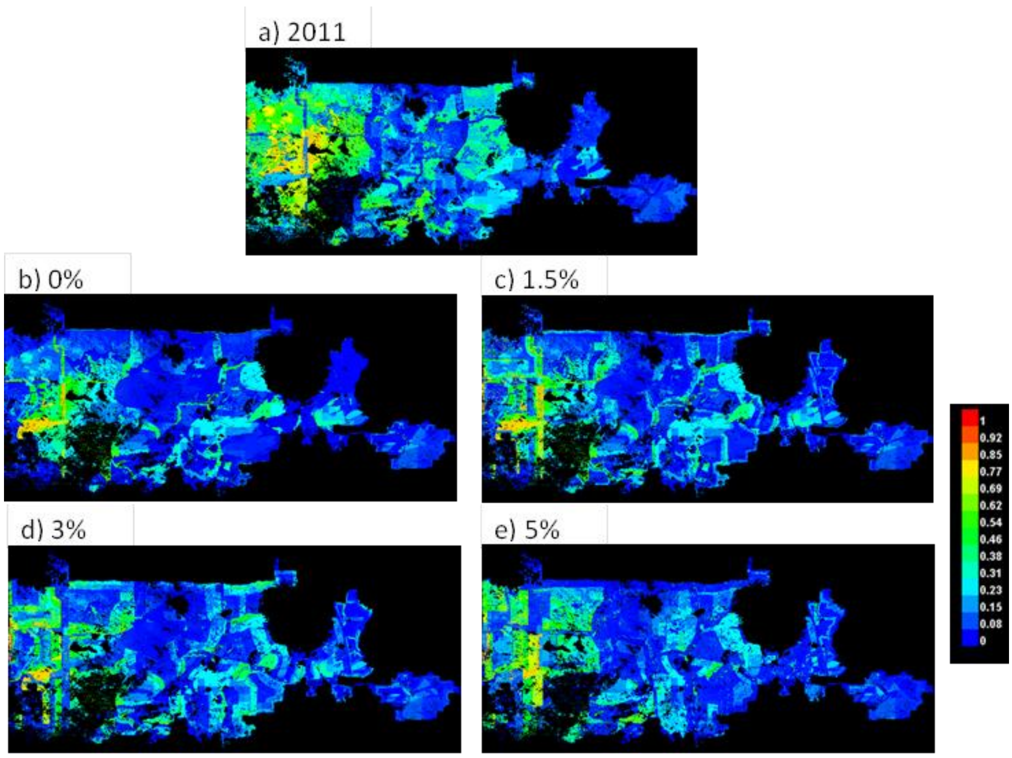
a) Mallee Emu-wren



b) Shy Heathwren



c) Black-eared Miner



d) Red-lored Whistler

Figure 6. Distribution maps at 2011 and 2032 (0, 1.5, 3 and 5% *p.a.*) depicting relative habitat suitability of the reserve for **a)** Mallee Emu-wren, **b)** Shy Heathwren, **c)** Black-eared Miner and **d)** Red-lored Whistler. Pixels of highest relative predicted occurrence (approaching 1) are indicated by red, intermediate (~0.5) green, and lowest (approaching 0) blue.

For remaining species, burning at 5% *p.a.* resulted in less marked differences in the final extent of most suitable habitat by 2032, nonetheless burning at 5% *p.a.* was not found to be most favourable for any species. The Regent Parrot, Striated Grasswren and Gilbert's Whistler each experienced a high reduction in extent of suitable habitat available under 5% *p.a.* relative to remaining treatments, although this difference was minimal.

Notably, for seven species (the Regent Parrot, Striated Grasswren, Shy Heathwren, Southern Scrub-robin, Chestnut Quail-thrush, Red-lored Whistler and Gilbert's Whistler) during the course of two decades of planned burning, the greatest extent of suitable habitat was lost under 5% planned burning *p.a.* (particularly 2023-26), but recovered by 2032 to an extent comparable, equal or higher than other treatment types. For the Striated Grasswren, Chestnut Quail-thrush, Southern Scrub-robin and Gilbert's Whistler these declines were most considerable, differing by up to ten percent relative to extent available under no planned burning in various years.

Mixed responses were shown to the remaining levels of planned burning, with little final distinction seen in the extent of suitable habitat for the Striated Grasswren, Southern Scrub-robin and Red-lored Whistler. Following no planned burning, the extent of suitable habitat showed greatest decline for four species. For the Shy Heathwren and Red-lored Whistler, under no planned burning extent of most suitable habitat was markedly lower than all other treatments, whilst for the Southern Scrub-robin and Chestnut Quail-thrush it was marginal.

Regardless of treatment type, the extent of most suitable habitat declined substantially over the two decades relative to 2011 for most species, by approximately five percent for the Black-eared Miner, to almost twenty percent for the Regent Parrot. Intermediate (21-40 years), late intermediate (41-50 years) and old (51-70 years) age classes were favoured habitat for most of these threatened bird species, and under all treatments vegetation either declined in value as it aged beyond a certain point (0% *p.a.*) or was burnt (1.5, 3 and 5% *p.a.*), resulting in substantial decreases in the percent contribution of intermediate vegetation across scenarios (Figure 1).

Isolated declines and inclines in extent of suitable habitat were observed across species over time, and were identified to the placement of planned burns or bushfire over patches of previously highly suitable habitat, and/or ageing of vegetation that led to in its inclusion or removal from a species' preferred post-fire age class (Figure 6). For example, for the Mallee Emu-wren, all treatments showed a slight increase in extent between 2011 and 2015, as more *Triodia* mallee vegetation entered the preferred age class of 18-28 years for the species. Subsequently, extent decreased across treatments as much of this vegetation was either 'reset' to younger age classes by planned burning, or aged beyond 28 years.

Discussion

We demonstrated the effects of the long-term application of varying levels of planned burning in a mallee reserve to post fire age class distribution, and the associated impact on available habitat for at-risk species. We showed that increased planned burning was associated with substantially higher proportion of very young and young vegetation, a higher loss of intermediate to very old post-fire age classes, and fragmentation of these older age classes. Incorporation of bushfire aimed to provide a more realistic assessment of likely risk in a mallee environment, and simulations provided an indication that a higher extent of planned strip burning was associated with reduced bushfire size. Whilst the age to which strip burns remain effective for mitigation purposes was not examined, land managers have reported this remains >10 years (Kathryn Schneider, *pers. comm.*). However, it has been found in other systems that effective mitigation of bushfire by planned burns was largely negated by severe fuel weather conditions (e.g. Fernandes and Botelho 2003) and thus the extent of bushfire control by scenario strip burns may have been underestimated. Interestingly, scenarios showed that the extent of reserve treated by planned burning, even at 1.5% *p.a.*, far exceeded the area subjected to bushfire when no planned burning was conducted, and these findings are consistent with formal investigations of fire behaviour in other ecosystems (Fernandes and Botelho 2003, King, Cary *et al.* 2006, Boer, Sadler *et al*. 2009, Penman, Bradstock *et al.* 2014). Given the low risk to loss of life and property in this remote region, it would be hoped that planned burning conducted would serve a beneficial ecological purpose to those species most at risk

However, our findings raise the concern that efforts to reduce bushfire risk to (ecological) assets may become counterproductive when the extent of planned burning required is higher than the likely size of bushfires (Bradstock, Bedward *et al.* 1998, Penman, Bradstock *et al.* 2014).

Following two decades of future fire, we showed that burning at 5% *p.a.* was found to have the most pronounced negative impact on available habitat for this suite of threatened and declining species. This finding is unsurprising given that almost all species had higher occurrence in vegetation >20 years, and is consistent with work by Taylor, Watson *et al.* (2013) who identified that, at a landscape scale, no common mallee bird species benefited from a high proportion of young post-fire vegetation. Two mallee endemics, the Mallee Emu-wren and Black-eared Miner, did however show strongest indication of being negatively impacted by higher burning, with greatest reduction in most suitable habitat evident under a 5% *p.a.* scenario. This is likely because both had highly localised distributions at the reserve level in 2011; suitable habitat for the Black-eared Miner was restricted to the far west of the reserve with preference for late intermediate and old post-fire vegetation, and the Mallee Emu-wren was tightly restricted to *Triodia* mallee only, and of intermediate age. These age classes both decreased in extent with increased planned burning. At the other end of the spectrum, no planned burning (but with continued occurrence of bushfire) in the landscape was associated with a declined extent of suitable habitat for a number of species, but most substantially for the Shy Heathwren and Red-lored Whistler. This is likely due to the Shy Heathwren's association with young post-fire ages (0-10 years), and the Red-lored Whistler with intermediate post-fire ages (20-40 years). With no planned burning, little vegetation remained which was of very young and young age (1-20 years), and in the Red-lored Whistler's stronghold in the west of the reserve, there was a declining amount of vegetation in the appropriate intermediate age range (21-40 years).

Higher levels of burning resulted in high fragmentation of suitable habitat for a number of species, particularly those with restricted distributions. As highlighted by our prior work, our ability to assess the value of small and isolated patches is limited until we better understand what patch sizes are required by species to sustain populations, and how readily they are able to move through unsuitable vegetation matrices (e.g. Radford and Bennett 2004, Radford and Bennett 2006). Such understanding of spatial connectivity is crucial to a proper evaluation of the long-term impact of high levels of planned burning.

Conclusions about the likely impact of planned burning cannot be based solely on final total quantity of projected suitable habitat. Whilst suitable habitat showed some recovery in extent by 2032 for a majority of species, projections showed most substantial slumps under 5% *p.a.* This demonstrated that final differences between treatments were not indicative of the full extent of the impact of planned burning on habitat. Recovery was likely seen because vegetation burnt by planned fire in the first years (2011-16) had, by 2032, aged to 16-20 years, and thus entered into a relatively more suitable post-fire age class for species like the Red-lored Whistler and Southern Scrub-robin. Despite this, our models cannot account for the likelihood that already at-risk populations would be sustained through those transitional bottleneck periods in which only less suitable habitat and associated resources would be available. Likewise, there must be connectivity of suitable habitat over time to permit species to disperse to newly emerging suitable habitat within the reserve.

Development of scenarios using both a realistic simulation of the landscape, and using a format consistent with current departmental protocol provided a novel approach with informative output, but was accompanied by a number of limitations. Concerning was the common trend of decline in most suitable habitat over time, regardless of burning treatment. We propose that this decline, however, is unlikely to have proceeded indefinitely. Whilst two decades of planned burning simulations provided a valuable preliminary indication of long term trajectories, anticipated successional cycles occur on a much greater time scale. Scenarios projected over a time frame which allowed for the full cycle of burning for all three treatments (with no repeat or sacrificial burn areas) would likely show a cyclical trend in changing habitat suitability based on post-fire vegetation age. Thus projections beyond approximately seventy years would ideally be developed (*i.e.* at 5% burning *p.a.*, most vegetation in the reserve was treated following twenty years and thus was mostly of twenty years of age or less; following on from this, at 3% *p.a.* all vegetation would be treated following approximately 34 years, and would be 34 years of age or less; and at 1.5% *p.a.* all vegetation would be treated following approximately 67 years, and would be 67 years of age or less).

Likewise, conclusions were restricted by the use of only one set of scenarios, which meant the results were susceptible to the chance placement of planned burns and bushfire occurrences. Use of emerging technology to automate FOP production would enable both much longer term projections to be developed, and a replicated design which would allow us to determine species average response and negate the significant effect of single burn placements. Nonetheless, as our method was specific to current land management practice within the Victorian mallee landscape, was conducted using simulations of the actual landscape, and incorporated a historically realistic assessment of bushfire threat, future projections of planned burning provide a preliminary and valuable indication of long term trends of risk.

Echoing prior conclusions, these results suggest that even within a suite of threatened and fire-sensitive species, it is challenging to identify a unified approach for appropriate fire management (Taylor, Watson *et al.* 2013). Burning at 5% *p.a.* was shown to convert too much vegetation to younger age classes. Given that most threatened bird species showed highest preference for intermediate to old post-fire vegetation classes, it would likely follow that even 1.5% *p.a.* planned burning would be too high to sustain suitably aged habitat for this suite of fire-sensitive species on an ongoing basis. However, simulations showed that an historically representative level of bushfire alone did not convert enough of the landscape to younger vegetation to allow for emerging intermediate age classes for two species. Additionally, the continued occurrence of bushfire in the system leaves highly localised populations of species like the Mallee Emu-wren, Black-eared Miner and Red-lored Whistler vulnerable to unbounded bushfire events if no or very little planned burning were to be conducted. Given that there is a distinction in the degree of vulnerability shown by species to population decline, based on population size, endemism and range restriction, it may be necessary to focus most concerted conservation action towards those most at-risk to fire management, like the Black-eared Miner and Mallee Emu-wren. Continued application of small amounts of planned burning would ideally be targeted to control the placement of emerging suitable habitat with connectivity in mind and, critically, to mitigate potential bushfire spread into areas identified as important for species of high conservation concern (as recommended by Sandell, Tolhurst *et al.* 2006, Brown, Clarke *et al.* 2009, Pastro, Dickman *et al.* 2011).

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Appendix 1

The natural patchiness of planned burns was simulated in ArcMap using the following procedure:

1. Mapped areas of previous planned burns were replicated and merged together to form a single layer that extended well beyond the boundaries of the LMU.
2. Once the pseudo-FOPs had been mapped they were clipped to the cover layer to produce a final area burnt.
3. The layer was created in such a way as to ensure that the coverage produced by clipping to the pseudo-FOP polygons produced burns with 50-80% coverage. This is the target specified for burns identified as Landscape Management Zone. Landscape Management Zone burns are those which aim to achieve bushfire protection by: reducing overall fuel hazard, promoting ecological resilience, and management of the land for particular environmental values (DSE 2012).
4. For each pseudo-FOP, the coverage layer was altered slighted by adjusting its extent and position in order to ensure clips with subsequent burn polygons produced differing patterns and extents of unburnt patches within the burn boundary.
5. The final planned burn polygons used for evaluation of fire impacts on threatened bird habitat were those with the simulated burn coverage applied.

26. Do we need better questions?

John DeJose, Malleefowl Preservation Group; Member National Malleefowl Recovery Team

Abstract

This paper examines historical roles of government and non-government sectors in Malleefowl conservation in Western Australia from the early 1990s including recent moves to again consider state-wide strategy. It suggests that legacy effects may have left us in Western Australia tending a resource-intensive survey and monitoring system which may nevertheless be inadequate to differentiate signals from the noise in WA's ecosystems which are highly variable across time and space.

Do we know what the key management questions are for Malleefowl in Western Australia? Can our processes, institutions and governance change the inflection of current trajectories? Can they cope with climate change? Are we working on the stool but taking insufficient notice of the piano?

NOTE: This paper was not available at the time of printing.

27. Applying Adaptive Management Principles to Malleefowl conservation

Cindy E. Hauser, The University of Melbourne; Member National Malleefowl Recovery Team

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Abstract

The Malleefowl Recovery Plan highlights numerous potential threats to Malleefowl persistence and recommends adaptive management as an approach to integrate monitoring and management activities across the birds' range. In a series of papers, the Malleefowl adaptive management research team outlines the structure for such a program. We use community knowledge, the existing National Malleefowl Monitoring Database and supplementary data to inform our approach. Network ecosystem models will capture and prioritise the range of threats and actions potentially affecting Malleefowl persistence. High-priority and high-uncertainty issues, such as the efficacy of fox baiting to improve Malleefowl persistence, can be researched as scientific experiments. In addition to Malleefowl mound activity, supplementary data may be collected to support such experiments. All evidence built and lessons learned from these detailed experiments can inform future iterations of the network ecosystem model and allow new priorities to emerge over time. While these models can develop scientific evidence and provide guidance for management, successful Malleefowl conservation will continue to depend on the co-ordinated efforts and enthusiasm of policy-makers, environmental managers and community groups across the Malleefowl's range.

Introduction

In a context of myriad environmental threats, limited management budgets and poorly understood ecosystem behaviours, adaptive management is a popular planning approach. Adaptive management is a philosophy and set of scientific methods that allow for evidence-based action in the face of uncertainty (Walters 1986). It creates space for learning from the actions that are undertaken, and is thus often known as 'learning by doing'. However, it is much more than simply trial-and-error or learning from mistakes. Adaptive management is a strategic approach that balances learning opportunities against ecosystem responses to maximise overall environmental benefits (Runge 2011).

Ecosystem monitoring is a crucial component of adaptive management. While initial actions may be based on scant evidence and careful risk assessment, monitoring the ecosystem's response to actions allows managers to accumulate more evidence, adapt their thinking when needed and 'learn by doing'. In order to document this learning experience scientifically, uncertainties must be clearly articulated from the outset. This means carefully eliciting expert knowledge and regularly analysing monitoring data, converting these into meaningful evidence, tracking reductions in uncertainty as time progresses and adapting management plans to reflect the current balance of evidence.

Adaptive management is centred on management and not research. Learning and research activities are embarked upon only insofar as they are expected to directly increase environmental benefits (Runge 2011). In order to focus on management benefits, adaptive management requires that the objectives of a project be specified in a clear and measurable way.

Malleefowl conservation is a current candidate for adaptive management (Benshemesh & Bode 2011). The National Malleefowl Recovery Plan highlights the many potential threats to Malleefowl persistence, and adaptive management offers a method for prioritising activities to combat these threats. This prioritisation can occur even in the presence of uncertainty regarding the intensity of threat and the effectiveness of the candidate conservation actions. Furthermore, historical Malleefowl monitoring data and community knowledge provide a foundation of evidence to form initial models and predictions.

Here we provide an overview of the adaptive management research project for Malleefowl; some project components will be presented in more detail elsewhere in the Proceedings (Bode *et al.* 2014, Lahoz-Monfort & Hauser 2014, van Hespen *et al.* 2014).

Project Structure

The scope of Malleefowl conservation is vast given their extensive distribution, the range of threats to their persistence, and the network of government agencies, land holders and community groups involved in the management of their habitat. In this project we address Malleefowl management at multiple scales. At the broadest level, we use expert workshops and network ecosystem models to coarsely capture this conservation challenge as a whole. Then we develop a more detailed experimental design for a single threat and explore supplementary data to support this experiment. Finally we outline the process of learning and updating that will make best use of Malleefowl data and knowledge.

1. Expert workshop

In October 2012 the research team gathered experts at the University of Melbourne to develop Malleefowl conservation objectives (Figure 1), and then construct models linking threats, drivers and potential actions for a whole-ecosystem view. The group agreed that the fundamental objective of adaptive management should be:

The long-term persistence of a self-sustaining Malleefowl population over an unspecified range.

Means objectives were identified as a measurable path to achieving this fundamental objective. These included adult abundance, juvenile abundance and occupancy/range.

In an effort to capture diversity of thought and potential uncertainties in ecosystem behaviour, the expert team was divided into three groups. These groups developed independent models of threats to Malleefowl persistence, environmental drivers and potential conservation actions (Figure 2). Grazing, fire, rainfall and predation emerged as key issues. Potential conservation actions included:

- reducing grazing pressure
- controlling other species, e.g. predators (including introduced ones like foxes and cats)
- fire management
- Malleefowl translocation
- road signs
- influencing land use change and protection
- revegetation
- supplementary feeding.

A full record of the workshop and its findings are available on request.

2. Network ecosystem models

The traditional mathematical modelling techniques adopted for adaptive management, such as stochastic dynamic programming (Walters 1986), are suitable for addressing a modest set of uncertainties and ecosystem responses. However the expert workshop revealed that Malleefowl are placed within a complex ecosystem with many uncertain interactions. Bode *et al*. (2014) are investigating new approaches in network modelling, which translate the workshop models into millions of possible numerical interactions. Some of these models and interaction rules have been presented at a second expert workshop, held in conjunction with this National Forum, to identify and remove unrealistic scenarios. The refined set of models will offer some insight into key threats and uncertainties affecting the persistence of Malleefowl.

3. Experimental design for a single threat

Network ecosystem models will provide a coarse, overarching view of Malleefowl persistence. However they may not be suitable for directing specific management actions to individual Malleefowl sites. For this purpose, we additionally focus on a single threat-action candidate and develop a more detailed management plan based on methods of experimental design and statistics (Lahoz-Monfort & Hauser 2014).

We propose fox predation and baiting as a suitable threat-action pair. While foxes have undoubtedly been documented preying on Malleefowl eggs, chicks, and captive-reared birds, their cumulative effect on Malleefowl persistence is uncertain (Bode & Brennan 2011). Furthermore, the efficacy of fox baiting to reduce fox densities and interactions with Malleefowl warrants further investigation (Walsh *et al.* 2012).

Lahoz-Monfort & Hauser (2014) seek to monitor Malleefowl sites across Australia, with some sites baited for foxes and some not baited, and all sites monitored for Malleefowl activity. The authors show generic preliminary models that calculate the quantity of data needed to detect a fox-predation-response in amongst the natural year-to-year and site-to-site variations in Malleefowl activity.

