# Malleefowl Conservation – informed and integrated community action


A final report to WWF Australia and Avon Catchment Council

by


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Cover photograph: A sign erected near Wubin by the North Central Malleefowl Preservation Group (NCMPG), warning motorists of Malleefowl feeding on the roadside. Numerous signs have been erected by the NCMPG and other community groups in the Western Australian wheatbelt to prevent road deaths, a common cause of Malleefowl mortality in the region.

# Malleefowl Conservation – informed and integrated community action

## Executive Summary

**The bird:** The Malleefowl (*Leipoa ocellata*) is a large (~2kg), sedentary, ground-dwelling bird that uses a combination of fermentation and solar radiation to incubate its eggs in mounds. It is one of three species of mound builders in Australia, the other two being the Australian brush turkey (*Alectura lathami*) and the orange-footed scrubfowl (*Megapodius reinwardt*). The Malleefowl is an iconic Australian species due to its unique biology and unmistakeable appearance.

The range of Malleefowl in Western Australia spans most of the southern half of Western Australia and includes much of the wheatbelt. Malleefowl were historically found in most vegetation communities present in the Western Australian wheatbelt, being most common in mallee, *Acacia* shrublands, and scrub thickets. To a lesser extent, they were known also from open woodlands such as York gum *Eucalyptus loxophleba* and gimlet *E. salubris*.

**The conservation problem:** The Western Australian wheatbelt has been extensively cleared over the past 100 years and vegetation remaining is typically small in area, fragmented, and isolated. The scale of clearing (>90% of all vegetation) has resulted in the wheatbelt being identified as one of the most stressed landscapes in Australia. This substantial loss of vegetation as habitat has led to concerns about the status of Malleefowl. Malleefowl are also subject to a variety of other threatening processes within their Western Australian range, including fox predation, unsuitable fire regimes, and grazing of their habitat by stock. This suggests a poor prognosis for long-term persistence.

Malleefowl are listed as "vulnerable" under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and in Western Australia, are listed as "fauna that is rare or is likely to become extinct". They are also listed as "vulnerable" on the 2007 IUCN Red List of Threatened Species.

The population of Malleefowl across Australia is believed to have decreased in size by at least 20% over the last three generations of the species and this rate of decline is believed likely to continue (Garnett and Crowley 2000).

**The resource:** There has been strong community interest in Malleefowl and their conservation in the Western Australian wheatbelt. This has been reflected in the number of rural-based community groups established with the express aim of conserving Malleefowl. One such group (the Malleefowl Preservation Group)

established a Malleefowl sightings scheme whereby members of the public were encouraged to report their sightings. This scheme was publicised via their newsletter and their website. By 2004, over ten years of data consisting of > 1000 sightings records had been accumulated, but had not been collated in any way. This resource formed the basis for our establishment of this project.

Over the past several years, we have amassed 2861 records of the occurrence of Malleefowl in the Western Australian wheatbelt. Community groups provided the majority of this data – 1397 records (49%) – with most coming from the Malleefowl Preservation Group. Much additional data was also provided indirectly via the knowledge of farmers (such as the data of Saunders and Ingram (1995) – 51 records (2%) - or through bird observers (through RAOU Atlas 1 and Birds Australia Atlas 2) – 230 records (8%).

**The technical problem:** Despite the enormous number of records of Malleefowl that had been accumulated by community groups and others, there was a view by some that these data (and Museum and other records collected over much longer time periods) were inadequate to answer important questions about Malleefowl status and conservation. This is because the data recorded only presence; but not absence. The dataset was largely collected from opportunistic sightings, rather than from a structured program. As a result, the level of effort varied greatly over time and space, greatly limiting the interpretations that could be made from the data.

Hence, a large part of this project has required finding new and innovative ways of making use of this *ad hoc* presence-only dataset.

**The technical solution:** We have made use of the presence-only dataset where possible. This included the use of BIOCLIM to establish the climatic envelope of the species; direct comparison to earlier analyses using the same methods (such as the assessment of decline of Malleefowl across all of Western Australian given in the National Recovery Plan (Benshemesh 2000)), and in local assessment of habitat use. Results of these analyses are detailed below.

However, in addition, innovative new solutions have been found to convert presence-only data to presence-absence data. These include the use of extensive postal and phone surveys of areas within the Western Australian wheatbelt to establish past and present occurrence of Malleefowl and the use of past Birds Australia Atlas 2 data to derive sites of bird survey that did not contain Malleefowl.

These solutions have allowed much more rigorous analysis of the available data and allow much more confidence in the conclusions generated.