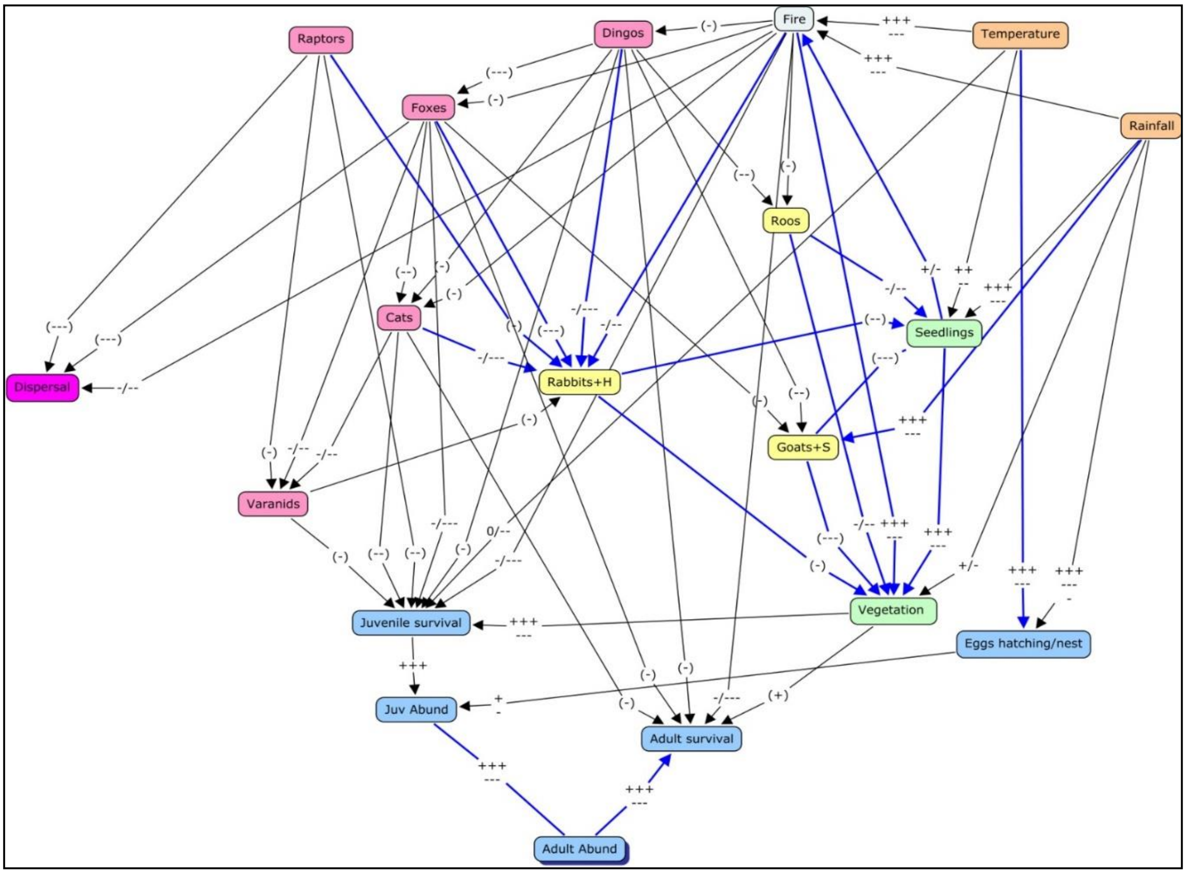
4. Supplementary data to support an experiment

Monitoring data in the National Malleefowl Monitoring Database will provide the important ecosystem response information for adaptive management. However it may be augmented with other data streams, particularly in the case of a focused management experiment.

As we evaluate the potential for fox baiting to reduce predation on Malleefowl, fox population density forms a crucial link between fox baiting and Malleefowl survival. Estimating fox density will allow us to distinguish the effect of fox baiting on foxes from the effect of foxes on Malleefowl.

Benshemesh (2014) has completed a pilot study on the use of camera traps in Malleefowl habitat and has secured funding for an expanded program. Van Hespen *et al*. (2014) will develop statistical designs that maximise the quality of information gathered by cameras, to help develop new evidence regarding fox response to baiting.

Figure 1. Brendan Wintle elicits knowledge from Malleefowl ecosystem experts at the 2012 workshop.



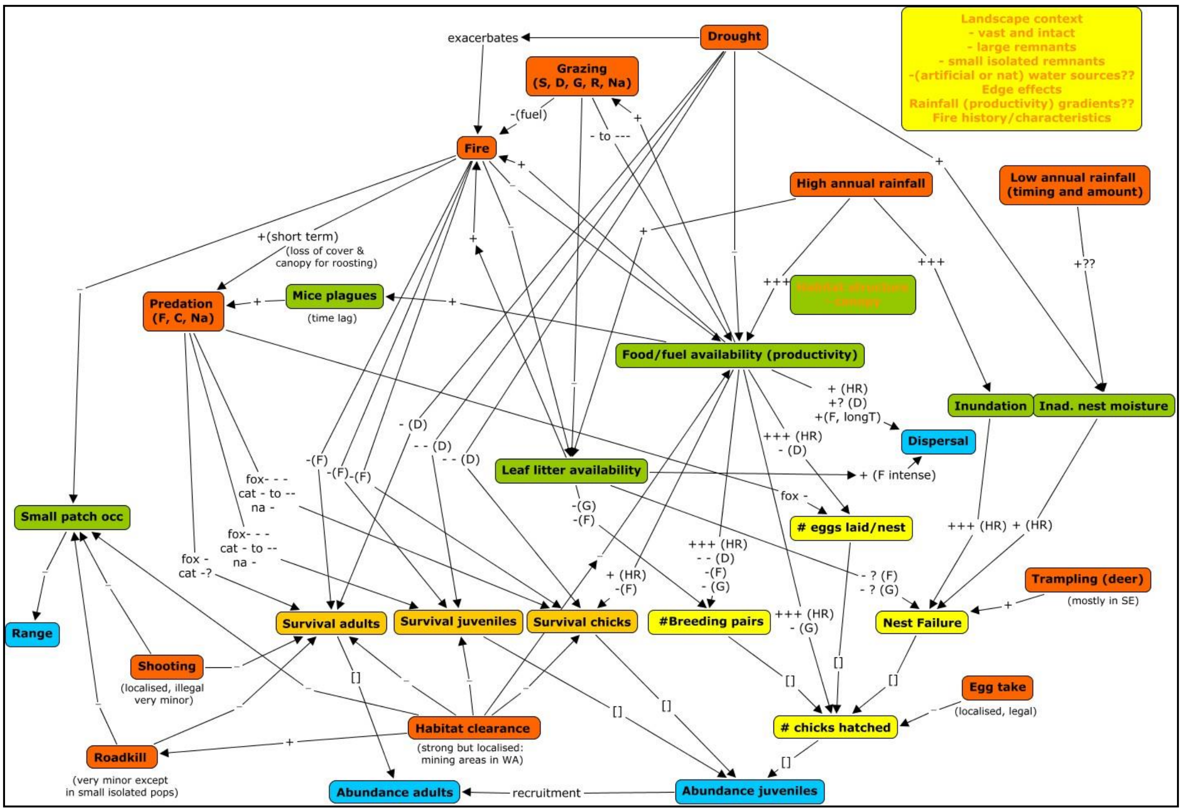


Figure 2. Two of the three independently-elicited ecosystem models for Malleefowl conservation and persistence developed at the 2012 workshop.

5. Learning and updating

The ecosystem network model, single threat experiment and supplementary data design described above can be considered a nested set of research projects operating at different scales and all serving an overarching adaptive management purpose (Figure 3).

We have drawn from community knowledge through elicitation workshops. This has provided structure to the *ecosystem network model*, which will allow us to prioritise promising threats and actions. When an action or threat is shown to carry influential uncertainty, a *single threat experiment* can be designed to learn more and resolve uncertainty. Malleefowl breeding activity drawn from the National Database will be an important resource, and the experimental design might also reveal other *supplementary data* (such as camera trapping to monitor fox activity) that will support the experimental design.

Supplementary data can then be used to update the findings of the single threat experiment. For example, fox camera trapping may help determine whether baiting affects fox density. Single threat experiment findings can be used to update the ecosystem network model, for example by establishing whether fox baiting influences Malleefowl persistence. Thus threats and actions can be reprioritised using updated knowledge and any remaining influential uncertainties become candidates for future single-threat experiments.

While experiments need not be restricted to one threat at a time, this formulation provides a simple template that demonstrates the range of issues and data that must be considered to build evidence and new understanding.

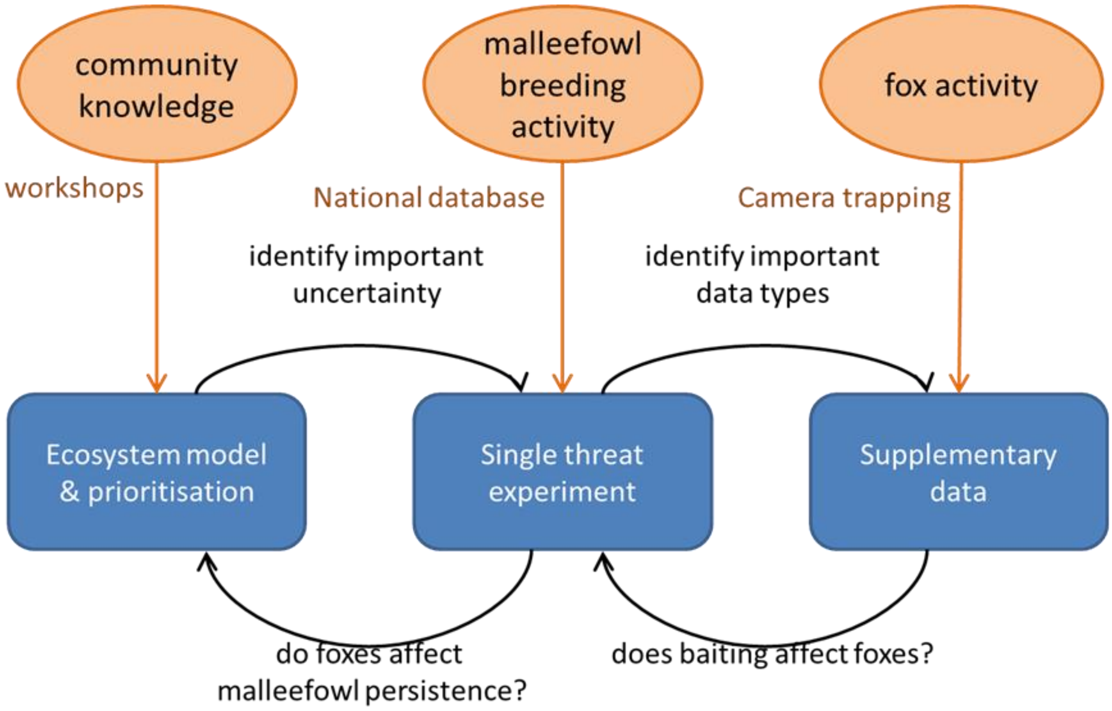


Figure 3. The adaptive management project structure. Research is divided into three components (blue boxes), each relying on knowledge and data (orange ovals). Progressing from left to right, projects become more narrow and detailed in scope. Narrow, detailed projects provide learning that can be used to update and influence projects with broader scope.

Conclusion

Malleefowl conservation is challenging, with numerous potential threats to their persistence via varying ecological processes. Their range covers vast areas and varied land tenures.

Adaptive management is a scientific approach that allows conservation objectives to drive the research questions. Coarse whole-ecosystem modelling is a means of structuring and prioritising these threats so that resources can be effectively allocated and bring Malleefowl the best chance of persistence. Experimental design and statistics will guide quality data collection. Data expands our evidence base and allows us to adapt. Nevertheless, it will require a co-ordinated and co-operative effort from many organisations and communities over decades to reap these benefits.

Acknowledgements

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28. Analysing the effects of ongoing and historical fox control on Malleefowl population viability

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Abstract

Although fox baiting is commonly applied to boost Malleefowl breeding activity, the performance of this intervention is contentious, with arguments and evidence on both sides of the debate. Reaching consensus is particularly difficult because historical data on fox baiting is uncertain, and has poor spatial resolution. We explore the logistics of what might be required in an adaptive management program to determine the effectiveness of fox baiting as a Malleefowl conservation tool. We calculate (1) how large the project should be (i.e. how many sites need to be observed), and (2) how long the experiment should be (i.e. how long they have to watch the sites for). A technique known as a 'power analysis' can be used to provide answers to these questions in advance, based on information already gathered by the National Database.

Introduction

The concept of experimentation is inherent to the adaptive management framework and relates to the need to monitor outcomes of management actions (Walters 1986, Runge 2011, see also Hauser *et al.* 2014 for an overview of the adaptive management project). Adaptive management sees management actions as experiments, chances to learn about the system. By monitoring the response of the system to 'experimental manipulation' in a way that is informative about our hypothesis, adaptive management seeks to reduce those aspects of uncertainty that impede clear decision-making so that we can be more confident about future management decisions.

Malleefowl conservation is a multifaceted and complex case. The ecosystem models elicited during an expert workshop (see Figure 2 in Hauser *et al.* 2014) reflect this fact. The adaptive management team is investigating mathematical modelling techniques to understand coarse scale relationships from these complex ecosystem networks (Bode *et al*. 2014). But decision-making regarding management actions related to specific links in an ecosystem within an adaptive management framework require more directed investigation based on experimental design and statistics. We select one of these ecosystem links (fox predation on Malleefowl) to showcase how experimental manipulation can be planned within the adaptive management framework.

Foxes and Malleefowl

There is ample evidence that foxes prey on Malleefowl at different stages of their life, from egg to adult (Benshemesh 2007). From the conservation management point of view, however, the real question is whether such predation compromises the long term survival of Malleefowl populations. This effect is uncertain (Bode & Brennan 2011). A population could withstand some level of predation, as long as during their reproductive lifetime each Malleefowl couple manages to produce on average two chicks that recruit into the population to replace them.

One of the main conservation actions currently undertaken in mallee areas where Malleefowl live is baiting to kill foxes and other predators. Whether this action actually contributes to the recovery of Malleefowl has been the subject of debate. The evidence in the scientific literature regarding these questions is rather mixed (Gates 2004, Walsh *et al.* 2012). The National Malleefowl Recovery Plan identifies the fox-Malleefowl ecosystem link as a high priority for investigation, because baiting is an expensive option but has the potential to prevent Malleefowl declines in some areas under some circumstances (Benshemesh 2007). We therefore selected fox predation to showcase an experimental approach for a single threat, within an adaptive management framework.

An experimental approach

The basic principle of the experimental approach is simple: we assume that a fox population in an area affects the Malleefowl population. Baiting for foxes takes place in an attempt to reduce fox density. The 'system response' (in this case the Malleefowl population) is observed, and statistical methods are used to try to find evidence in the collected data of whether the Malleefowl population has benefited from this action at the population level in the long term. Since measuring Malleefowl abundance (the ultimate reflection of the status at a population level) is in practice difficult, 'breeding activity' can be used as a proxy of how well a Malleefowl population is faring in a given area and year. For this species, breeding activity can be monitored through mound activity, a type of data that is already being collected by volunteers across the species' range and stored in the National Malleefowl Monitoring Database.

One powerful way of conducting the experiment is to use pairs of 'treatment' and 'control' sites, statistical terms for sites where the management action (here: baiting) is applied and sites where no action is applied, respectively. The mallee environment is variable, both temporally and geographically, and pairing similar sites in that way ensures that the comparison is as fair as possible.

Pairs of baited and unbaited sites should be selected with care. Within a pair, they should be close enough to share the same environmental conditions and their fluctuations over time (e.g. rainfall patterns). On the other hand, the sites should not be so close that the potential effect of baiting in a site influences the fox population at the unbaited site. For example, if foxes from the unbaited site end up poisoned at the nearby baited site, Malleefowl in the unbaited site will accidentally suffer lower predation and data will indicate that the baiting does not have a strong effect. Or if Malleefowl chicks born in the baited site (hopefully under lower predation pressure) end up eaten by foxes at the nearby unbaited site (where predation is high), it will again look like the baiting does not have a strong effect. A final practicality to keep in mind is that both control and treatment sites must have mound activity monitoring in place or starting for the experiment, in order for the system response to be observed.

In order to allow good statistical modelling and give the experiment a fair chance at disentangling the potential effect of fox baiting on Malleefowl abundance from the temporal and geographical fluctuations in environmental conditions that may also affect their abundance, we need replication. Replication simply means that several pairs of baited-unbaited sites are required, to capture that nuisance variation that is not of interest thus giving the best chance to detecting the true effect of fox baiting. In simple words: if the same reaction to baiting is observed again and again at many pairs of sites, conclusions can be drawn with more confidence.

In practice, the overall effect of foxes on Malleefowl can be divided in two parts or questions:
1. Is baiting effective to reduce fox densities?
2. Does a reduced fox density help increase Malleefowl population in the long term?

An important modifier could be added: under which geographic and environmental circumstances do the answers to these question matter most? What our current experimental approach attempts to find is whether there is an overall effect of fox baiting on Malleefowl abundance. Hopefully in the future we can use data from camera traps (Benshemesh *et al.* 2014, van Hespen *et al.* 2014) to collect data and understand the intermediate step: whether baiting is effective to reduce fox densities.

Preliminary power analysis

The next question when planning the experimental approach is how many pairs of baited-unbaited sites are needed to be able to make some useful inference about fox baiting. The adaptive management team conducted a simple 'statistical power analysis' to help answer that question. This statistical procedure requires lengthy computer simulations and analyses, but the basic principle behind it is quite simple. If the increase in Malleefowl breeding activity due to fox baiting is very large, then observing it at a few sites would be enough. At the other end of the spectrum, if the effect of baiting is very small, it will take many sites to detect it in a statistical analysis. Furthermore, a very small effect might not matter because it would indicate that fox baiting is not an efficient way of increasing Malleefowl breeding activity.
In order to conduct the power analysis, we first assumed a model that describes differences in mound activity between baited and unbaited sites in a statistical way (i.e. we created a 'system model').

Although the model was simple (e.g. it assumes all sites have 30 mounds, close to the average in the historic data) and does not reflect actual existing sites, we chose the parameters for the model based on historical data from the National Database. We then used a computer to simulate mound activity monitoring randomly using that system model, assuming a given effect of baiting (described as an X% increase in mound activity) and a number Y of pairs of baited-unbaited sites. We analysed the simulated monitoring data using the same system model and checked in what percentage of these analyses we would have detected (statistically speaking) a difference between baited and unbaited sites. That is, given that the effect did exist in the simulated data, how frequently our experiment would have been able to conclude it did exist: this percentage represents the power to detect that effect size. We then repeated the process for different scenarios representing combinations of: i) different strength of the effect of baiting (X%), ranging from very strong to negligible effects; ii) different number of pairs of baited-unbaited sites; iii) different number of years monitoring the system. Although not describing the procedure in detail, this is conceptually the idea behind a statistical power analysis.

The results of all these computer simulations can be plotted to show how power to detect an effect varies with the number of sites and the strength of the effect, for a given number of monitoring years (Figure 1).

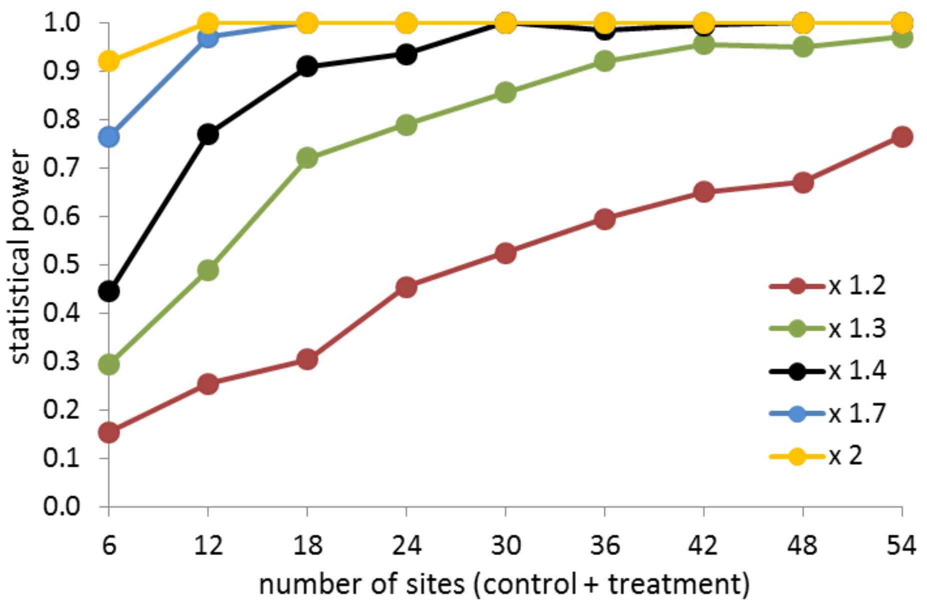

Figure 1. Statistical power after 4 years of experiment as a function of the number of experimental sites (significance level α=0.05). The curves represent different strengths of the effect of baiting on mound activity (increase in mound activity under baiting, compared to a baseline mound activity of 11%, the historic average of monitoring sites in Victoria). The horizontal red line marks the level of 80% power and the vertical line the power achieved for 18 sites (nine pairs of baited and unbaited sites).

The curves in Figure 1 show, for a given effect size, what is the statistical power that we can expect to achieve given a number of sites in the experiment, where statistical power represents the probability of detecting an effect of that size, if it exists. This is an important point: we are not saying it does, but estimating the power if that was the true value. The figure shows how the number of pairs of sites required for achieving a given level of power depends on how strong an effect of baiting we want to be able to detect: for a given number of sites, the stronger the effect, the fewer the numbers needed. For example, the horizontal line that marks 80% power indicates that around 12 sites (i.e. six pairs of baited/unbaited sites) are needed if the effect of baiting was an increase of 1.4 times in mound activity (black curve), but 24 sites if the true effect was an increase of 1.3 times (green curve). Conversely, for a fixed number of sites, higher power is achieved for stronger effects of baiting, as expected (see vertical red line). Note how it is rather 'easy' (high power) to detect large effects (e.g. approximately a doubling of mound activity; yellow or blue curves), and very 'hard' (low power) to detect small effects (even 50 sites are not enough if the effect is 20% increase (red curve).

Also, the longer the experiment is run, the higher power is achieved for a given number of sites, and different figures can be produced for different lengths of time.

Conducting experiments with natural systems is often trickier than in a laboratory. Ecosystems are always messier and more nuanced than the simplified model used in our power analysis. It is also difficult to find pairs of sites that experience exactly the same environmental conditions over time. Furthermore baiting can be conducted at different regimes of intensity and timing, and the experimental sites will be located within a broader geographic landscape in which other landowners may conduct baiting. As we begin incorporating real sites into the experiment, we can collect more detailed information and conduct a more detailed power analysis based on the specific conditions of the proposed sites, so that part of that real-world variability can be accounted for.

Furthermore, when analysing in the future the real data collected from the experimental sites, we will incorporate in the model information on the environmental variation to increase its power. We therefore expect that an effect of baiting will probably be slightly easier to detect than what is indicated by the current preliminary power analysis based on a non-tailored 'standard design'.

Conclusions

In summary, the ideal way of conducting such an experiment would be to find pairs of neighbouring sites where: a) one site can be baited and the other left unbaited as a reference; b) Malleefowl mound activity (the 'response' of the species) is being monitored or monitoring can be started; and c) paired sites are close enough to share the same environmental variability (such as how much rain falls in a given year), but not so close that baiting can affect what happens at the non-baited site. Finding pairs of sites that fulfil these conditions is challenging. The adaptive management team at the University of Melbourne, together with Tim Burnard and Joe Benshemesh, have set out to plan and organize such an experiment across the species' range. The process of contacting managers of potential sites has already started, with several potential sites in Western Australia and South Australia already under consideration.

Despite the challenges mentioned in the previous section, the experimental approach we propose is still our best shot to obtain a robust answer to the question of fox baiting as a management tool for Malleefowl conservation. A growing network of experimental sites will establish a solid base to provide the learning we need to improve management practices. And the methodology can be used more broadly, as it will serve as a blueprint to tackle other management uncertainties in Malleefowl conservation, such as the effect of fire regimes on Malleefowl populations.

It will take several years to gather enough data, so the sooner we start the better. In the adaptive management team, we are really excited to see the progress so far, and we are certainly open to suggestion regarding potential sites and participation in this large-scale fox baiting experiment.

Acknowledgements

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29. Camera trapping analysis of mallee wildlife

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Abstract

Joe Benshemesh has demonstrated the feasibility and promise of camera traps for observing mallee wildlife. Camera traps could provide important data on fox activity in both baited and unbaited sites as part of the adaptive management assessment of fox baiting. Camera traps would provide a crucial link between baits and foxes (does baiting successfully reduce fox density?) so that we can better establish the link between foxes and Malleefowl (does fewer foxes mean more Malleefowl?). We will model how fox activity is detected by camera traps and make recommendations on camera trap placement in the landscape to support a fox control experiment.

Project outline

Malleefowl (*Leipoa ocellata*) conservation is a complex process. Many different threats play a role in the decline of this bird species (Benshemesh 2007). Foxes are thought to be a major threat, but fox baiting in Malleefowl-inhabited areas has not led to a significant increase in Malleefowl abundance (Walsh *et al.* 2012). In an attempt to resolve uncertainty around the relationship between foxes and Malleefowl, a fox baiting experiment has been designed (Hauser *et al.* 2014, Lahoz-Monfort & Hauser 2014) to compare fox and Malleefowl abundance across paired treatment and control sites in various locations across Australia (Lahoz-Monfort & Hauser 2014).

Although established programs and protocols for monitoring Malleefowl exist across Australia, we lack data on fox densities in Malleefowl habitat. Fox density is the missing link between baiting actions and Malleefowl persistence. Camera traps promise to be a highly useful way to monitor foxes in remote areas. They are relatively low in cost, provide a non-invasive survey technique (Silveira *et al.* 2003), and have been successfully used in other fox monitoring projects (Sarmento *et al.* 2009).

In this project we will design a camera trap arrangement that is capable of detecting relevant changes in fox abundance. The first step will include a review of the literature on the use of camera traps, obtaining advice from experts, and analysing pilot data from a pre-existing camera trap survey (Benshemesh *et al.* 2014). Based on these findings, we will focus on designing a ‘prototype’ camera trap arrangement. Simulations will then be conducted to examine fox abundance in relation to different intensities of fox baiting, and the simulated data will be used to test the first camera trap arrangement. The camera trap arrangement will be adjusted accordingly, such that we are able to detect the smallest change possible for a stated monitoring budget.

Collecting data using a carefully designed camera trap arrangement will offer a new dimension to the existing Malleefowl activity data. It offers our best chance to discover whether baiting is useful to reduce fox density in Malleefowl habitat, and whether reducing fox density can benefit Malleefowl persistence. These data will support the broader adaptive management project (Hauser *et al.* 2014) in developing effective conservation actions for Malleefowl.

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30. Predicting Malleefowl dynamics using decision theory and qualitative ecosystem modelling

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Abstract

Conservation management often needs to answer urgent questions without knowing everything about how an ecosystem operates. Rather than ask for more time or resources to resolve this uncertainty, the field of decision theory gives managers the tools to make informed decisions using the current understanding of the ecosystem and its dynamics. Australia's mallee ecosystems and the Malleefowl (*Leipoa ocellata*) are both threatened and poorly understood. Although experts can readily describe the qualitative interactions between the ecosystem components, and although they have decades of observations and understanding of the ecosystem to draw on, it is not clear how to convert this information into the types of data required by decision theory tools. In this paper, I describe an approach that can potentially convert expert opinions into explicit and quantitative decision theory models. Building on cause-and-effect model frameworks developed by Parks Victoria, a series of expert elicitation exercises is used to describe both the model structure and parameterisation of an ecosystem model, without experts having to directly engage with the mathematical components of such models. As well as an outline of the methods, I provide preliminary results from two sets of expert workshops aimed at understanding and managing the threatened Malleefowl.

Introduction

Arid and semi-arid ecosystems contain some of the continent's most fragile and threatened species and communities (Millennium Ecosystem Assessment 2005, UNEP 2006). Australian is the globe's driest inhabited continent, with 70% of the land area being either arid or semi-arid, and this landscape contains some of the nation's most recognisable, unique, and threatened biodiversity (Stafford-Smith 1995). Australia has experienced one of the fastest rates of vertebrate extinction in modern history (Short and Smith 1994, Cardillo and Bromham 2001), and the biodiversity impacts of European colonisation have fallen disproportionately on low rainfall regions (Burbidge and McKenzie 1989, Stafford-Smith 1995, Sattler and Creighton 2002, McKenzie *et al.* 2007, Morton *et al.* 2011). In the coming years, the effects of anthropogenic climate change will be acutely felt in semi-arid and arid zones, and on these regions' uniquely adapted biodiversity. Without rapid and extensive management intervention, high post-colonial extinction rates will therefore continue.

The mallee is a fascinating and widely-appreciated semi-arid ecosystem in Australia, and one that has historically experienced severe environmental degradation and habitat loss. The Malleefowl (*Leipoa ocellata*) is one of the many species from the mallee whose populations have declined drastically since the arrival of European colonists, and whose range has contracted substantially (Benshemesh 1992, 1994, 2007, Parsons 2008). The species is now listed as threatened in every state that it occurs, and regarded as Vulnerable nationally. The Malleefowl is threatened by a range of factors (Woinarski and Recher 1997, Benshemesh 2007, Bode and Brennan 2011). These include inappropriate fire regimes, habitat loss and degradation, over-grazing, introduced species, and climate change that have also contributed to the decline or extinction of many other native species, including most medium sized (i.e., "critical weight range") vertebrates that are, like the Malleefowl, the preferred prey of invasive predators (Johnson 2006, Chisholm and Taylor 2007, 2010).

While the declining condition of Malleefowl and their fragile ecosystem is undeniable, realising this fact does not explain how these declines can be arrested and reversed. Despite more than one hundred years of research into the conservation of the species (Mellor 1911, North 1917, Frith 1959, Priddel and Wheeler 2004, Parsons 2009, Wheeler and Priddel 2009, Bode and Brennan 2011), it is not clear what management interventions will reverse their decline. For example, recent debates over more than two decades of Malleefowl monitoring data across Australia have questioned the conventional wisdoms that foxes (*Vulpes vulpes*) are a key threat to the species, and that poison baiting can improve the populations' viability (Benshemesh *et al.* 2007, Bode and Brennan 2011, Garnett 2012, Walsh *et al.* 2012). This uncertainty is not surprising – dryland ecosystems like the mallee are intrinsically difficult to understand due to their complex ecosystem structure, and their high spatial and temporal variability. These uncertainties will be compounded by the unpredictable results of future climate change. Managers in the mallee are therefore faced with a difficult situation – immediate action is required if further losses are to be averted, however, existing uncertainties obscure the choice of the most appropriate intervention.

Conservation management, a "crisis discipline", constantly confronts iterations of this difficult question: how should urgent action be taken with incomplete information? The field itself – an amalgam of practical management theory and ecological science – embodies the tension between a scientific desire to understand complex systems through further research, and practical need to act quickly, while funding and time remain. Pervasive uncertainty can no longer be seen as an excuse for delaying action until certainty is reached (Walters 1986, McLain and Lee 1996, Benshemesh and Bode 2011), since delays bring threatened species closer to extinction (Grantham *et al.* 2009), and may simply represent an unconscious desire to avoid facing invidious questions (Martin *et al.* 2012b). Conservation is therefore increasingly turning to quantitative decision theory to resolve the conflict. Decision theory approaches explicitly characterise and quantify the nature of key uncertainties, and also the benefits expected from either additional research or immediate action. As a consequence, decision theory allows managers to balance these competing factors, and thus to make decisions that maximise the "average" outcome. Among many other examples, decision theory has been used to make recommendations about the sustainable harvesting of wild species (Reed 1979, Hyberg 1987); the translocation of threatened species (Tenhumberg *et al.* 2004); the construction of predator exclusion fences (Bode and Wintle 2010, Bode *et al.* 2012); the eradication of invasive species from islands (Brooke *et al.* 2007, Bode *et al.* 2013) and their suppression in mainland landscapes (Baker and Bode 2013); and the effective reintroduction of captive-bred individuals from highly-threatened species (Runge *et al.* 2011).

Each of the decision theory examples listed in the previous paragraph is centrally concerned with decision-making under uncertainty. However, in every case the ecological system being managed is either relatively simple, or has been simplified for the purpose of analysis. This is true of decision theory as a broader field, perhaps because many of its applications have been interested in the management of single species– principally natural resource management questions concerning forestry, fisheries and game species management. A few notable exceptions exist in marine conservation and fisheries (Kellner *et al.* 2011, Hastings *et al.* 2014). However, these are often for only a handful (i.e., less than five) interacting species, and the techniques used are unlikely to be feasible in larger systems. Managing ecosystems that include dozens of key species (and therefore inevitably contain large amounts of uncertainty) remains an open question in both decision theory and conservation management.

The main limitation is not necessarily the ability to create ecosystem models that reflect the number of species in the real system, and the complex network of their interactions. Ecologists and conservation managers can readily and rapidly construct qualitative models that describe how the components in the system are connected. For example, Parks Victoria have created "Conceptual Ecosystem Models" for every one of Victoria's ecosystems, including the Mallee (White 2012). Although these ecosystem descriptions are not necessarily new (they are derived from food web theory), their use by management agencies is unusual. Constructing, publishing and using these ecosystem models are a considerable advance in the formal representation of complex ecological systems by managers. By explicitly describing the workings and dynamics of the ecosystem, these models provide a mechanism for translating individual understanding into shared institutional knowledge, and offer a foundation and language for discussion, debates and decisions.

However, despite their strengths, these tools have limited scope as predictive tools, because they are currently only qualitative. We call them qualitative because they describe what eats what, what competes with what, which species support each other, and which compete with each other. They are not quantitative because they do not specify how much of species i is eaten by species j. The main limitation is the inability to turn these qualitative models into quantitative models that will make precise predictions about the effects of an intervention. Qualitative models are useful tools for formalising our understanding of a system, but they cannot predict the consequences of actions. With only a qualitative understanding of a system, a particular conservation intervention (e.g. fox baiting or fencing) could have either positive or negative consequences on a species of interest (Levins 1974, Dambacher *et al.* 2003, Raymond *et al.* 2010).

Although there are tools available that can turn qualitative models into predictive quantitative models, the process requires a large amount of data. Unfortunately, while the ecological community has a very large amount of data available to it, much of it resides in the experiences of individual ecologists, land managers and natural historians. These data are inaccessible to most quantitative modellers because they are difficult to convert into specific numbers – growth rates, interaction strengths etc. Modellers have attempted to resolve this issue by asking ecosystem experts to estimate the numerical value of these parameters, but the process is difficult and painful because the relevant experts do not understand the system in these terms (Dexter *et al.* 2012). In this paper, I describe a novel method for collecting such data on mallee ecosystems, and converting it into quantitative model parameters. Essentially, I propose methods for turning experience and data into numbers, predictions and decision theory models. The method draws on the understanding and experiences of experts on mallee ecosystems and Malleefowl using a two-step elicitation process. This process first involves the creation of qualitative ecosystem models of cause-and-effect, and then involves eliciting information that can be used to parameterise these models using indirect methods. I finish by illustrating how the elicited data will be used to parameterise the models.

Methods and Results

Our method contains four steps: two elicitation workshops, and a parameterisation analysis. The purpose of the first elicitation workshop is to construct a qualitative model of mallee ecosystem dynamics. This model describes the key components of the mallee ecosystem, and indicates how they are connected through a series of directed, cause-and-effect linkages. The second elicitation workshop is aimed at creating quantitative information about the dynamics of the linked components of the mallee ecosystem, by mining the experiences of the participants. The final step is to join the results of these two workshops into a quantitative ecosystem model. The qualitative model of Malleefowl dynamics that was elicited in the first workshop will be formulated as a mechanistic mathematical model of the mallee ecosystem. Then, the information on dynamics elicited in the second workshop will be used to constrain the enormous uncertainty present in this quantitative model through a series of training steps. The actions involved in each of these steps is described in detail below.

Step 1: Eliciting the cause-and-effect models

To make predictions about the consequences of interventions into the mallee ecosystem, a quantitative model of that ecosystem needs to be formulated. The first step in this process is to describe the broad, qualitative structure of that model. The result is known as a “cause-and-effect” model, or a “qualitative model”. It describes the major components of the ecosystem, and how they are connected. These connections are not described in a very precise way; instead, each component is linked to other components using connections that are only described very broadly: predation, competition, etc. This information is much less precise than quantitative relationships, but it is much easier to elicit from experts in that ecosystem.

A workshop was convened in October 2012 at the University of Melbourne that comprised 22 individuals with expertise on mallee ecosystems, with a particular emphasis on the Malleefowl species itself. Participants included expert ecologists, managers from the state and federal government, university researchers, and stakeholders from the Malleefowl conservation community. These individuals were asked to list and describe all of the important elements in the mallee ecosystem, particularly those that are likely to have a direct or indirect effect on the Malleefowl species. These components included the key species (e.g. Malleefowl, foxes, goats, kangaroos), threats (e.g. fire, habitat loss), environmental variables (e.g. rainfall, temperature), and ecological processes (e.g. dispersal).

After each group enumerated the primary components of the ecosystem, participants were asked to join these components via cause-and-effect linkages. Essentially, they were asked to identify which of the components had a direct effect on any other component, and then to describe whether that effect was positive or negative. Direct effects exclude impacts that are mediated by another component (these are indirect effects). For example, foxes have a direct effect on Malleefowl, because individual foxes consume individual Malleefowl. If a room contained nothing but a fox and a Malleefowl, predation could still occur. In contrast, the effect of rabbits on Malleefowl will be indirect. Rabbits could impact Malleefowl by either providing resources that increase the population of foxes in the environment, or by damaging the quality of the vegetation that Malleefowl require for resources and shelter. These are both indirect effects (and would therefore not be included in our model), since their impacts on Malleefowl require the presence of another component. Returning to our room: if a rabbit and a Malleefowl were placed inside it alone, there would be no negative effects on the Malleefowl.

Once all these direct cause-and-effect linkages were identified, the component lists were translated into a qualitative model of the mallee ecosystem, with a focus on the Malleefowl (Figure 1). Diagrams of the model were returned to and discussed within the group to verify that it captured participants' beliefs about cause-and-effect, and to add in any remaining interactions not captured. These qualitative models are useful goals and products in their own right. The process of constructing them helps to formalise and capture beliefs about how ecosystems operate, and how their different components impact key management objectives (e.g. Malleefowl abundances). Moreover, explicitly capturing these beliefs in an easily communicated format (a cause-and-effect network), can help stakeholders understand each other's beliefs about the ecosystem, and identify precisely where they differ.

These cause-and-effect models are also an important foundational step towards the goal of making quantitative predictions, and thereby applying decision theory to the problem of Malleefowl management. As mentioned in the introduction, because they have extensive and complicated indirect interaction networks, cause-and-effect models cannot predict precisely what the effect of a given action will be, until the connections themselves are defined more precisely and quantitatively. To move towards this goal, following the workshop, the qualitative model shown in Figure 1 was converted into an equivalent quantitative form. Specifically, the qualitative model was translated into a sign-structured interaction matrix (Table 1). Then, the network nodes and interactions were expressed as a deterministic series of coupled differential equations of Lotka-Volterra form (May 1972):

$$\frac{dN_i}{dt} = \left[r_i + \sum_{j=1}^{S} \frac{\alpha_{ji} N_j}{K_i} \right] N_i$$

(Equation 1)

where N_i is the size of the population of species i, K_i is the carrying capacity of the environment for species i, r_i is the intrinsic growth rate of species i, α_{ji} is the per-capita effect of species j on species i, and S is the total number of species in the model (encapsulated in Table 1). The role of the ecosystem model described by the workshop was to constrain the matrix of interaction terms α_{ji}. Specifically, if the workshop participants did not connect nodes 2 and 3 directly (e.g. where 2 indicates Malleefowl and 3 indicates rabbits), then they were implying that $\alpha_{23} = \alpha_{32} = 0$. In contrast, if they drew an arrow with a negative sign from node 2 to node 1 (e.g. where 2 indicates Malleefowl and 1 indicates foxes), they were implying that $\alpha_{21} > 0$ and $\alpha_{12} < 0$. As a consequence, the interaction network described by the participants can therefore be considered equivalent to a sign-specified Lotka-Volterra interaction matrix (see Figure 2 for a simple example). The consequence is that there is a mechanism through which the dynamics of the ecosystem can be predicted using the model in Equation 1, and the specifications of the elicited interaction network (Figure 1, Table 1).

Table 1. Interaction matrix describing the direction and connection between ecosystem components shown in Figure 1. This table is equivalent to both the conceptual model in the Figure, and to the Lotka-Volterra systems used to generate the ecosystem dynamics in Figure 3 and Figure 4.