**Results from analysis:**

<u>Decline</u> – Analyses were conducted at two scales to establish the extent of decline in range of Malleefowl over time in the Western Australian wheatbelt. The first, for all of Western Australia, mimicked the method of Benshemesh (2000), but utilized a

greatly expanded presence-only dataset. Contractions were most evident in the far south-west (near-coastal) and eastern (arid) extremes of the historical range. However, the sparse available data for the eastern extreme in particular were insufficient to provide a confident prediction of decline.

The analysis for the Western Australian wheatbelt emphasised the importance of mallee and shrub/thicket as habitat for Malleefowl. Malleefowl declines were greatest in areas with the most extensive clearing, areas cleared earliest (pre-WWII), and areas with highest sheep numbers. However, there is some suggestion that these were always marginal habitats for Malleefowl.

Climate – Climate across the range of Malleefowl is diverse, likely translating into differences in habitat and vulnerability to threats. Malleefowl locations within the northern wheatbelt and adjacent pastoral areas of Western Australia were identified as climatically distinct from other locations within the range of the species. This climatic distinctiveness was matched by distinct habitat types utilized by Malleefowl (*Acacia*/*Allocasuarina* thickets). All three climatically distinct zones within the range of Malleefowl were present in Western Australia.

There have been a multitude of studies of Malleefowl ecology in eastern Australia, all in one of the three climatic zones identified: the semi-arid group. This corresponds to an area of the southern WA wheatbelt, in the vicinity of Ongerup.

Three scenarios of climate change (CSIRO 2001), if realised, suggest that Malleefowl may experience a substantial reduction in range over the next 20 to 60 years. The most extreme scenario (reduction of rainfall in each season by 15-20% and an increase in mean temperatures throughout the year by c. 1.5°C) would likely cause an estimated 53% reduction in range by 2030 with the species' range contracting towards the mesic south-west.

Habitat – This analysis employed a presence/absence dataset with absences derived from surveys conducted in the 1990s and reported via the New Atlas of Australian Birds. Malleefowl were found to be associated with landscapes with lower rainfall, greater amounts of mallee and shrubland, typically in remnants > 500 ha, and with lighter soil textures. Hence, much of the western half of the wheatbelt was deemed less suitable due to higher rainfall, more woodland and less mallee and shrubland, and more extensive clearing.

Fire – Malleefowl are considered highly sensitive to frequent fire and, in the Victorian mallee may need a fire interval of > 60 years (Benshemesh 1992). Our assessment of fire in south-west Western Australia found frequency to vary with remnant size. Few small remnants (100-500 ha) had burnt in the past 30 years, and in those that had, the extent of the burn was small (mean of 80 ha). Fire in larger remnants (> 500 ha) was moderately common and a greater proportion of the remnants had burned. Continuous vegetation adjacent to the wheatbelt, in contrast, burnt frequently and the scale of the fires was much greater. This work emphasises the disproportionate importance of smaller remnants to the long-term conservation of Malleefowl in south-west Western Australia.

Our space-for-time analysis of the regeneration of Malleefowl habitat following fire indicated that mallee developed a complex understorey and rich litter layer after about 15 years and maintained these characteristics beyond 45 years. In contrast, *Acacia* shrubland took somewhat longer to develop a litter layer and this layer and the shrubby understorey tended to diminish after about 25-30 years.

This work suggests that fire history may not be so critical in Western Australia as suggested by work in the Victorian mallee. It appears that Malleefowl may be able to re-occupy key habitats 15 years post-fire. Lack of fire may be an increasing issue, particularly in fragmented parts of the northern wheatbelt where *Acacia* shrubland is the dominant habitat for Malleefowl.

**Regional Model:** The habitat model described above permits a spatial assessment of the extent of Malleefowl habitat within the wheatbelt. We created a spatial plot of the model and 95% confidence intervals for the wheatbelt. Our model identified 8 689 500 ha of the wheatbelt as having a 50% or greater chance of containing a Malleefowl presence. If we omit farmland, we find that the model predicts 2 016 000 ha of remnant vegetation as having a 50% or greater chance of containing Malleefowl. This suggests an approximate 77% reduction in available habitat through the process of clearing for agriculture over the past 100 years, considerably less than that of the wheatbelt as a whole.

Approximately 55% of this area is part of the public estate (e.g. reserves, unallocated crown land, unmanaged reserves) with approximately 45% on private lands. Remnant vegetation formally reserved as part of the conservation estate (i.e. managed by the Western Australian Department of Environment and Conservation) makes up approximately 36% of the area predicted.

The extent of Malleefowl habitat on private land suggests an ongoing need to incorporate the wider farming community in Malleefowl related actions for conservation.

**Spatially explicit population model:**

We used a combination of mound densities from Western Australia, estimates of breeding birds per active mound from eastern studies, and the regional model to identify interconnected 'neighbourhoods' for Malleefowl within the wheatbelt. We identified 14 neighbourhoods, seven of which we considered viable (> 300 breeding birds), seven at-risk neighbourhoods (100-300 breeding birds), and 371 non-viable neighbourhoods (< 100). The seven viable neighbourhoods contained an estimated 36,786 breeding birds, some 94% of the estimated wheatbelt population. The seven at-risk neighbourhoods together contained some 930 breeding birds, and the 371 small and isolated 'non-viable' neighbourhoods collectively about 1,350 breeding birds.

The largest neighbourhood (some four million hectares) extended from Beacon in the north-eastern wheatbelt to the south coast and east to Scaddan (north of Esperance), and included many of the big nature reserves of the eastern and southern wheatbelt.

**Conclusion**:

Two views:

1. Malleefowl have declined in the wheatbelt because of high levels of clearing and fragmentation and are likely to continue to do so. This view is reflected in the National Recovery Plan (Benshemesh 2000). Key evidence is the substantial spatial decline to date from the central and western wheatbelt with the expectation of on-going major declines; or
2. The level of decline in wheatbelt is less than previously suggested. Much of the areas of putative decline may have been somewhat marginal as habitat for Malleefowl, as they were largely dominated by woodland (i.e. Malleefowl would have occupied the embedded smaller areas of mallee/shrubland, etc). The eastern parts of the wheatbelt are vitally important to Malleefowl in that they are represent the core range of the species, have much retained favourable habitat, good levels of connectivity, the exclusion of fire maintains vegetative cover, and the possible impact of vegetation senescence of food supply may be countered by ready availability of food in adjacent paddocks. There are some substantial areas with fox control and there is direct connection to large areas of habitat to the east that have not been cleared (although this area is subject to a higher fire frequency, and uncontrolled goat browsing in the north-east).

While we favour the latter explanation we acknowledge there is still the possibility of continued decline of Malleefowl in heavily cleared areas and in more recently cleared areas if there is a continued erosion of landscape connectivity for Malleefowl and of habitat quality of remaining remnants. We need to guard against the gradual erosion of landscape quality in more recently cleared parts of the wheatbelt to ensure that they are not on a trajectory to the landscapes that are present in much of the central wheatbelt, characterised by high levels of clearing, small remnants, and little connectivity.

Within the wheatbelt, it is likely that the northern populations of Malleefowl are under most threat from a combination of climate change and lack of fire in smaller remnants (the habitats of the north appear to have a lesser period of suitability for Malleefowl in the fire cycle). Browsing by goats is a significant issue in adjoining pastoral areas.

While we have painted a relatively optimistic picture of the status of Malleefowl in the wheatbelt, we would caution against down-listing the official status of the species in Western Australia until there is more knowledge of the status of the species in the pastoral zone and in the large woodland areas to the east of the wheatbelt.

Our population model, although crude, provides an estimate of the overall population of Malleefowl in the wheatbelt, and an idea of where numbers are concentrated. This suggests an overall population size of *c.*40,000 breeding birds, divided between 14 neighbourhoods (each being an area of farmland and remnant vegetation in which the Malleefowl population is likely to form an interconnected whole). It also helps to identify priority populations for management action, identifying apparently secure, at-risk, and non-viable neighbourhoods. This model emphasises how the conservation of Malleefowl and other species in a fragmented landscape requires management to extend beyond the patch scale (or scale of the individual nature reserve) to incorporate landscape context. A key result was that extensive farm bush and major nature reserves of the eastern and southern wheatbelt complement each other and form one major interconnected neighbourhood of *c.* 4 million hectares, with a number of discrete satellite neighbourhoods of varying extent and viability.

Local government has a key role to play in maintaining existing connections across the landscape, farmers have a responsibility to maintain their remaining remnants by excluding grazing and some degree of fox control, and the Department of Environment and Conservation have a continuing role in the promotion of a diverse fire regime dominated by older fire ages within their large reserves. Ultimately the long-term conservation of Malleefowl in the wheatbelt will require the cooperation of all land managers, private and public.

**Recommendations:**

1. A more strategic approach to revegetation based on the regional model developed in this study;

2. A wheatbelt–wide survey to establish the extent and severity of grazing of farm remnants by stock;

3. Development of a fine scale GIS layer for habitat connectivity (e.g. roadside vegetation and retained and newly planted corridors) for the wheatbelt to assist spatial interpretation of isolation and fragmentation;

4. Continued promotion of community and farmer involvement in the long-term conservation of Malleefowl, particularly given the disproportionate role (relative to their size) of farm remnants in the conservation of Malleefowl;

5. Initiate research on "ecological renewal" by fire with respect to Malleefowl food plants and develop further knowledge on appropriate fire intervals for Malleefowl habitat. This might include a study of differential use of habitat in Lake Magenta Nature Reserve (southern wheatbelt) or Charles Darwin Reserve (northern wheatbelt) in response to varied local fire history;

6. Lobby for greater conservation security for the extensive areas of vacant crown land to the east of the wheatbelt (Great Western Woodlands, Watson

*et al*. 2008) as a major resource for Malleefowl (and other biota) and a counter to climate change because of its north-south extent;

7. Initiate more research on the first four years in the life cycle of Malleefowl , particularly with respect to dispersal and survival;

8. Further investigate the notion of fragmentation as an asset to Malleefowl rather than a cost (cf Benshemesh 2000), due to the close juxtaposition of food and shelter provided by cropping alongside ungrazed bushland remnants.