	1. Rain	2. Temp	3. Fire	4. Dingoes	5. Foxes	6. Cats	7. Varanids	8. Raptors	9. Goats	10. Kangaroos	11. Rabbits	12. Seedlings	13. Vegetation	14. Malleefowl
1. Rainfall	-1	0	-1	0	0	0	0	0	1	0	0	1	1	1
2. Temp	0	-1	1	0	0	0	0	0	0	0	0	1	1	2
3. Fire	0	0	-1	1	1	1	1	1	-1	-1	-1	-1	-1	-1
4. Dingos	0	0	0	-1	-1	-1	-1	0	-1	-1	-1	0	0	-1
5. Foxes	0	0	0	0	-1	-1	-1	0	-1	-1	-1	0	0	-1
6. Cats	0	0	0	0	0	-1	-1	0	0	0	-1	0	0	-1
7. Varanids	0	0	0	0	0	0	-1	0	0	0	-1	0	0	-1
8. Raptors	0	0	0	0	-1	-1	-1	-1	0	0	-1	0	0	-1
9. Goats	0	0	0	1	1	0	0	0	-1	0	0	-1	-1	0
10. Kangar	0	0	0	1	2	0	0	1	0	-1	0	-1	-1	0
11. Rabbits	0	0	0	1	1	1	1	1	0	0	-1	-1	-1	0
12. Seedlg	0	0	1	0	0	0	0	0	1	1	1	-1	1	1
13. Veg^n	0	0	1	-1	-1	-1	-1	-1	1	1	1	1	-1	1
14. MalleeF	0	0	0	0	1	1	1	1	0	0	0	0	0	-1

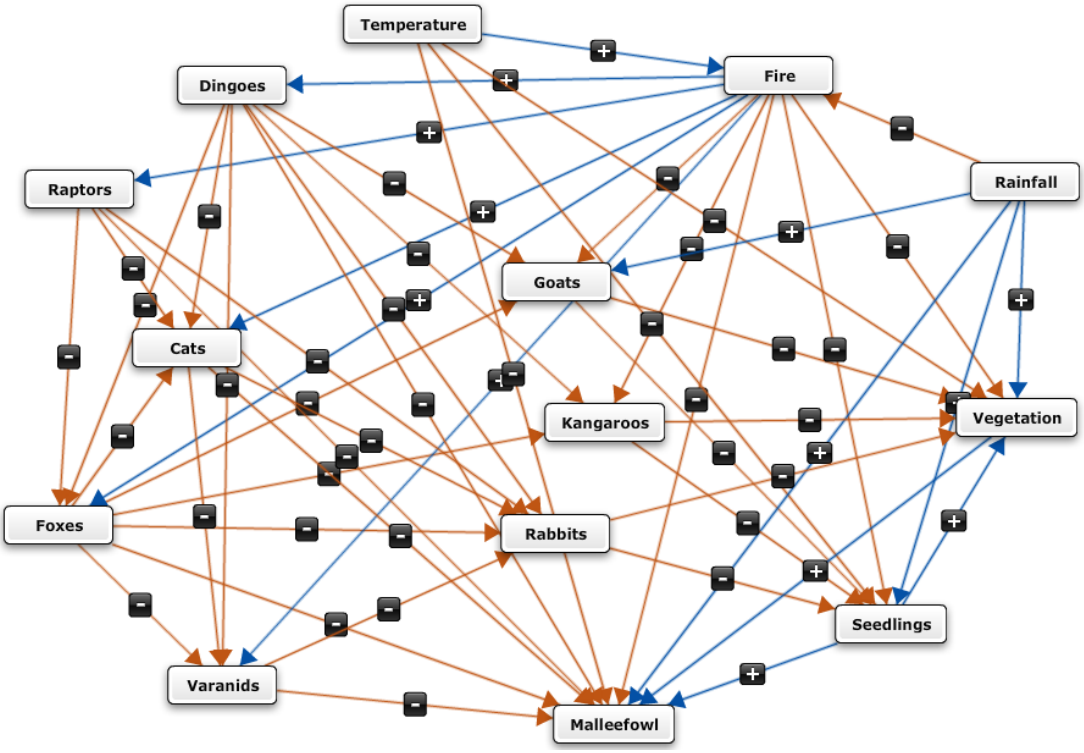
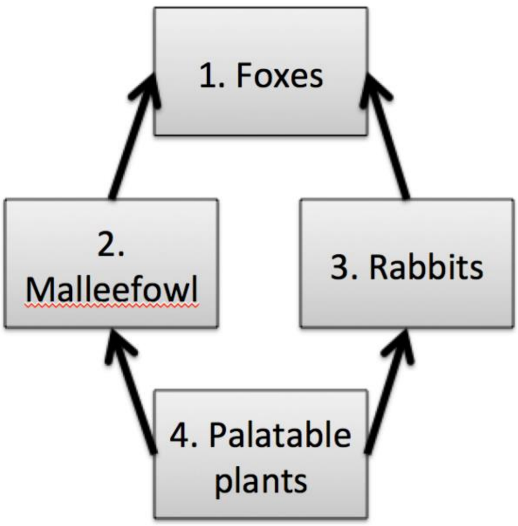


Figure 1. Conceptual cause-and-effect model of the mallee ecosystem devised in the first workshop. Each labelled node refers to a key ecosystem component considered important by the workshop group. Arrows indicate the direct cause-and-effect connections between the nodes, with the signs and colours (red is negative; blue is positive) indicating whether those connections had a positive or negative effect on the population at the arrow-end of the connecting line. Many negative effects have symmetrical positive effects in the opposite direction (e.g. predation is negative for the prey and positive for the predator). These are not shown here, although they can be seen in Table 1, which is equivalent to this model.



$$\alpha = \begin{bmatrix} - & - & - & 0 \\ + & - & 0 & - \\ + & 0 & - & - \\ 0 & + & + & - \end{bmatrix}$$

Figure 2. Example conceptual model of a four-node ecosystem (left). The Lotka-Volterra interaction matrix corresponding to the conceptual model (right).

Step 2: Eliciting information about the mallee ecosystem dynamics

Models are only as good as the information that goes into them. The purpose of the second workshop was therefore to gather together a set of mallee ecosystem and Malleefowl experts to help train these models for the mallee ecosystem. To this end, 18 participants gathered together at Dubbo Zoo in October 2014 from a range of stakeholder groups. Once again this included expert research ecologists, Malleefowl conservation volunteers, and managers from the state and federal government. These experts were chosen because they had observed Malleefowl and the mallee ecosystem for a long period of time, not because they had particular quantitative skills. As a result, no attempt was made to elicit a priori numerical data from this group. Instead, a structured elicitation process was undertaken where participants were separately asked to choose between a range of options, each of which represented the consequences of a particular set of quantitative assumptions. Through a series of questions and discussions, the quantitative beliefs of the group were indirectly revealed, without participants being required to explicitly express those beliefs in a quantitative form.

Each of the participants was given a series of timeseries graphs that illustrated the response of a hypothetical mallee ecosystem to a particular disturbance (see Figure 3 for an example). These timeseries were called “ecosystem scenarios”. Each ecosystem scenario is defined by only two factors. The first is the dynamics of one particular ecosystem species, shown by coloured lines, the second is the dynamics of a particular ecosystem driver, shown by coloured bars. “Mallee ecosystem” meant a local region made up of approximately 10,000 hectares of mallee habitat that was suitable for Malleefowl, similar to that found in north-western Victoria (i.e. “Murray Mallee”). The habitat quality in the location is not necessarily pristine, but it is still predominantly intact and healthy mallee.

The first part of the timeseries shown in each scenario (the far left hand side) represented the initial conditions present in the area for the ecosystem component. In Figure 3, the chosen component was Malleefowl, but different scenarios involved other ecosystem components as well, chosen from the ecosystem model. These initial conditions represented a “normal year” in the mallee. In this case, normal meant that there hadn’t been any serious events (e.g. fires, droughts, floods, locust outbreaks) for more than five years. The abundance of all the components of the ecosystem are therefore around their normal levels during the initial phase, which we represent as a value of 100% (see the y-axis).

After one year (i.e. at $t = 1$), a perturbation impacts the system. This can be seen by the immediate change in the previously constant bars. In Figure 3 this change was the increase in the amount of rainfall in the first month of the second year (the first year begins at $t = 0$), that continues through until the end of that first year. It is assumed that that there are no other exogenous changes occurring in the system (i.e. that any other changes that occur are the direct or indirect result of this change).

In response to this perturbation, the abundance of the species may also change (although it may not). The scenarios proposed a series of six different hypothetical ways in which the particular ecosystem component could respond (note that this number may vary slightly between scenarios). These different responses represent different descriptions of the underlying ecosystem dynamics, any of which may be true. They were chosen to represent a wide variety of possible outcomes, including populations that increased, decreased, oscillated and were unaffected by the perturbation in the ecosystem driver. As stated earlier, there are no other exogenous perturbations occurring during this timeseries, although the other components of the system are changing, but are not shown.

The task of the workshop participants was to choose which one of the six scenarios accurately represented their personal prediction about how the ecosystem would respond to the perturbation. In each scenario, the participants were asked to consider the scenario, and then to pause and consider (1) The component of the ecosystem that is responding to the perturbation, (2) The role played by that component in the ecosystem, (3) The direction of the response to the perturbation (e.g. increase, no change, cyclic), (4) The magnitude of the response (e.g. 50% increase, doubling in abundance) and (5) The speed with which the species responds to the perturbation (e.g. immediate, or delayed). Once these factors had been considered, the participant was asked to classify each possible outcome as either possible or impossible, or whether they could not be certain. Possible motivations for considering a particular dynamic possible were that the participant may have observed this outcome first hand. Alternatively, they may have heard about this outcome from someone else who observed it themselves. Finally, it is possible that they consider it plausible because it agreed with their understanding of the ecosystem.

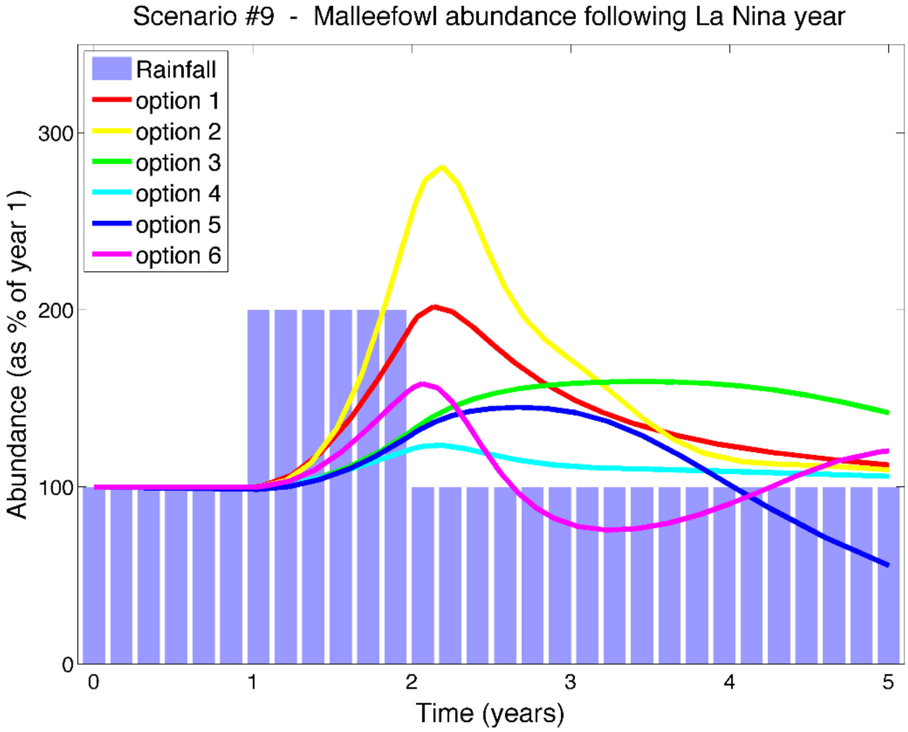


Figure 3. An example ecosystem scenario, as used in the second workshop. Modelled dynamics correspond to Figure 1 and Equation 1. Scenarios are defined by two factors: (1) the dynamics of a particular ecosystem species, shown by coloured lines. Each line offers an alternative response of the species to the perturbation. (2) The dynamics of a particular ecosystem driver, shown by coloured bars. In this case the driver is rainfall. In response to a perturbation in the driver, the abundance of the species may change. Participants were asked to choose between these alternatives, or to offer another option.

The participants were then asked to report their beliefs about each outcome, briefly explaining why they had come to that conclusion. Finally, they were asked to draw their belief about the dynamics onto the graph, indicating how they thought the ecosystem component would respond (their best guess), and also their level of uncertainty around that best guess, drawn using an uncertainty envelope (Figure 4). If they believed that one of the six proposed dynamics was an accurate reflection of their belief, they were asked to expand an uncertainty envelope around that best guess to indicate how unsure they were of what the true dynamics would be. This envelope represented plausible bounds, rather than confidence intervals, and so it was assumed to imply nothing specific about the shape of the participant's belief distribution (i.e. it did not imply that dynamics toward the middle of this envelope were proposed as being more probable than dynamics which were toward the periphery of the envelope).

Figure 4 shows the beliefs of one participant about how Malleefowl populations (defined by all individuals older than 3 months) would respond through time to a 100% increase (i.e. a doubling) of the average rainfall for a single year. The grey envelope described a broad range of responses that the participant thought were within the bounds of possibility. The workshop generated 75 such results, indicating the responses of 14 participants to 15 scenarios, involving four perturbations on six different species (note that not all participants were able to respond to all the scenarios in the time allotted during the workshop). The perturbations were an increase in rainfall for a single year; an intense fox baiting program, a two year period of intense overgrazing, and a severe fire that impacted more than half of the habitat. The responding species were Malleefowl, palatable vegetation, cats, rabbits, kangaroos, and foxes.

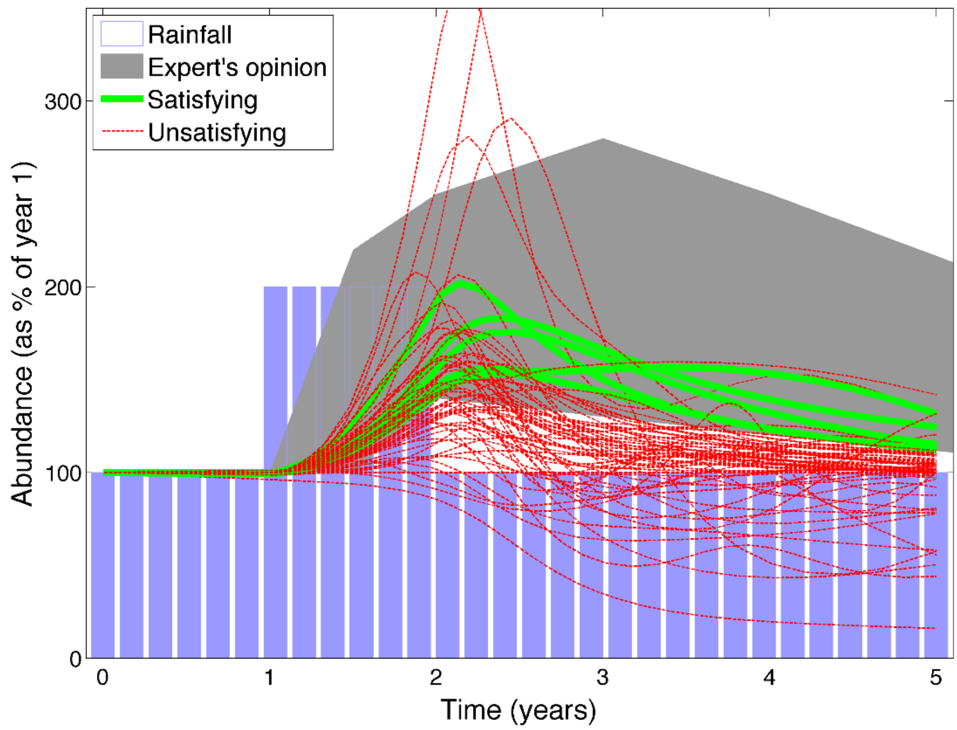


Figure 4. As in Figure 3, the bars indicate the change in an ecosystem driver in the model shown in Figure 1 and Equation 1. However in this figure the grey envelope indicates the opinions of an expert from the workshop. The lines represent predictions of random ecosystems generated by the modelling framework. Green lines correspond to five randomly generated models (the predictions of these five models are shown in green) that agree with the expert opinion. Red lines (that fall outside the envelope) correspond to 50 different randomly generated models that do not agree with the expert, and which would therefore be discarded from further consideration.

Step 3: Parameterising the ecosystem models using the dynamical information

The information elicited from each of these two workshops are interdependent – they concern the same ecosystem and species. The data contained in both was gathered with the purpose of constraining our understanding, and narrowing our predictions about mallee ecosystem dynamics. Our uncertainty about the dynamics of the mallee can be thought of as a very large set of models, which vary in (a) their structure, and (b) their parameterisation. We're initially faced with an enormous number of models, any of which could be true. If this number of models is reduced, our uncertainty about the dynamics of the system is reduced also. The goal of the two workshops is to reduce our uncertainty by removing models from consideration in two different ways.

The first workshop described the key functional components of the complex mallee ecosystem, with a particular focus on identifying those components that would have the greatest impact on Malleefowl populations. It then connected those components that were directly interdependent. Defining the cause-and-effect relationships in an ecosystem dramatically narrows our uncertainty about mallee dynamics. It does this in two ways. First, by identifying a group of approximately 20 important species, functional groups and drivers from an ecosystem that contains many more. Second, by identifying which of those important components interact, and which do not. This latter step is a considerable specification of the system – a dynamical system of 20 components could be described by an effectively infinite number of different cause-and-effect models (each component i could be joined to each component j by either a positive value, a negative value or zero, giving 3,400 options. There are vastly more of these than there are atoms in the observable universe!). From among this vast number of options, the first workshop highlighted a very small subset as being in keeping with our ecological understanding of the mallee.

Even though this structural description of the system reduces the number of potential ecosystem models, an unlimited number of potential ecosystem models still remains. Random number generation can be used to generate any number of these models as follows. Equation 1 can completely describe the dynamics of a system of S species, if $S(S+1)$ parameters are specified. For example, to model the ecosystem shown in Figure 2, Equation 1 needs a specification of 20 different parameters (Table 2; note that the population abundances Ni are variables and not parameters since they will change through time). An ecosystem model can be specified simply by choosing random values for these 20 different parameters. As long as the values are chosen from an unbounded probability density function (e.g. a one-tailed normal distribution, or a lognormal distribution), any ecosystem that can be described by Equation 1 can be randomly generated (in practice, the probability density function from which these values are chosen will influence the relative probability of choosing any particular ecosystem model).

Table 2. Parameters used in the Lotka-Volterra equivalent of the conceptual model shown in Figure 1.

Parameter symbol	**Parameter interpretation (all effect parameters are per-capita *i*, per-capita *j*)**
r_1	The growth rate of foxes
r_2	The growth rate of Malleefowl
r_3	The growth rate of rabbits
r_4	The growth rate of palatable plants
α_{11}	The effect of foxes on foxes (density dependence, and therefore negative)
α_{12}	The effect of foxes on Malleefowl (predation, and therefore negative)
α_{13}	The effect of foxes on rabbits (predation, and therefore negative)
α_{14}	The effect of foxes on palatable plants (no effect, and therefore zero)
α_{21}	The effect of Malleefowl on foxes (preyed upon, and therefore positive)
α_{22}	The effect of Malleefowl on Malleefowl (density dependence, and therefore negative)
α_{23}	The effect of Malleefowl on rabbits (no effect, and therefore zero)
α_{24}	The effect of Malleefowl on palatable plants (herbivory, and therefore negative)
α_{31}	The effect of rabbits on foxes (preyed upon, and therefore positive)
α_{32}	The effect of rabbits on Malleefowl (no effect, and therefore zero)
α_{33}	The effect of rabbits on rabbits (density dependence, and therefore negative)
α_{34}	The effect of rabbits on palatable plants (herbivory, and therefore negative)
α_{41}	The effect of palatable plants on foxes (no direct effect, and therefore negative)
α_{42}	The effect of palatable plants on Malleefowl (potentially consumed and used for reproduction, and therefore negative)
α_{43}	The effect of palatable plants on rabbits (consumed, and therefore positive)
α_{44}	The effect of palatable plants on palatable plants (density dependence, and therefore negative)
N_1	The population density of foxes
N_2	The population density of Malleefowl
N_3	The population density of rabbits
N_4	The population density of palatable plants

Most of these randomly generated models will be incorrect, even though they match the structure of the mallee ecosystem. The purpose of the second workshop was to provide a method for identifying and discarding incorrect ecosystem models. The envelopes described by the experts for each scenario can be directly compared to the output of one of our ecosystem models. When a model is randomly generated, the envelopes allow us to consider whether that model satisfies the opinions of our different experts. If it does not, then it is removed from consideration. If it does, then it is saved into a pool of satisfying models, where it will await comparison with the next envelope. If enough different envelopes are applied, that pool will only contain models of the mallee ecosystem that can recreate a wide range of plausible mallee ecosystem dynamics.

Figure 4 illustrates this process for one of the envelopes created during the workshop, by a single expert. The grey region captures the uncertain beliefs of one particular expert about the response of Malleefowl to a year of higher-than-average rain. The different lines illustrate the predictions of 50 different ecosystem models (Equation 1), parameterised in accordance with the cause-and-effect model structure. Most of these different ecosystem models do not agree with the expert's opinion (the red dashed lines), and are therefore discarded from further consideration. However, five of the options considered did fit entirely within the expert's envelope (the solid green lines). These models would then be returned to the plausible set for further consideration.

Discussion and future directions

The results shown in this paper are only the partial outputs of two workshops. In their entirety, the first workshop constructed three ecosystem models, while the second workshop produced 75 envelopes. However, while very preliminary, these results do demonstrate that the two forms of data are not incompatible (Figure 4). The construction of the ecosystem models, and their comparison with the expert information remains incomplete at the time of this writing because both steps are computationally very time-consuming. The methods described here are extensions of ideas first devised by Richard Levins in the 1970s (Levins 1974), but which remained beyond the scope of computational tools until only the last decade (Raymond *et al.* 2010). Therefore, expanding them to multiple ecosystem models and multiple expert opinions will involve entry into novel scientific waters.

As well as offering useful tools for the management of both Malleefowl and mallee ecosystems, these methods raise a number of interesting conceptual issues and offer new analytic perspectives from which to consider them. Parameterising the expert-derived ecosystem models with the expert-derived dynamical envelopes demands a large degree of consistency between two very different expert representations of the ecosystem. The first is a cause-and-effect model of the ecosystem, similar to a food web. The second is a partial description of the ecosystem dynamics' response to exogenous perturbations. This method therefore offers an interesting and quite novel integration of the two fields.

Finally, by performing the elicitation of both models and envelopes multiple times, the method is also testing the consistency of different descriptions and understandings of how the ecosystem operates. The degree to which these different understandings align is an interesting question, since consistency among experts is currently a matter of some debate and importance in applied ecology and conservation management (Kuhnert *et al.* 2010, Burgman *et al.* 2011, Martin *et al.* 2012a). Furthermore, given that there will inevitably be some degree of disagreement between the experts, it will be interesting to see whether a single quantitative model of the ecosystem will nevertheless be able to satisfy all, or a large proportion of experts.

As described in the introduction, conservation management involves the difficult process of making urgent decisions under uncertainty. Qualitative descriptions of ecosystem structure are readily available, as illustrated by this project's ability to elicit three different ecosystem models in a week-long workshop, and by Parks Victoria's creation of ecosystem models for all 16 of the state's natural ecosystem groups. The dynamical envelopes elicited in the second workshop also represent readily available information on ecosystems. The fact that it was possible to elicit 75 different time-series predictions from a group of 14 participants in approximately three hours attests to the large amount of latent information held by experts in land management, research and natural history. It also illustrates how this approach, which emphasises simple graphical descriptions of different ecological scenarios, represents a much less painful form of expert elicitation (painful for both the experts and the elicitors) than asking them to numerically estimate parameters. This is despite the fact that both methods are providing essentially the same information. The approach described in this paper therefore has the potential to play an important role in future ecosystem management if the results prove interesting – even more so if they prove useful.

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31. A brief history of Malleefowl conservation and monitoring efforts in the Goonoo forest, New South Wales

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Abstract

The Goonoo forest consists of both public and private forest covering an area of around 90,000 hectares (ha). Low sandstone ridges and slopes comprising low fertile sandy loams dominate the area with a few major alluvial valleys of clays, silt, sand and gravels. Black cypress pine, ironbarks and red gums dominate the area with common understorey species that include allocasuarinas and wattles. The forest supports the most eastern population of Malleefowl remaining in Australia.

Landholder and agency interest in the local Malleefowl population sparked the beginning of a fox control program in the 1980's. The program progressively grew with the aim to control foxes in the public forest and the surrounding land within a 20 kilometre (km) buffer.

Malleefowl monitoring activities have included ad hoc breeding observations, coordinated mound searches, recording mound activity and mound observations using remote cameras. Other studies in the area have assessed the effectiveness of the fox control program. Results showed that locally fox activity can be reduced following baiting however across the landscape temporal and spatial gaps in baiting can lead to foxes not encountering baits, thus reducing the effectiveness of the program as foxes move quickly into baited areas.

In spite of these initiatives and efforts, the state of the Malleefowl population in the forest remains unclear. Limited resources inevitably reduce the effectiveness of monitoring activities and restrict the understanding of the stability, or otherwise, of the population. Monitoring activities have, however, uncovered interesting and important aspects of potential threats to the success of Malleefowl in the area, such as the observation of high levels of goanna activity detected at active mounds. Future research and the development of a more rigorous monitoring program, including targeted mound searches, is a high priority for the population and will direct more effective management actions.

The Goonoo Forest

The Goonoo is an area of public and private forest located approximately 40 km north-east of Dubbo on the central western slopes of New South Wales. The public forest covers an area of around 62,500 ha and is adjoined by a further 27,000 ha of private forest, all together surrounded by farm land. The Goonoo is the largest remnant forest in the region, with the Pilliga forest (530,000 ha) around 100 km to the north. The forest originally supplied timber for settlement needs and then became an important supplier of railway sleepers during the late 19th century. The Goonoo State Forest was dedicated in 1917 and continued to supply timber for sleepers, fencing and firewood (FCNSW 1988) prior to 2005 when the forest was gazetted National Park and State Conservation Area. The adjoining landscape comprises a forest and cleared land matrix.

Low sandstone ridges and slopes with low fertility sandy loams dominate the area while the few major alluvial valleys are comprised of clays, silt, sand and gravels. Elevation ranges from 320 m above sea level in the west where the terrain is relatively flat to 500 m to the east where the country has more defined gullies and ridges with a mean altitude of 387 m (SD = 31). The vegetation formation is classified as western slopes dry sclerophyll forest (Keith 2004) and is dominated by black cypress pine (*Callitris endlicheri*) and less commonly white cypress pine (*C. glaucophylla*), ironbarks (*Eucalyptus crebra, E. nubila* and *E. beyeriana*) and red gums (*E. dwyeri* and *E. blakelyi*) (Beckers & Binns 2000). Understorey vegetation includes *Allocasuarina diminuta*, *A. gymnanthera*, *Acacia triptera* and *Calytrix tetragona*. The forest supports one of the few populations of *Zieria ingramii*, an endangered shrub found only in central

New South Wales, from Goonoo to Cobbora forest. Long term mean annual rainfall for Dubbo is 585 mm, while mean daily temperatures range from 2.6 to 15.2 C in winter and 17.9 to 33 C in summer (http://www.bom.gov.au/climate/averages/tables/cw_065012.shtml, accessed 2007).

The Goonoo forest is important ecologically because of its isolation from areas of mallee to the west and it supports a number of species, including the Malleefowl (*Leipoa ocellata*), that are at or close to their eastern limits (Heron 1973). The NSW Fox Threat Abatement Plan (Fox TAP) lists Malleefowl in the Goonoo as a high priority threatened species for fox management (NPWS 2001). The Goonoo has been listed as one of around 12,000 Important Bird Areas across the world and identifies the need to protect and manage the isolated populations of the vulnerable Malleefowl, as well as significant numbers of the near threatened diamond firetail (*Stagonopleura guttata*) and small numbers of the vulnerable painted honeyeater (*Grantiella picta*) (BirdLife International 2014). Other species of interest in the Goonoo forest include the glossy black-cockatoo (*Calyptorhynchus lathami*), koala (*Phascolarctos cinereus*), regent honeyeater (*Anthochaera phyygia*), gilbert's whistler (*Pachycephala inornata*), turquoise parrot (*Neophema pulchella*), barking owl (*Ninox connivens*), masked owl (*Tyto novaehollandiae*), square-tailed kite (*Lophoictinia isura*), squirrel glider (*Petaurus norfolcensis*) and the eastern pygmy-possum (*Cercartetus nanus*). The bush-stone curlew (*Burhinus grallarius*), a largely sedentary bird, is found in the woodland areas surrounding the forest; this, and other species restricted to the forest, such as the pygmy-possum, are also considered susceptible to fox predation. The main threats to Malleefowl in this area include loss of habitat from clearing and fire as well as predation by foxes. Recent major fires occurred in 2004 and 2007 affecting large areas of the forest. Hazard reduction burns are carried out to minimise the large-scale threat to Malleefowl and other assets.

Malleefowl observations in the Goonoo

The first published report of Malleefowl occurring in the Dubbo area was in 1954 when the Breelong forest, which then adjoined the Goonoo forest was mentioned in Griffiths NSW survey of Malleefowl (Korn 1989). Additional reports were published by Sharland (1966), Heron (1973) and Morris (see Korn 1989) where his survey in 1984 estimated a maximum of 12 breeding pairs. Korn (1989) suggests, following his investigations over the six years prior to 1989 that many more pairs than this estimate breed in the forest or its immediate surrounds. Korn (1986) also noted a Malleefowl attacked by a Brown Goshawk, and made other observations using a hide installed at a mound in the Goonoo forest. These early observations and those of many others since inspired actions to protect the Malleefowl in the area.

Goonoo Fox Control Project

Landholder and government agency interest in the local Malleefowl population sparked the beginning of a fox control program in the 1980’s. The program progressively grew with the aim to control foxes in the public forest and the surrounding private land within a 20 km buffer. The then Rural Lands Protection Board (RLPB, now Local Land Services), Forests NSW (FNSW) and National Parks (NPWS) staff together with a group of landholders met to plan fox control operations in autumn and winter.

Members of this coordinators group had specific roles and tasks to ensure the programs implementation was successful. RLPB was responsible for media releases, preparing and distributing newsletters and facilitating coordinator meetings. FNSW and NPWS notified neighbours, attended coordinators meetings, distributed baits and monitored bait stations. Private landholders notified neighbours, organised bait distribution meetings, “sold the program” to the community and provided feedback. To encourage and maintain participation of stakeholders, bait distribution meetings on the landholder coordinators’ properties would also include guest speakers on current issues from experts such as the district vet, rural fire service or the local weeds council.

Bigfoot Walk through

A Malleefowl conservation program known as the “Goonoo Lands Bigfoot Project” operated between 2004 and 2007 with the aim of monitoring the Malleefowl population. The program was coordinated by a community representative with assistance and guidance from FNSW, RLPB and NPWS staff and the local community. Monitoring included periodic visits to Malleefowl mounds that were known to have been recently active. In 2004, 107 agency staff and volunteers walked strategically through forest compartments (2.8% of the Goonoo forest area) and successfully carried out searches for unknown mounds. An additional 53 mounds were located at varying stages, the majority inactive. This collaborative approach (Invasive Animal CRC 2012) to protect both natural and agricultural assets, with its high level of stakeholder interest, has and continues to, provide a good foundation for research, and a number of projects have been carried out with the support of the program

Goonoo research

Fox range area - Between 2005 and 2007 13 foxes were radio-tracked using VHF and GPS collars in the southern half of the Goonoo. The results were somewhat surprising with foxes across larger areas than expected. Mean VHF and GPS range areas were 836 ha (range 172.8 – 1817.7 ha, n=9) and 6096 ha (range 3947.2 – 9217.6 ha, n=3) respectively (Towerton 2014). Range areas were larger than other VHF tracked foxes in Australia and around the world, while GPS collared foxes were considerably larger in comparison. Foxes were tracked for short periods only as they succumbed to poison baits as well as the difficulty in tracking VHF collared foxes onto private property and obtaining signals from within densely forested areas. We thus suggested that the VHF collared range areas are underestimated. GPS collars allowed us to examine fox movements at a fine scale, with individual foxes displaying preferences for forest and cleared areas. We also examined movements during a typical "baiting window", which at the time was around two weeks, and found that only a proportion of the entire range area might be visited during that time. This has implications for bait density and placement.

Fox bait uptake – Information routinely collected on bait-take at pre-defined stations throughout the forest between 2000 and 2005 found that there was no consistent decline in relative fox abundance but instead increases in the index occurred in successive checks within most operations (Towerton 2014). Spatial analyses of checks within control operations showed that consecutive baits were removed at more than 70% of bait stations that were visited by foxes. Temporal analyses found that within an operation, successive bait-takes occurred at around 20% of stations and, across all operations, hot spots of activity were identified. This suggests that the small baiting window in standard baiting operations may not be effective in reducing the activity of foxes across the landscape. It is likely that a large proportion of baits were being cached during each operation. Fox activity was assessed before and after four operations using sand plots, and on two occasions in spring 2005 and autumn 2006, a significant reduction in activity was observed, however, although not significant, the following two operations saw slight increases.

Fox activity remote cameras - We explored the use of remote cameras to estimate the activity of foxes and potential prey species before and after poison baiting operations (Towerton *et al.*. 2011). We placed cameras in forest and cleared areas, on tracks only, at 100 sites covering an area of ~441,500 ha during winter 2009. Thirty-six species were identified from photos. No clear effects of fox-baiting were detected on foxes or potential prey species at the landscape scale, but a trend for reduction in fox activity was observed. The number of sites occupied by foxes increased after baiting, but 12 sites occupied during the pre-baiting sample detected no foxes post-baiting, a 36% reduction in these previously occupied sites. Fifteen previously unoccupied sites detected foxes post-baiting. The sustained and new detection of foxes at sites may be due to increased movements as young males disperse and new home ranges become available following fox baiting operations. Evidence of foxes with prey was also observed, most identified as macropods. The activity of foxes in surrounding agricultural areas was higher than in forests, highlighting the difficulty in managing foxes in fragmented native forests surrounded by farmland.

Fox control effort - With a clear understanding of how important the coordinated approach is to fox control, we sought to provide a structure for collecting, storing and using the existing monitoring data more strategically (Towerton *et al.* 2013). Fox baiting effort was assessed across the landscape by mapping bait stations set on public and private land in order to identify gaps in baited areas across the Goonoo Fox Control Program area. As foxes are capable of dispersing large distances and recolonising areas rapidly after removal, the aim was to develop an approach whereby land managers could examine spatial and temporal gaps in baiting operations, which were the potential source of recolonising foxes, so that these areas could be targeted and covered in subsequent operations. Large unbaited areas were identified around the areas that were baited where the distribution of baits was clustered across the landscape. This information can then be presented at coordinators meetings allowing decisions to be made based on bait monitoring results. Collecting this information from landholders is more difficult and we suggest setting up permanent bait stations on private property that would allow at least parts of this analysis to be carried out. Strategic planning to address spatial and temporal gaps in bait placement is likely to improve effectiveness.

Malleefowl cameras 2006 -Three remote cameras were trialled on Malleefowl mounds before they were all destroyed during a wildfire in 2006 (Towerton *et al.* 2008). A total of nine species were identified including mammals (fox, echidna, goat, swamp wallaby and dunnart), reptiles (lace and sand monitors) and birds (raven and common bronzewing). Three species of concern were identified (the fox and two goanna species) that may predate upon eggs and or young Malleefowl or adults and one species that may damage the mound (goat) potentially effecting breeding success.

Fauna cameras 2009 – Trials were carried out to explore the use of remote cameras to monitor terrestrial biodiversity, in particular Malleefowl and pygmy possums, at six sites where nine cameras were setup within a 1 km grid at each site (den Boer 2010). The sites overlaid previous fauna survey sites. This project identified 21 species, including a range of native and pest species. In comparison to the previous survey, 14 species out of a possible 31 species recorded at the selected sites were identified by the remote cameras. Unfortunately however this didn't include the Malleefowl or the eastern pygmy possum.

Malleefowl cameras 2009 – Remote cameras were used to assess activity at 15 Malleefowl mounds in the Goonoo, and found three of these to be active (Brown 2009). Species visiting mounds included red-necked wallabies, lace monitors, koala, goats, feral cats, echidnas, foxes, goats, goannas as well as the Malleefowl. Three cameras were then set at each of the three active mounds to test different camera setups and attempt to determine the breeding success, or otherwise, of the Malleefowl. Initial results found many behaviours observed such as courtship displays, mound preparation, digging holes for egg laying as well as potential predation by goannas.

Conclusions

Malleefowl monitoring activities have included ad hoc breeding observations, coordinated mound searches, recording mound activity and mound observations using remote cameras. These activities have uncovered interesting and important aspects of potential threats to the success of Malleefowl in the area, such as the observations of foxes, high levels of goanna activity detected at active mounds and the presence of goats and other species that may disturb mounds. In spite of these initiatives and efforts, the state of the Malleefowl population in the forest remains unclear. Limited resources inevitably reduces the effectiveness of monitoring activities and restricts the understanding of the stability, or otherwise, of the population.

Although the long-term public and private participation in efforts to manage fox impacts in the study region has been excellent, the evidence collected suggests that managing foxes to minimise their predation threats on native species and livestock, even with this level of support, remains problematic and its success unclear. The sparse and patchy distribution of resources available to foxes in the forest appears to promote large movements and thus unstable range areas. Any spatial and temporal gaps in baiting can lead to foxes not encountering baits, or the continuous migration of foxes into baited areas, as well as those from the surrounding unbaited areas into the buffer zone and then potentially the forest. Baiting operations were shown to be successful in that up to 75% of collared foxes succumbed to poisoning, while fox activity was reduced following some baiting operations. The mixed successes may suggest that the current approach is close to being sufficient to reduce fox activity and increase the protection of native species and livestock, but improvements need to be made for any long-term benefits to be sustained.

In concluding, Malleefowl conservation efforts can be improved in the Goonoo by a collaborative approach across all aspects of conservation management (pest control, habitat management, monitoring) through the development of a robust, long-term Management Plan. Improved planning of fox control efforts to minimise spatial and temporal gaps, benefits both Malleefowl conservation and agriculture production. Continued monitoring to improve our understanding of the threats limiting Malleefowl survival in the Goonoo will assist long-term planning and adaptive management triggered by these monitoring results.

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32. Malleefowl activity at nesting sites increase fox and other feral animal visitation rates

Milton Lewis, Central Tablelands Local Land Services; Member National Malleefowl Recovery Team

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Abstract

The activity of foxes were monitored at Malleefowl nesting sites within the rangelands of western New South Wales during the Malleefowl breeding season of 2012 – 2013. Cameras were placed at 10 sites each for four treatments: active Malleefowl nests, inactive Malleefowl nests, artificial nests (created by the authors) and random sites. No differences in fox activity were found between random sites and artificial nests. However, active nests of Malleefowl recorded significantly higher levels (80%) of visitation by foxes throughout the egg laying period compared to all other treatments. Inactive nests recorded intermediate levels of disturbance by foxes, but were not significantly different to active nests. These results indicate that a factor associated with the presence of Malleefowl (possibly odour) attracts foxes to active nests rather than the disturbance of nest digging or random chance. Past baiting strategies for foxes within Malleefowl nesting areas have avoided placing baits in the vicinity of nests because of the fear of attracting these predators to nests and Malleefowl. Clearly, the presence of Malleefowl is already acting as an attractant and it might be that future baiting protocols should investigate placing baits at known active mounds as a more efficient method of removing foxes that are already accustomed to eating Malleefowl eggs and chicks.

Introduction

Malleefowl *Leipoa ocellata* were formerly distributed through much of western New South Wales from the slopes of the Great Dividing Range to the arid rangelands in the far west of the state and in particular the fertile mid-western plains referred to as the "wheat belt". Although there are a variety of factors listed as contributing to this serious decline, including native vegetation clearing, one of the now recognised national key threatening processes has been the introduction of the European red fox *Vulpes vulpes*. Priddel and Wheeler (1996) during early attempts to reintroduce hatchling captive bred Malleefowl into western New South Wales documented mortality rates as high as possibly 92% and that was a key failure in their experiment. These authors had slightly greater success with the release of sub-adults (14 – 28 months) but even this age class suffered a loss of two thirds of the total birds released.

Monitoring of Malleefowl nests since 2009 by the senior author of this paper has consistently found the presence of fox tracks and scats at both active and non-active nests throughout the study area. Many of these mounds are several kilometres from vehicle tracks and for more than a dozen mounds the distance is over six kilometres. Current accepted fox control methods deploy 1080 impregnated baits along vehicle tracks and fence lines primarily because this allows the land owner to cover greater distances with limited effort (driving verses walking). There is good evidence to suggest that there are greater levels of fox activity along vehicular tracks (Towerton *et al.* 2011) however where there are no vehicle tracks it does not mean there are no foxes. In highly remote areas such as the western rangelands of New South Wales it is possible that some foxes never travel through the landscape using vehicle tracks and are therefore unlikely to encounter baits.

The nests of Malleefowl represent very important resource locations for predators and particularly species such as the fox that defend these resources over an extended period. Nest locations are scent marked by territory owners (foxes) and visited throughout the year but there is a lack specific knowledge about exactly how these foxes use and monitor the nests within their territories. In order to significantly control fox populations and their impact upon Malleefowl populations it is essential that we understand more fully the ecology of foxes where their territories overlap with the territories of Malleefowl. This paper represents as far as the authors can determine the first attempt to explore the detail of fox visitation rates at Malleefowl nest sites in relation to the seasonality of egg production and explores the possibility that foxes do not move randomly through the landscape but use resource sites (nests) for navigation.

Methods

The study area for the data reported in this paper was situated about 60 kilometres north of Hillston in western New South Wales (55 H 401546 6330022). Vegetation within the study area was typically characterised as mallee woodland with a canopy height of 3-5m and a sparse shrub layer averaging 1m in height. The dominant tree species were *Eucalyptus socialis* and the most common shrub species were *Melaleuca uncinata*, *Acacia colletioides*, *Vittadinia sulcata, Olearia pimelioides, Eremophila glabra*, and *Bossiaea walker*. This site is part of a much larger region that has been monitored for Malleefowl nesting activity by the authors since 2009.

Paired surveillance cameras were placed at 40 sites within mallee woodland vegetation for four treatments with 10 replicates in each treatment. Control treatments consisted of random points in the landscape chosen through random number generation and grid coordinates, however cameras were not placed to record movement on known animal paths or within non-mallee woodland vegetation. Disturbance sites replicated the appearance of active Malleefowl nesting mounds in which the authors constructed an artificial nest by digging and turning over soil in a 3m diameter circle. Inactive nest mounds for the third treatment were mounds constructed and used during previous three years by Malleefowl but were not being actively attended during the data collection period for this study. Active nests were those being used by Malleefowl during the period of the data collection reported in this paper.

All cameras were attached to steel pickets at a height of 1.5m, four metres from the edge of the nest and facing south to avoid reflective aberrations in the camera lens due to daily sun movement. Cameras were programmed to capture three medium resolution images in rapid succession with each triggered animal movement and a fixed delay between photo triggers of one minute. Two cameras per site were used to ensure that fox movements were not missed through camera failure and final data sets were combined to check validity of data. Cameras were downloaded every two weeks, batteries checked and replaced if necessary and jpeg photos stored in date labelled folders. Each photo was reviewed for the presence of foxes and Malleefowl and the date, time and animal activity recorded on a Microsoft excel spread sheet. Comparisons of fox and Malleefowl activity between treatments were analysed using ANOVA from the StatSoft programme Statistica version 10.

Results

Control sites within the four week period of the experiment reported within this paper received only four fox visits in 280 capture nights (4 weeks x 7 nights x 10 camera sites) (Figure 1). Disturbance treatments with artificial mounds received six fox visits, inactive nests recorded 250 visits and active mounds were visited by foxes on 242 separate occasions. During this period Malleefowl conducted 572 visits to their active nests. Malleefowl were not recorded at control sites but were recorded visiting artificial mounds on three occasions and at non-active nests on 29 occasions. No significant differences in fox sightings were recorded between control and disturbance treatments ($t_{78} = -1.38$, $p < 0.17$) however significant differences in total fox visits were found between controls, non-active and active nests ($t_{78} = -10.17$, $p < 0.0001$) ($t_{78} = -7.48$, $p < 0.0001$) (Figure 2). Significant differences in total visitation rates were found between disturbed sites and non-active sites ($t_{78} = -9.64$, $p < 0.0001$) and disturbed and active nests ($t_{78} = -6.84$, $p < 0.0001$). There were no significant differences in fox visitation between non-active and active nest. Malleefowl nest attendance was significantly greater than all other treatments ($t_{78} = -7.68$, $p < 0.0001$).

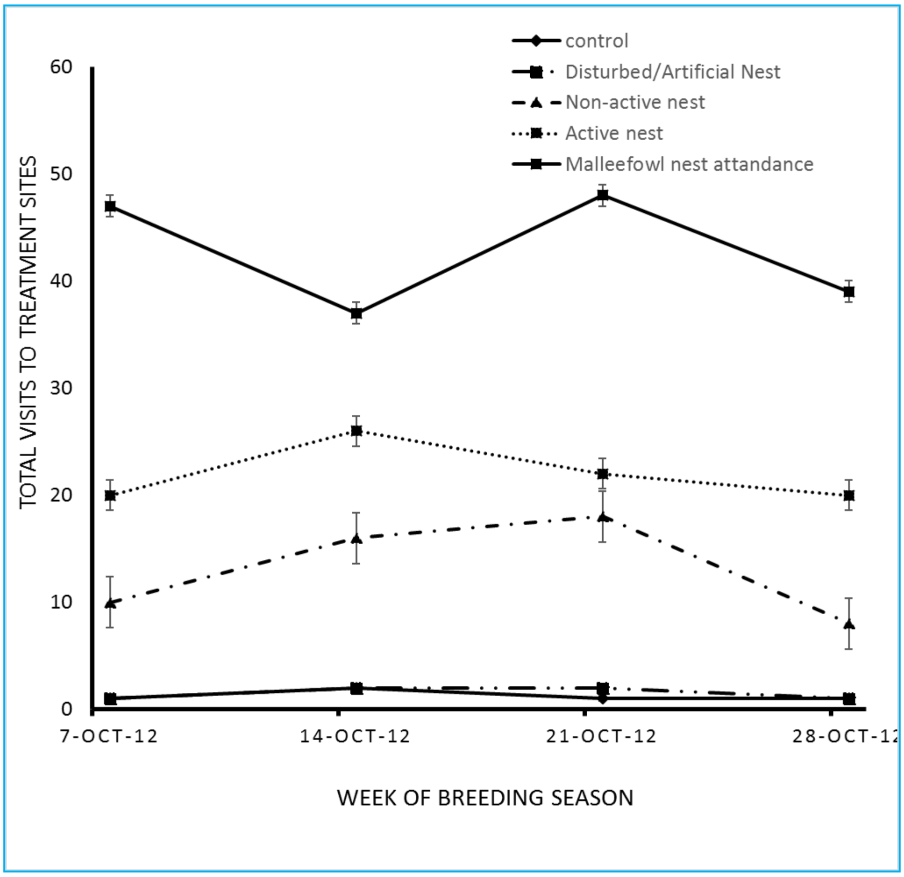

Figure 1. Weekly total treatment site visits by foxes and Malleefowl during the peak egg production period of the 2012 nesting season.

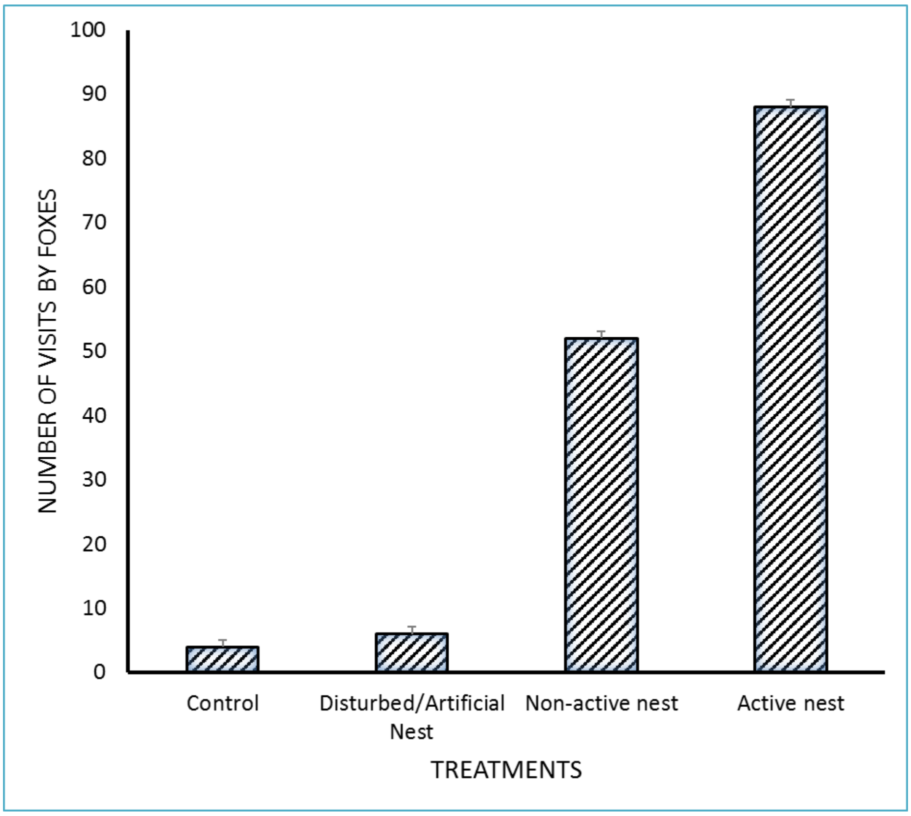

Figure 2. Total number of fox visits at control, disturbed and Malleefowl nest sites during October 2012.

Discussion

Fox predation is recognised as a key threatening process in the decline and recovery of Malleefowl. Data from this study exemplifies the ongoing threat posed by this predator through the frequent visits by foxes at active nests. We have long been aware of the presence of foxes at nesting sites but we can now show that the visitation frequencies of foxes to the resource rich nests containing firstly eggs and later nestlings is tuned to the breeding cycle of the birds. Egg laying by Malleefowl in western mallee rangelands of New South Wales occurs between August and October and during this period the frequency of both attending Malleefowl and foxes increases compared to other periods of the nesting cycle and territory occupation. This project investigated the visitation frequencies of foxes at active nest sites, inactive nests (active in previous five years), control random sites and disturbance sites simulating nest digging activity.

Foxes were observed infrequently at control sites and artificial disturbance nesting simulations. There were no significant differences between these sites, but there were noted differences in the behavioural responses of foxes. At control sites foxes were observed walking across the camera field of view but did not stop at the location. Foxes at the disturbance sites investigated the artificial nests for several minutes and in all cases marked these areas with both urine and faeces. Foxes visited inactive nest sites at a significantly higher rate than either of the previously mentioned treatments. Visits consisted of mound investigation and as with the previous disturbance sites the areas were scent marked. Active nesting sites were frequently attended by multiple fox individuals (recognised by pelage pattern and sex from multiple photographs). This visitation rate was significantly higher than other treatments but less than Malleefowl attendance levels. In most cases foxes were seen at nests during the early morning between 12:00 – 03:00 and around dawn (05:00 – 06:00), but there were occasional daylight visits. During these visits predation events removing eggs (often multiple eggs per visit) and capturing emerging chicks were recorded. These nests were again scent marked suggesting that nests may be an important asset within a territory as a food resource. It was also observed that female foxes with attendant cubs regularly visited these nests (Figure 3).

Figure 3. Female fox with attendant cub attending an active Malleefowl nest.

The continuum of fox visitation frequency between the treatments of this experimental investigation would suggest that foxes are targeting sites that are regularly visited by Malleefowl in a non-random pattern. Photography revealed that individual foxes repeatedly visited the same nests in successive nights and removed eggs. Malleefowl would return to these nests in the morning, cover the egg chamber and continue nesting activity. In many instances evidence of the fox visit was obliterated by the activity of the Malleefowl pair. The authors have been concerned that human activity checking nests may increase the success of foxes also finding nests but the lack of fox visits to disturbed treatment sites would suggest that foxes have not associated human scent with Malleefowl activity. Some suggestions have also been made in the past that it would not be appropriate to place fox baits at Malleefowl nests because this activity and the odour of the bait may increase fox activity around nests. Our data clearly shows that foxes are regularly visiting nests at very high rates without attractants other than the Malleefowl themselves. Foxes with Malleefowl nests in their territories have habituated their foraging behaviours to incorporate nightly nest checks during the breeding season. This learned behaviour is then passed to following generations with female foxes teaching their young where these nests are located and how to collect eggs (Figures 3 and 4). Baiting foxes at nest sites within these large rangeland locations may be the only option in successfully controlling the loss of Malleefowl eggs through fox predation.

Figure 4. Sub-adult foxes continuing their learned behaviour of visiting Malleefowl nests.

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33. Feral goat removal to restore habitat quality within Malleefowl nesting areas in the rangelands of New South Wales

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Abstract

Feral predators have been continuously cited over the last decade as one of the primary causes for the decline of Malleefowl, but limited research has been conducted to investigate the role of habitat degradation by the increasing threat of feral grazing. Baseline monitoring of vegetation condition during 2011-13 found that within the rangelands of western New South Wales there were no sites unaffected by goat *Capra hircus* browsing and grazing. Impacts are significant with goat exclusion sites having double the number of plant shrub species and three times more ground cover ($p = 0.0001$, $n = 20$). Lower plant species diversity and ground cover possibly reduces foraging availability and choice for Malleefowl. The reduction of ground cover may negatively influence Malleefowl survivorship from fox and cat predation. Goats have created a difficult dilemma in balancing conservation outcomes and maintaining income for landholders. In addition to installing a network of 56 water point goat traps, we have developed a landscape scale fencing method of passively removing feral goats from critical Malleefowl breeding habitat. In the long-term this new innovative use of strategic fencing to create a system of controlled traffic will reduce the impact of goat grazing in habitats of high conservation value. Simultaneously landholder costs will be reduced, making goats profitable under most financial situations. In the first year of total goat exclusion we have observed an increase of 20% (two new pairs) Malleefowl nesting activity. A neighbouring paired control without goat exclusion suffered a 50% decline (three less pairs).

Introduction

The decline of Malleefowl in western New South Wales has been attributed to a variety of factors and although this species is listed nationally as Vulnerable under the *Environment Protection and Biodiversity Conservation (EPBC) Act* 1999, within New South Wales Malleefowl are recognised as Endangered under the *Threatened Species Conservation Act* 1995. There are at least four primary threats and one potential threat that have been identified as the causes behind the decline of the Malleefowl (Benshemesh 2007). These threats begin with clearing and fragmentation of habitat for the purpose of agriculture primarily concerning wheat and sheep production but also more recently for the harvest of broombush (*Melaleuca uncinata*). Fire has also been listed as a primary threat because of its potential to destroy vast areas of mallee habitat in single events that can then take 30 to 60 years to recover to a state suitable for Malleefowl. The third threat is that of grazing by both feral and native species such as goats, sheep, rabbits and kangaroos. The latter species have in recent decades increased in numbers because of increased agricultural watering points but in addition to natural grazers there are now vast numbers of feral grazers living within Malleefowl habitat. These species directly compete for foraging resources as well as changing habitat structure through selective browsing. The final current threat is predation and has been well documented as a serious cause in the decline of the Malleefowl (Priddel and Wheeler 1997, 2009). Foxes have been the major species considered as a threat but there is also concern regarding increasing cat numbers. Climate change is now recognised as a potential threat to the future recovery of Malleefowl in New South Wales. Resultant shifts in rainfall patterns and temperature changes are predicted to lead to substantial declines in Malleefowl populations across their current range and will require adaptive management as the shifts manifest.

Methods

In July 2010 as part of an ongoing landscape scale vegetation monitoring project an area of land was selected 65km north of Hillston (55 H 401546 6330022) to begin a goat exclusion fencing trial. The site was 18km x 9km (16,000 hectares) in size, privately owned and without managed grazing stock. Grazing on the property consisted of uncontrolled feral goats, fallow deer and pigs. The area was divided into a northern and southern section for the purpose of ongoing replicate vegetation monitoring where only the northern section would be fenced to exclude goats re-entering the site following their removal. Fencing in the exclusion area was completed in October 2011 (Figure 1) and consisted of 120cm high ring-lock wire netting with two strands of barbed wire along the top and one along the bottom at ground level (addition of barbed wire was at property owner's cost and negotiation). At intervals of about 300m, a one-way gate was constructed allowing exit of goats from the area. There were no ground water sources within either sites, so goats voluntarily exited in their search for water (daily requirement) without the need for costly stock mustering or disturbance of Malleefowl.

Figure 1. Goat fence and one-way gate.

In each of the northern (site A) and southern (site B) areas, 20 permanent vegetation monitoring sites were placed and data collected in November 2011, 2012 and 2013. Each monitoring site consisted of a 50m transect, where data was collected for each 1m^2 area along the length of the transect (total data collection area = 50 m^2). In each quadrat we recorded total plant species present, number of each plant species, average height of each plant species, vegetative state for each species (flowering, seeding, dormant, developing leaf buds), litter ground cover, percentage live vegetative cover and percentage overhanging canopy vegetation. This report only provides discussion regarding total percentage live vegetative cover and plant species diversity. Percentage live vegetative cover was defined as the total live vegetative cover, excluding tree canopy over-hang of the combined plant species for each quadrat. In general vegetation within the study area was characterised as mallee woodland with a canopy height of 3-5m and a sparse shrub layer averaging 1m in height. The dominant tree species were *Eucalyptus socialis* and the most common shrub species were *Melaleuca uncinata, Acacia colletioides, Vittadinia sulcata, Olearia pimelioides, Eremophila glabra* and *Bossiaea walker*.

Results

Comparing vegetation between sites A and B prior to the removal of goats indicated that there were no significant differences in either plant species diversity ($t_{38} = 0.31$, $p < 0.76$) (Figure 2) or plant ground cover ($t_{38} = 0.14$, $p < 0.89$) (Figure 3). Repeated assessment of the sites two years after goat removal indicated highly significant increases in both plant diversity ($t_{38} = -8.98$, $p < 0.0001$) and live vegetative cover ($t_{38} = -6.57$, $p < 0.0001$) within the area of goat exclusion. Repeated assessment of the sites where goats had not been removed indicated no significant differences in either of the vegetation measures between years (plant species diversity $t_{38} = -0.37$, $p < 0.71$) (live vegetative cover $t_{38} = -0.28$, $p < 0.78$).

Although the data collected for this paper was not designed to measure the breeding response of Malleefowl with the removal of grazing by goats there was an increase in the number of pairs nesting within the exclusion area. In the first year of total goat exclusion we observed an increase of 20% (two new pairs) nesting activity. A neighbouring paired control without goat exclusion suffered a 50% decline (three less pairs). Due to the low sample size of only one treatment and one control we were not able to test this result and cannot conclude significance.

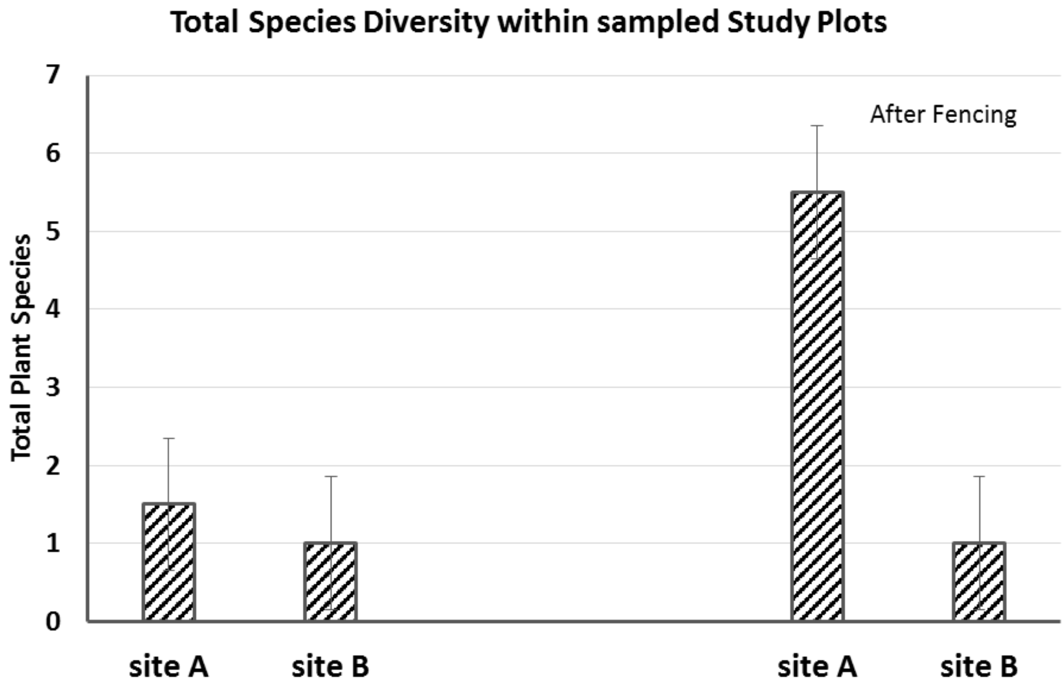

Figure 2. Comparisons of plant species diversity before and after fencing to exclude goats. Site A was fenced, site B remained as a control throughout the project without fencing.

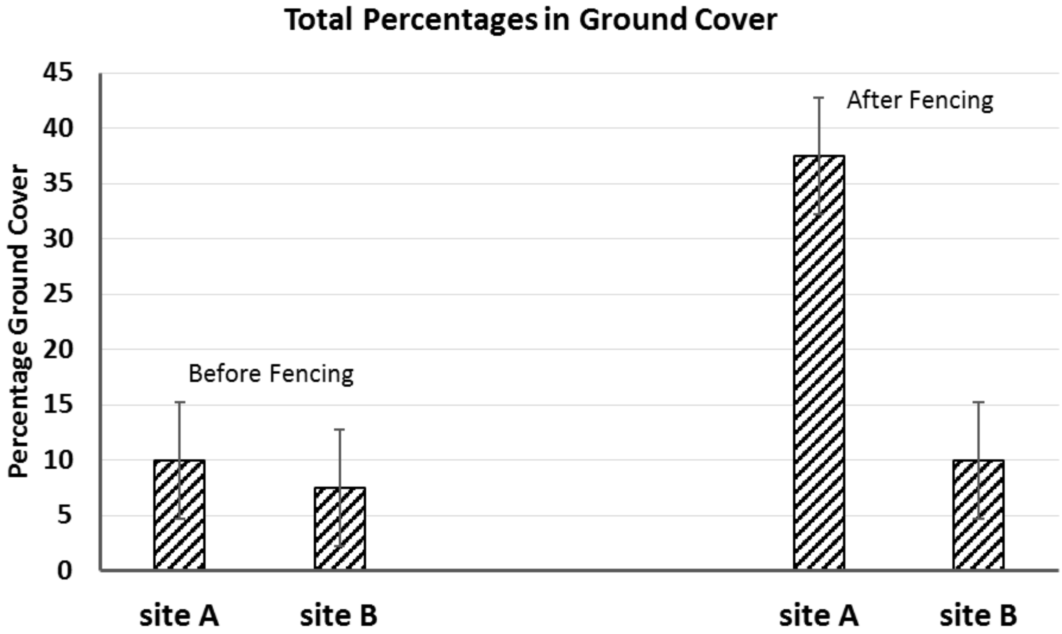

Figure 3. Comparisons of ground cover before and after fencing to exclude goats. Site A was fenced, site B remained as a control throughout the project without fencing.

Discussion

This study has shown that the loss of plant diversity and shrub layer vegetative cover in the mallee woodlands as a direct result of feral goat grazing is highly significant. Unfortunately this appears to be poorly recognised by rangelands managers as a threat to either the quality of vegetation communities or the faunal communities depending upon this vegetation. In the situation of the Malleefowl the degrading of vegetation in any form could have negative effects on several critical stages of this species' life history.

A reduction in plant species diversity could lead to a reduction in food resources. Seeds from native shrubs and grasses probably form a substantial component in the diet of Malleefowl. Different plant species vary in the seasonality of flowering and thus seed production. In an environment not modified by feral grazing there would be a wide choice of seed and its time of availability but in the current woodland system as many as two thirds of the plant species are either missing or significantly reduced in density. Reductions such as this leave restrictive periods in the year where nutrition is so reduced that it may limit the survival of some individuals that are either poor foragers or dispersers, such as young birds. Territory quality may also be reduced leading to pairs expanding the size of the area they defend. This will push some individual birds out of areas that in the past have supported higher population densities and into poorer vegetation types that may not support breeding and even limit survival.

It is interesting to note that Priddel and Wheeler (2009) concluded that food within the Yathong Nature Reserve was not a limiting factor in the survival of young Malleefowl. However, reviewing the data (Priddel and Wheeler 1997) from which they made their conclusions suggests that the evidence may have been limited by both sample size and the time period / extent of observations. Their conclusions were based upon two lines of reasoning: released surviving Malleefowl weight gain and vegetation sampling for abundance of Malleefowl food items. In the first instance although the authors reported significant weight gains in their surviving birds this appears to be skewed by three of the 12 birds released. These birds nearly doubled their mass, whereas many of the other birds made almost inconsequential gains. For instance in the first four birds that only survived 16 days, three of these lost weight. In the next group of two survivors, one bird (increased by 503g after 18 days) was one of the three outliers but the other bird only gained 126g.

A similar story can be seen throughout this data with many of the birds only gaining a very small amount of weight and there are no base-lines to compare the information with how much weight gain should be expected if food is in the appropriate abundance prior to grazing by goats. The poor survival rate of these birds may not have been solely the consequence of fox predation but may have been confounded by the birds being in very poor body condition and easily caught by foxes.

The second line of reasoning by Priddel and Wheeler (2009) is based upon evidence from previous work (Harlen and Priddel 1996) examining the abundance of seeds, ground-dwelling invertebrates and leaf buds over time in mallee vegetation. This is perfectly reasonable except the evidence for what constitutes the diet of a Malleefowl is perhaps a little generalised and lacking seasonal detail. Frith (1962) and Booth (1986) describe the Malleefowl as opportunistic herbivorous foragers and although other authors have added subsequent information there appears to have been limited detailed long-term observations (Brickhill 1987, Benshemesh 1992 (in Priddel and Wheeler 1997), Kentish and Westbrooke 1993). We have seen in other endangered species such as the Gouldian Finch that detailed knowledge of seed availability is vital in restoring the health and survivorship of a population (Lewis 2007). Within the time frame between the conclusions by Priddel and Wheeler (2009) and the work presented in this paper there has also been a substantial increase in goat population numbers (personal communications with landholders). Currently there are now thousands of goats being trapped within the mallee woodlands of western New South Wales and landholders do not believe there has been a significant reduction in numbers even with more efficient control measures.

Goats and, to a lesser extent, feral pigs and fallow deer, which all occur within the Malleefowl nesting sites of this study cause added disturbance that in general has gained little recognition. All of these species frequently visit active nests, using them for dust bathing and often mark nests with urine. Surveillance cameras have recorded hundreds of visitations during single breeding seasons but at this stage we have not been able to assess the damage caused by disturbance to the nest, eggs or the nest attendance of the Malleefowl. We have not recorded any of these feral species eating eggs or chicks.

The impact of loss of vegetation cover on survival of young Malleefowl was explored in previous work but found that the density of cover had no significant effects (Priddel, Wheeler and Copely 2007). Although this is a counterintuitive finding, the main vertebrate predators in this system are foxes and cats which are highly efficient and naïve nestlings are probably easily found and caught. In our study area, despite thrice yearly baiting by New South Wales National Parks and Wildlife Service our nest camera surveillance detected both predator species on all nests at least twice per week. Given that finding we would probably conclude that the major impact of goat grazing upon Malleefowl survival is more likely to be via the pathway previously described as reduction in food availability rather than vegetative cover. However there may still be cases where density of vegetation may succeed in enhancing the survival of some individual birds even though this may be a very low percentage.

Acknowledgements

The authors would like to thank the community of Mount Hope for their exceptional support, allowing us on their properties and coming to our rescue whenever required. Throughout the project many staff members of the former Lachlan Catchment Management Authority assisted in field work, but in particular we would like to acknowledge Lyndal Hasselman, Angus Arnott, Angela Higgins, and Jasmine Wells. Additional highly valued field staff included Ted and Kerry Davenport, Elizabeth Langdon, Kevin Solomon and Andrea Lewis. The work reported in this paper was financially supported by the Australian Federal Government through Caring for Our Country and additional funding was supplied by the Lachlan Catchment Management Authority.

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PRESENTATIONS – POSTER

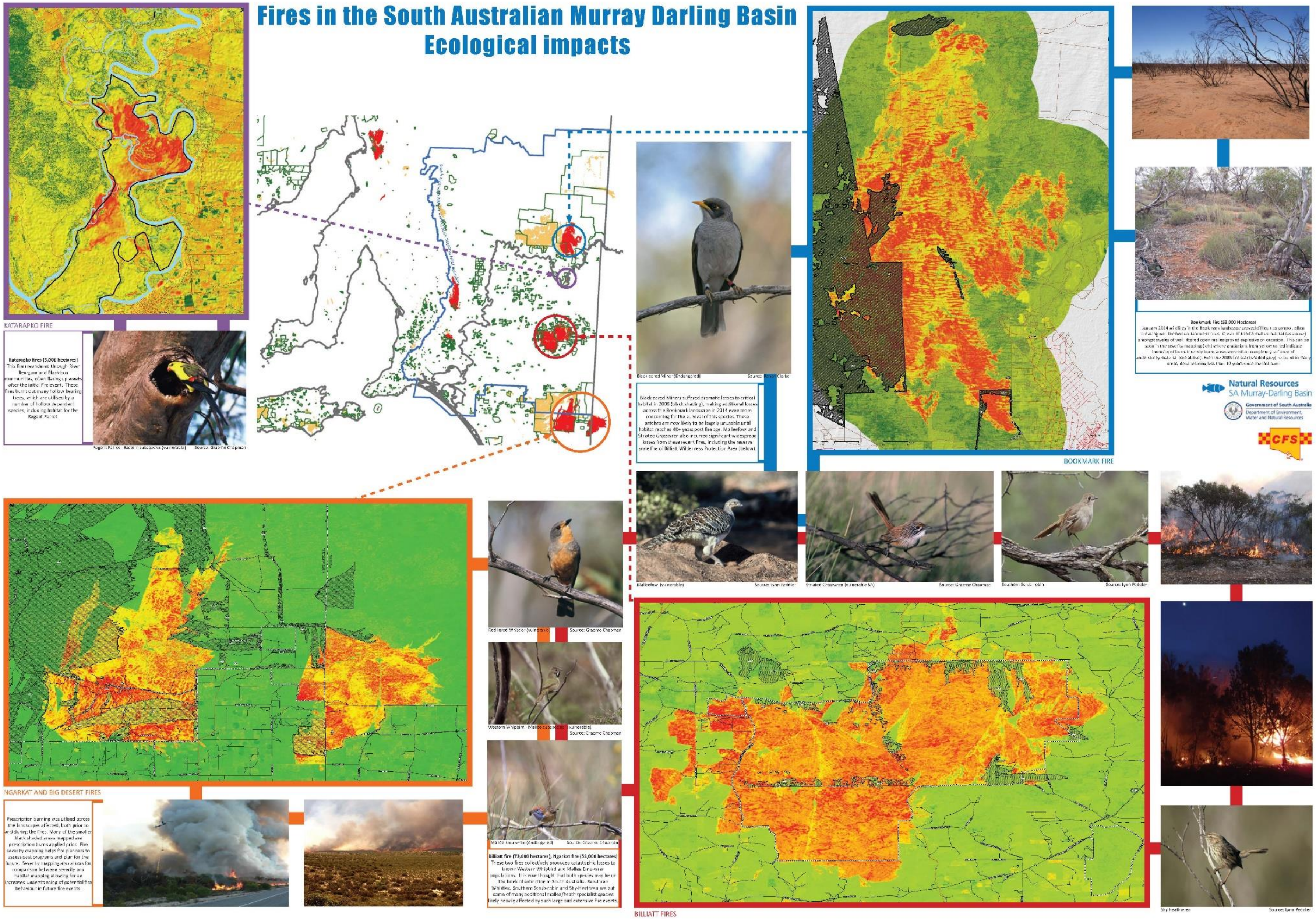
1. Mallee fires in the South Australian Murray–Darling Basin – losses, learnings and linings

Chris Hedger, Natural Resources SA Murray-Darling Basin

Authors: Chris Hedger, Fire and Threatened Mallee Bird Ecologist and Jared Pippos, Fire Management Officer, NR SAMDB

Abstract

Large fires were a consistent theme across Australia this fire season and in the South Australian Murray–Darling Basin, over 200,000 hectares of mallee and heath communities were burnt in three large fire events. The poster will visually present the burns themselves through detailed fire severity mapping. It will highlight where losses are known or expected from the fire events, including Malleefowl. Such maps can provide valuable information to learn from in the future and this will be demonstrated on the poster. Lastly positives, or silver linings, from these large fires will be discussed.


Fires in the South Australian Murray Darling Basin
Ecological impacts
KATARAPKO FIRE
Katarapko fires (5,000 hectares)
This fire meandered through River Red-gum and Black-box communities, often flaring up weeks after the initial fire event. These fires burnt out many hollow bearing trees, which are utilised by a number of hollow dependent species, including habitat for the Regent Parrot.
Regent Parrot – Eastern subspecies (Vulnerable) Source: Graeme Chapman
Black-eared Miner (Endangered) Source: Clarke
Black-eared Miners suffered dramatic losses to critical habitat in 2005 (black shading), making additional losses across the Bookmark landscape in 2014 even more concerning for the survival of this species. These patches are now likely to be largely unusable until habitat reaches 40+ years post fire age. Malleefowl and Striated Grasswren also incurred significant widespread losses from these recent fires, including the reserve scale fire of Billiatt Wilderness Protection Area (below).
BOOKMARK FIRE
Bookmark Fire (53,000 Hectares)
January 2014 wildfires in the Bookmark landscape proved difficult to control, often breaking well-formed containment lines. Clears of triodia mallee habitat (as above) amongst swales of well littered open mallee proved explosive on occasion. This can be seen in the severity mapping (left) where gradations from yellow to red indicate intensity of burn. Intensely burnt areas were often completely stripped of understorey material (see above). Even the 2005 fire scar (shaded grey) re-burnt in many areas, despite being less than 10 years since the last burn.
Natural Resources
SA Murray-Darling Basin
Government of South Australia
Department of Environment, Water and Natural Resources
CFS
Red-lored Whistler (Vulnerable) Source: Graeme Chapman
Western Whipbird – Mallee subspecies (Vulnerable) Source: Graeme Chapman
Mallee Emu-wren (endangered) Source: Graeme Chapman
Malleefowl (Vulnerable) Source: Lynn Pedler
Striated Grasswren (Vulnerable SA) Source: Graeme Chapman
Southern Scrub-robin Source: Lynn Pedler
Shy Heathwren Source: Lynn Pedler
NGARKAT AND BIG DESERT FIRES
Prescription burning was utilised across the landscapes affected, both prior to and during the fires. Many of the smaller black shaded areas mapped are prescription burns applied prior. Fire severity mapping helps fire planners to assess past programs and plan for the future. Severity mapping also allows for comparison between severity and habitat mapping allowing for an increased understanding of potential fire behaviour in future fire events.
Billiatt fire (73,000 hectares), Ngarkat fire (53,000 hectares)
These two fires collectively produced catastrophic losses to known Western Whipbird and Mallee Emu-wren populations. It is now thought that both species may be on the brink of extinction in South Australia. Red-lored Whistler, Southern Scrub-robin and Shy-Heathwren are but some of many additional mallee/heath specialist species likely heavily affected by such large and extensive fire events.
BILLIATT FIRES

2. Is road kill the greatest threat to adult Malleefowl survival in bush remnants in agricultural areas?

Gordon McNeill, North Central Malleefowl Preservation Group, WA

Summary

Data emerging from the monitoring of sites in the central wheat belt and pastoral areas of Western Australia suggest that the loss of adult birds through road kill critically undermines the sustainability of Malleefowl populations in remnant bush reserves.

Abstract

The North Central Malleefowl Preservation Group (NCMPG) has been observing Malleefowl populations for 21 years and monitoring four sites of remnant bushland in the Dalwallinu and Perenjori Shires in the central wheat belt of Western Australia since 2007. The NCMPG has also assisted in the collection of data from a fifth site, a mining lease at Mt Gibson in pastoral country to the northeast in the Yalgoo Shire. Of the four sites being monitored in the wheat belt, Malleefowl populations are being sustained in two of the sites recording nesting activity at a rate of 9%-14% of surveyed mounds. In the other two sites Malleefowl populations appear to have reached an unsustainable level and the rate of nesting activity has dropped to 0%-2%. In the control site on the mining lease in the pastoral region nesting rates remain stable at about 8%-9%. This begs the questions: what is the same and what is different about the sites of remnant bushland in the wheat belt and what allows Malleefowl populations to be sustainable in two of the sites but not the other two? Of the known threats: predation, lack of recruitment, natural deaths, fire and lack of food source, all five sites under consideration appear to be affected or unaffected in similar ways. The significant difference appears to be in the location of the sites and their proximity to roads carrying grain, livestock and tourist traffic. A case study of one site illustrates the critical effect that proximity to these roads has on the viability of Malleefowl populations in remnant bushland.

IS ROAD KILL THE GREATEST THREAT TO ADULT MALLEE FOWL SURVIVAL IN BUSH REMNANTS IN AGRICULTURAL AREAS?

North Central Mallee Fowl Preservation Group WA

A STUDY OF FOUR SITES IN WA

Evidence from 4 sites shows that activity has noticeably diminished in 2 of the sites. Our question is WHY?

THREATS TO MALLEE FOWL

1. Predation: equal across sites
2. Recruitment: equal across sites
3. Natural deaths: equal across sites
4. Wild Fire: all remnant sites have had a long period of time since fire (estimated at 100+ years)
5. Lack of Food: all remnant sites are bounded by crop paddocks on two or more sides

6. Road Kill: the two sites most under threat are on much busier roads & have been known to lose more adult MF to road kill in the last twenty years than the other sites.

In 1993 in a crop paddock across the road from one of the most threatened sites up to 23 adult MF could be regularly counted feeding (over a distance of 2 kms). Prior to that sightings were not as great but MF were regularly sighted.

At harvest time at the end of 1993 at least 10 adult MF were killed on that 2kms of road including 3 killed together within a metre of each other. Over the years since 1993 there has been a steady death toll from road kill at the site.

Since the site was completely searched 42 mounds have been monitored. The maximum number active in any season has been 3 (down from 8 known from a previous incomplete search). In the last five seasons there has only been at the most 2 mounds active equal to about 2%. In the other site under threat which has 31 mounds there have been 0 active mounds for the last two seasons.

However, in the two other remnant bush sites the percentage of mounds active is approximately 9% & 14% respectively & at Mt Gibson outside the agricultural area the activity rate is approx. 8.5%. What does this evidence mean?

3. Emergency Summit for Threatened Mallee Birds

Janelle Thomas, BirdLife Australia

Authors: J. Thomas[1], R. Boulton[2], J. Lau[1], S. Vine[1], J. O'Connor[1], D. Ingwersen[1], G. Maurer[1]

[1.] BirdLife Australia, [2.] The University of Adelaide

Summary

With a number of mallee birds facing a significant risk of extinction, BirdLife Australia's 'Emergency Summit for Threatened Mallee Birds' gathered together experts to address priority conservation actions.

Abstract

The Murray Mallee provides habitat for six nationally-listed threatened species: Mallee Emu-wren (Endangered), Black-eared Miner (Endangered), Regent Parrot (eastern) (Vulnerable), Red-lored Whistler (Vulnerable), Malleefowl (Vulnerable) and Western Whipbird (eastern) (Vulnerable).

Fire is a major threat to many of these species as they require relatively long unburnt mallee. Earlier this year, large wildfires burnt out 90 per cent of Bronzewing Flora and Fauna Reserve (VIC) and Billiatt Conservation Park (SA). The Bronzewing fire most likely wiped out the 'insurance' population of the Black-eared Miner and a significant population of Malleefowl. The Billiatt fire resulted in the global population of the Mallee Emu-wren now being confined to one contiguous area that covers Murray-Sunset and Hattah-Kulkyne National Parks. Mallee Emu-wren and Black-eared Miner are now highly vulnerable to a reserve-wide fire extinction event. In addition, fires have recently destroyed large tracts of habitat for other nationally threatened mallee species including the Red-lored Whistler, Western Whipbird (eastern) and Regent Parrot (eastern).

In response to this, BirdLife Australia recently hosted an 'Emergency Summit on Threatened Mallee Birds', attended by fire and mallee species experts from universities and representatives from State and Federal governments, to identify urgent actions needed to prevent these species from becoming extinct. Key outcomes of the summit include the ongoing development of Conservation Action Plans for a number of species, captive breeding and translocation feasibility studies for Mallee Emu-wren and agreement on the need to finalise the national Threatened Mallee Bird Recovery Plan and form a Recovery Team.

Threatened Mallee Bird Emergency Summit: *Outcomes and Actions*

Janelle Thomas[1], Rebecca Boulton[2], Jenny Lau[1], Samantha Vine[1], James O'Connor[1], Dean Ingwersen[1], Golo Maurer[1]
[1]BirdLife Australia, [2]University of Adelaide

Why we held the Summit

In early 2014, extensive wildfires in south-east Australia burnt large areas of mallee habitat known to be important refuges for a range of threatened mallee birds. Given the grim situation that these birds already faced, BirdLife Australia organised an 'Emergency Summit' to assess their current situation and to identify urgent recovery actions needed to prevent these species from becoming extinct. The **Threatened Mallee Bird Emergency Summit** focussed on the region of Murray Mallee habitat extending across three states; South Australia, Victoria and New South Wales.

Summit participants

The summit was held over three days in mid May and early August 2014 at BirdLife Australia's national office in Carlton, Victoria. It was attended by 36 experts in fire and mallee species ecology from universities, NGOs and representatives from State and Federal governments.

Major discussion points emerging from the Summit

- Most of these species require long unburnt mallee habitat (>15 years).
- Historically, extensive land clearance, large scale fires and habitat degradation by grazing herbivores has resulted in small isolated populations.
- Active management for these species is currently limited due to funding and there are still large knowledge gaps around ecological requirements.
- Under Recommendation 56 of the Victorian Bushfires Royal Commission all of the Victorian mallee would be burnt over the next 20 years resulting in a significant threat to threatened mallee birds.
- Large wildfires in early 2014 have significantly impacted threatened mallee bird populations with five populations lost from large conservation reserves (see table):

2014 Fires in Conservation Reserves	Impacted Species
Bronzewing Flora and Fauna Reserve (VIC)	Black-eared Miner – insurance population lost Malleefowl – significant population lost
Billiat Conservation Park (SA)	Western Whipbird – last population in Murray Mallee lost Mallee Emu-wren – population lost
Ngarkat Conservation Park (SA)	Mallee Emu-wren – population lost
Riverland Biosphere (SA)	Black-eared Miner – extensive critical habitat lost

The situation for Mallee Emu-wren, Western Whipbird and Black-eared Miner is now dire with Mallee Emu-wren and Black-eared Miner now highly vulnerable to extinction events from fires.

Recommended actions

- The current draft of the *National Recovery Plan for Mallee Emu-wren, Red-lored Whistler and Western Whipbird*[1] should be endorsed by Federal and State governments.
- There is an urgent need for a full Conservation Action Plan (CAP) to be developed for threatened mallee birds, to build on the draft CAP developed at the Summit.
- The following emergency actions are required for the endangered Mallee Emu-wren over the next 12 months.
  - Improve information sharing
  - Improve initial fire response
  - Prepare translocation feasibility study
  - Prepare captive breeding feasibility study
  - Formation of a Mallee Emu-wren working group

[1] Baker-Gabb, D. 2012. Draft National Recovery Plan for the Mallee Emu-Wren *Stipiturus mallee*, Red-lored Whistler *Pachycephala rufogularis* and Western Whipbird *Psophodes nigrogularis leucogaster*. Department of Sustainability and Environment. Melbourne.

Conservation Action Plan (CAP) for Threatened Mallee Birds

A draft Conservation Action Plan was developed during the summit to assess the status and threats and devise conservation strategies for the six threatened mallee birds.

Goals and Targets

Scope: To protect and help maintain mallee >15 years post-fire for threatened mallee birds.

Vision: Protect, improve and conserve mallee habitat to decrease the extinction risk of threatened mallee bird species.

Goals for Species

Target Species	Population Rating
Black-eared Miner	POOR
Mallee Emu-wren	POOR
Malleefowl	FAIR
Red-lored Whistler	FAIR
Regent Parrot	FAIR
Western Whipbird	POOR

- Mallee Emu-wren – Establish and maintain > 4 populations that are stable or positive trending, in large reserves across northern and southern reserve systems in 20 years.
- Black-eared Miner – Five subpopulations with a total effective population of 1000 birds of high genetic integrity by 2034, each with habitat of sufficient quality and extent to maintain these subpopulations.
- Malleefowl – Increase distribution and abundance of Malleefowl in south-eastern range in 10 years.
- Regent Parrot – Secure and improve core habitat within 10 km of breeding sites to increase populations for Regent Parrots in 20 years.
- Red-lored Whistler – Five subpopulations of 500 each by 2034 each with habitat of sufficient quality and extent to maintain these subpopulations.
- Western Whipbird – Four subpopulations of 500 each by 2034 each with habitat of sufficient quality and extent to maintain these subpopulations.

Threats

Threats were ranked across all species according to the scope, severity and irreversibility of the threat. An overall rating was given to the threat (low, medium, high and very high).

Thirteen threats were identified with seven of these ranking *Very High, High or Medium* as listed in the table.

Threats	Overall Threat Rating
Catastrophic wildfire	Very High
Past habitat loss and fragmentation	Very High
Drought	Very High
Inappropriate fire management	Very High
Total grazing pressure	High
Inappropriate water management	Medium
Action or inaction drives hybridisation	Medium
Overall threat rating for threatened mallee birds	Very High

Strategies

Summit participants devised nineteen *strategies* to mitigate the effects of threats ranked *Very High and High*. The following seven strategies rated as high priority:

- Trial in-situ habitat manipulation
- Control genetic introgression for Black-eared Miner
- Work with fire crews on bushfire response plans
- Strategic risk-based bushfire planning
- Remove artificial watering points
- Gear existing recovery actions to the current situation for conservation outcomes
- Find alternative funding sources

Actions - Summit participants determined actions required to achieve each strategy with costings, timeframes and the agency best placed to deliver them.

Priority actions identified in the Conservation Action Plan are now underway - a great first step for threatened mallee birds

Acknowledgements: Thank you to the following organisations for participating in the Summit: Department of Environment, Department of Environment, Water and Natural Resources, Department of Environment and Primary Industries, Zoos SA, Parks Victoria, Mallee CMA, NSW Office of Environment and Heritage, La Trobe University, Monash University, Arthur Rylah Institute, Australian National University, BirdLife Australia
Photo credits: Chris Tzaros (bird species & background), Zoe Reynolds (burnt mallee vegetation), Dean Ingwersen (mallee vegetation), Paul Sullivan (workshop)

For further Information contact Janelle Thomas – Threatened Bird Network Coordinator, BirdLife Australia at janelle.thomas@birdlife.org.au

birdlife AUSTRALIA

4. Thinking outside the jerry can

John DeJose, Malleefowl Preservation Group, WA

Abstract

Three active Malleefowl mounds on a 300 hectare bush property in south-west Western Australia were closely observed over several years. It seemed to the property owner that, during dry seasons, the mounds produced fewer chicks. In one dry season, water was added to the mounds to see what happened. Apparently, a high number of chicks (up to 35-40) were observed to hatch from each mound that season. Whether anecdotal reports such as this can inform the management of Malleefowl is discussed.

Thinking Outside the Jerry Can - John DeJose, Malleefowl Preservation Group

ABSTRACT

Three active Malleefowl mounds on a 300ha bush property in SW Western Australia were closely observed over several years. It seemed to the property owner that, during dry seasons, the mounds produced fewer chicks. In one dry season, water was added to the mounds to see what happened. Apparently, a high number of chicks (up to 35-40) were observed to hatch from each mound that season. Whether anecdotal reports such as this can inform the management of Malleefowl is discussed.

BACKGROUND

MPG member, John Chandler, has spent much of his life in the WA bush. Like most with such long exposure, he has a great store of intuitive but unquantified knowledge of much that goes on in nature. Normal science has little or no use for such informal, anecdotal and unquantifiable data.

Post-normal science recognises that there are many ways of knowing. For example, it gives credence to the knowledge indigenous peoples carry in their oral traditions and other forms of knowing which are relevant to natural resource management. Our NRM institutions, academia and practitioners are starting to take notice of these other forms of knowledge but it still sits uneasily within the sector.

Command and control hierarchies, which typify many NRM stakeholders, have to date poorly embraced informal knowledge and scientists in the sector are similarly disinclined, for the most part. Social science does sometimes get a mention but normal science has usually been dismissive of its importance.

Most academic institutions continue to produce graduates who have little to no experience integrating informal knowledge or even that from other disciplines in their work. This surely bodes ill for those of us attempting to slow and even reverse the environmental declines of recent decades. We have ample proof that the way we have been going about the business of natural resource management is insufficient to realise this ambition.

Adaptive management is a process by which the informal knowledge of communities can be brought to bear upon complex environmental problems characterised by a high degree of uncertainty, such as changing the inflection of long term environmental decline. This is why the Board of the Malleefowl Preservation Group has resolved it to be the default operating system for the group.

For the purposes of this discussion, the salient point about adaptive management is that there is no privileged way of knowing. The process demands participants develop a common language and understanding of the problem and the workings of the system in which it nests. If we focus downscale on the conservation of one species, the Malleefowl, adaptive management would have us recognise informal knowledge such as concerns this presentation.

HYPOTHESIS

Presumably due to the high variability in rainfall across space and time within the Malleefowl distribution in WA, nesting success appears to be variable across the landscape. During his life as a bushman, John Chandler noticed that successful mounds seemed to occur where there had been soaking rains during the season when litter collection takes place. Those mounds tended to be smaller than less successful mounds found in areas where much less rainfall occurred during the critical period.

John also observed that those birds which owned successful mounds foraged closer to their mound than those owning less successful mounds which foraged further afield. By any measure, the Malleefowl is a high energy bird. The energy required to work the mound is legendary. Both the number and relative size of eggs produced by the female is prodigious, attesting to the need for calories in to be much greater than calories out over a long period.

If John's observations are borne out, this could indicate that the success of reproduction may be sensitively dependent not only upon the right amount of rain at the right time but, perhaps, also upon the balance of the birds' energy budget. Could this be related to the reproductive strategy of the Malleefowl, which defies nicely defined categories?

EXPERIMENT

The Chandlers own a bush property fronting the Pallinup River, which provides a corridor to other locations which can support Malleefowl. On acquisition 7 years ago, the block was full of weeds, foxes and cats and no nesting Malleefowl. After extensive weed and feral predator control, the property now has 3 productive Malleefowl mounds.

John reasoned that, in a highly cleared landscape, such as the WA wheatbelt, where Malleefowl exist only in small remnants, the combination of patchy rain and patchy habitat would be bad for Malleefowl reproduction. Knowing that critical winter rains were already being affected by climate change, John decided to see if he could make more Malleefowl by 'just adding water' at the right time.

During the litter collecting season, John added water to one or more mounds on the property, keeping another as control. He remotely captured and then reviewed many thousands of hours of video footage of Malleefowl over 7 years, allowed him to see females laying and chicks hatching on a regular basis.

RESULTS

Available details are sketchy in John's extended absence, but this much we do know. Water was applied experimentally to nests over at least a three year period, always during the time the Malleefowl were collecting litter.

In the first year (a very dry year) one nest was 'watered' (with much more than 40 litres) and another served as a control. John captured remote video of both nests which allowed egg laying and hatching of chicks to be recorded. The watered nest produced about 40 eggs and the control produced none.

In Year 2, John added a total of about 40 litres of water (much less than used on the experimental nest in Year 1) to the control nest and from the video evidence it seems that only about 10 chicks were produced, according to camera trap footage.

In Year 3, the control nest was given "the full water treatment" (as much water as the experimental nest) and about 30 eggs resulted. There had been no storms in the area; it was a relatively dry litter collecting season.

John estimates over 300 Malleefowl have been added to the local pool for recruitment due to the changes made to the block and extra watering in 7 years.

CONCLUSION

John Chandler 'knows' that 'just add water' does produce more eggs and chicks than not doing so. There are many uncertainties as well as flaws in methodology but this experiment does give an indication of how sensitively dependent reproduction of the Malleefowl is to adequate amounts of rain at the right time. From an adaptive management perspective, this may cause us to speculate as to whether there are any potential landscape-scale management actions which might be considered as a buffer to climate change for the Malleefowl of WA.

DISCLAIMER

Both state and federal legislation prohibit interfering with Malleefowl. Not only might it be illegal, but adding water could also be fatal to Malleefowl eggs if applied at the wrong time. Dr Joe Benshemesh, arguably the best-informed Malleefowl scientist, has advised that the mound environment is so finely balanced that such perturbation could easily result in diminished reproductive success. Accordingly the Malleefowl Preservation Group advises that it does not advocate any interference with Malleefowl or their mounds. Additionally, it was a condition of the National Malleefowl Recovery Team that this poster could only be presented if this disclaimer was included.

5. Malleefowl at Monarto Zoo

Vaughan Wilson and Mal Norman

Authors: V. Wilson[1] and M. Norman[2]

[1.] Monarto Zoo, Zoos SA, [2.] Adelaide Zoo, Zoos SA

Summary

This poster presentation is an update on the progress made to re-establish a wild population of Malleefowl on the Monarto Zoo property.

Abstract

The Monarto area, including the 1,000 hectare area of Monarto Zoo, once had a diverse range of fauna living in a mosaic of dryland habitats. With European settlement, and large scale clearance of arable land, this mosaic of habitats slowly reduced and, with the introduction of feral predators and herbivores, the fauna diversity also reduced. With this decline went the Malleefowl from most of its local territory.

In recent years, much work has been carried out on the Monarto Zoo property to reverse these trends, including re-establishing a mosaic of habitats on the variety of soil types; ensuring vegetation corridors connect all vegetation zones; excluding and removing all feral predators and controlling feral herbivores; determining what fauna species remain; and working towards the introduction of locally extinct fauna species.

To re-populate Malleefowl onsite, a number of Malleefowl eggs were removed, under DEWNR permit, from mounds in nearby Ferries McDonald Conservation Park. The number of eggs removed, and from which mounds, was strictly controlled to ensure there was minimal impact on the wild population, while providing as diverse a captive population as possible. The resulting chicks have now grown to full size and will hopefully breed once mature. The resulting hatchlings, it is hoped, will then be able to be released into the feral free environment recreated at Monarto Zoo, thus not only protecting the species but increasing its range back into areas where it is now extinct.


Zoos SA
Supporting
Malleefowl
Conservation
Zoos SA's Monarto Restoration Project
• The Monarto Restoration Project (MRP) commenced in 2010 under the stewardship of Zoos SA's conservation department. Over that time it has received valuable funding support from several State and Australian Government funding programs and sponsorship investment.
• The project's aim is to: protect and restore existing native habitat on the property, manage the natural assets on Monarto well such as our ephemeral waterways, improve connectively across both the property and the surrounding landscape, and to provide opportunities for our visitors to experience and learn more about the mallee and grassland habitat and wildlife we enjoy on our site.
• The MRP fulfils the two aspects of Zoos SA's Mission and demonstrates that – we exist to save species from extinction and connect people with nature.
The work of our restoration project so far
• The MRP employs a small dedicated team and involves volunteers from all walks of life. Over the last three years 1,200 volunteers have contributed 5,000 hours. The financial value of their contribution is estimated at $125,000 however their support is priceless.
• As part of our team we host an Aboriginal Learning on Country program which enables a small team to gain hands-on work experience and make a valuable contribution to our team while studying to achieve certificates in land management.
• The project includes a feral predator-proof upgrade to the zoo's 14km perimeter fence and management of cats, rabbits and foxes. The ultimate goal is to feral proof the entire 1,000 ha site.
• Since 2011, 33 hectares of degraded agricultural land have been restored and planted and 44,000 tubestock representing 60 native plant species have been propagated and planted on site.
• In the last year alone 120,000 visitors had the opportunity to travel through and find out more about the work that we are doing via guided zoo bus tours.
• We monitor our success via regular bio-surveys.
What we plan to do next
• Develop a Land Management Plan that takes in to account all the different natural resources on the Monarto Zoo property to ensure we manage the whole site well and maximise the benefits for animals and visitors.
• Continue weed and feral species management on site.
• Infill previous large revegetation sites to ensure tree planting becomes future habitat for wildlife.
• The Zoos SA's Master Plan (2014-2034) highlights a number of opportunities to make more of our education role at Monarto including a mallee trail, mallee ecosystem exhibits including one for malleefowl, a precinct dedicated to Australian species and the history of Monarto's land management and more breeding facilities for threatened native species. The MRP will play a valuable role in the delivery of this plan.
Adelaide
Monarto Zoo
Murray Bridge
Malleefowl
Insurance Population of Malleefowl for Ferries McDonald Conservation Park
• Monarto Zoo provides accommodation to eight adolescent Malleefowl provenanced to Ferries McDonald Conservation Park. As there is a very real risk that a significant fire event could do serious damage to the population of Malleefowl within Ferries McDonald, we will continue to hold an insurance population to guarantee the genetics of this outlier population continue.
Breed for release
• The establishment of captive breeding of Malleefowl at Monarto Zoo has the capacity to provide a large number of captive bred young which may be released to natural environments both within the park and beyond.
Display and Interpretation
• The endearing qualities of our captive birds can be used to take advantage of the large visitor base at the zoo to promote an increase in public awareness of the plight of Malleefowl and other species under threat in the region due to habitat loss and predation by feral animals. New interpretation graphics have been installed at the Malleefowl aviary, while during the last school holidays, Malleefowl activities and threats were also highlighted to all young visitors and their families.
School Holiday Activities
• During the last school holidays, Malleefowl activities and threats were highlighted to all young visitors and their families through the use of the "Mallee Tales" trail. These holiday activities encouraged visitors to visit all of the platforms on foot leading to an informational display highlighting Malleefowl unique mound building activities.
Poster presented by
Vaughan Wilson - Keeper - Monarto Zoo
Mal Norman - Keeper - Adelaide Zoo.
For more information on the MRP
Dr Phillip Ainsley (Manager Australian Conservation Programs, Zoos SA) painsley@zoossa.com.au
Dr Briony Horner (MRP Conservation Project Coordinator, Zoos SA) bhorner@zoossa.com.au
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Westpac

6. Malleefowl mound building: Effects on fire behaviour and habitat

Amy Smith, La Trobe University, Vic

Authors: A.E. Smith[1], S.C. Avitabile[1] and S. Leonard[1]

[1.] La Trobe University, Vic

Summary

The removal of leaf litter by Malleefowl during mound building potentially influences fire behaviour.

Abstract

Malleefowl remove large amounts of leaf litter from the areas surrounding their mound for use in egg incubation. This study is investigating the reduction of litter around the mound and the potential effects it could have on fire behaviour. Four 30-metre line transects radiating from the mound were used to measure leaf litter depth and vegetation structure. These measurements were compared to paired "non-mound" sites. There was a significant difference between mean litter around the mound compared to the non-mound. To investigate effects of fuel reduction on fire intensity, I compared minimum branch diameter between mound and non-mound sites in an area recently burnt by wildfire. There was a trend for braches to be smaller around mounds, suggesting reduced fire intensity. However this result was statistically non-significant. Malleefowl mound building reduces litter fuel loads in the area around mounds, and may contribute to variation in fire behaviour.

Malleefowl Mound Building: Effects on Fire Behaviour and Habitat

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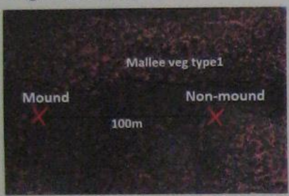
Introduction

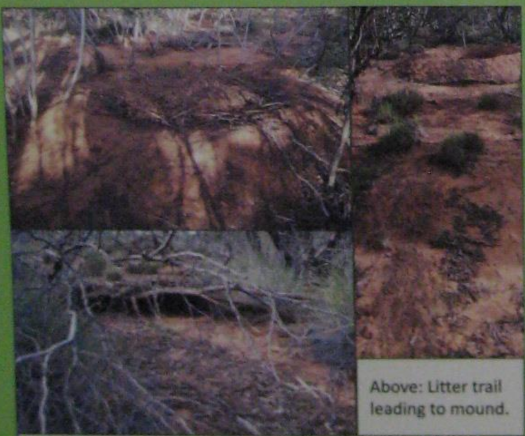
Malleefowl remove large amounts of leaf litter from the area surrounding their mound for use in egg incubation. This means the presence of the mound creates a "halo effect" where litter load is reduced for approximately 0.2ha^2 surrounding the mound . A reduction in litter is related to a reduction in fire intensity in mallee vegetation. This study investigated whether the removal of litter by malleefowl was significant enough to reduce fire intensity. To investigate effects of fuel reduction on fire intensity, we compared minimum branch diameter between mound and non-mound sites in an area recently burnt by wildfire. In addition we looked at whether vegetation structure was effected by mound presence.

Methods

Litter and vegetation: 70 mounds were sampled in Northern Victoria. At each mound 30 meter transect lines were run out in 4 directions from the mound. Litter depth and vegetation structure were measured every meter along 4 30m transects running N, S, E and W. The same measurements were carried out at a non mound site with matched for aspect, soil, fire history, and vegetation type.



Fire intensity: Fire intensity measurements were carried out in Bronzewing reserve, which was burnt in January 2014. Minimum stem diameter was measured within 10 meters of burnt mounds and compared to stem diameter in nearby burnt areas.

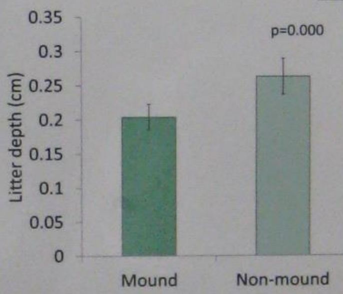


Above: Litter trail leading to mound.

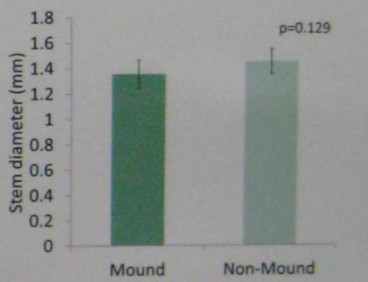
Top left: malleefowl mound full of leaf litter.
Bottom: A pile up of litter where a litter trail has gone over a tree branch.

Well-worked area near a malleefowl mound compared to normal litter under trees in mallee scrub.

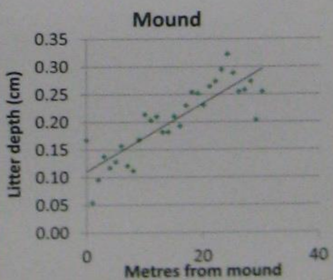
Results



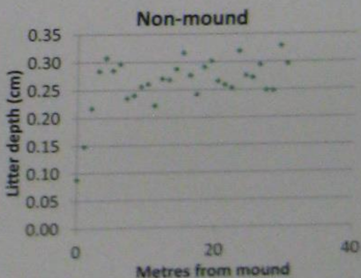
Mound sites had a 22.4% reduction in litter compared to non mound sites.



Mound sites had only a 6.9% reduction in stem diameter compare to mound. This difference is not statistically significant.



Litter depth was found to increase with distance from the mound.



In the absence of a mound litter showed little variation over the 30m.

Discussion

Malleefowl removal of leaf litter was found to reduce fuel load around malleefowl mounds. However whether or not this could reduce fire intensity is unclear. In burnt mallee vegetation there was a trend for braches to be smaller around recently burnt mounds, suggesting reduced fire intensity. However this result was statistically non-significant.

Acknowledgements: Thanks to the Victorian Malleefowl Recovery Group for providing mound locations.

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Photo: © S Gillam