9. Initiate a study to address the dearth of knowledge of Malleefowl in pastoral areas of Western Australia.

## Acknowledgements

We warmly thank the Malleefowl Preservation Group, for their dedication, support and provision of Malleefowl sightings data for this study. In particular we thank Susanne and Alan Dennings for generously offering their time, and Claudine Deering and Sean Fletcher for their support. We also thank Susanne and Alan Dennings for conducting school visits across south-west W.A.

We thank the North Central Malleefowl Preservation Group for their invaluable contribution. We particularly thank Sally and Wally Cail, Peter Waterhouse, Kevin Jones, Gordon McNeil and Roger Forte for acquainting us with the northern wheatbelt as well as providing data and housing us during survey work.

We thank Mick Davis (Friends of North Eastern Malleefowl) for provision of Malleefowl data.

We thank the many landholders and agency staff who contributed to various surveys during this project and took the time to share their knowledge regarding Malleefowl with us. Their intimate knowledge of Malleefowl and the landscape is irreplaceable and is critical to the successful management of the species into the future.

We thank members of the Malleefowl Network for advice and support, including network facilitators Raquel Carter, Alice Rawlinson, and Carl Danzi and current chair Dr Stephen Davies.

The Western Australian Museum, Department of Conservation and Land Management, and Dr Joe Benshemesh provided Malleefowl sightings data to the project. Bush Heritage Australia, Australian Wildlife Conservancy and the Department of Environment and Conservation (DEC) allowed access to their land. Kind thanks also go to Andrea and Kurt Tschirner (Bush Heritage Australia) for offering their support and knowledge regarding fire management.

Klaus Braun (ICS Group) and Mitch Davies (DEC) kindly provided digital fire history and vegetation data. Jessica van der Waag (MPG), Georg Wiehl and Dr Carl Gosper (CSIRO Sustainable Ecosystems) provided valuable assistance with fieldwork. Drs Mike Austin, Suzanne Prober, Nick Nicholls, and Tony Arthur (CSIRO Sustainable Ecosystems) provided advice on experimental design and modelling techniques, as did Dr Terry Walshe (UWA) and Dr Lesley Gibson (DEC). Jeremy Wallace and Suzanne Furby (CSIRO Mathematical and Information Sciences) provided remote sensing data used in spatial analyses. We thank them all.

Finally, we thank Natural Heritage Trust, Avon Catchment Council and WWF Australia for provision of funding and/or project administration and CSIRO Sustainable Ecosystems for providing additional funding to support Blair Parsons.

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## Introduction

This report details work carried out as part of a joint Wildlife Research and Management (WR&M) / WWF Australia project for the Avon Catchment Council (Project 033145 – Malleefowl conservation - informed and integrated community action).

The project is comprised of two parts – one relating to community engagement and support (for which WWF Australia is responsible) and one relating to the distribution, ecology and status of the Malleefowl in the Western Australian wheatbelt (for which WR&M is responsible). This report details the achievements of the latter sub-project only. This sub-project has WWF Australia reference number 40902.

### Project history

Susanne Dennings of the Malleefowl Preservation Group (MPG) approached CSIRO Sustainable Ecosystems in 2003 seeking scientific support for the ongoing effort of the MPG to conserve Malleefowl in Western Australia. Dr Jeff Short of CSIRO developed a relationship with the MPG and was invited to present a paper at the Malleefowl Forum in Mildura in January 2004 (Short 2004). This led to the development of a proposal for funding, based largely on the untapped resource of over 10 years of community reporting of Malleefowl sightings by the MPG. Susanne was also lobbying WWF Australia at this time and they had contact with a number of rural groups active in Malleefowl conservation.

Both Jeff Short of CSIRO and Raquel Carter of WWF Australia independently developed projects in 2004 to submit for a particular funding round – the Natural Heritage Trust Cross-regional Component. These projects had very different foci – one being a scientific analysis of the available data on Malleefowl distribution and the other being focussed on the social processes required to support conservation efforts by volunteer groups. At a late stage, a decision was made to combine these projects for submission to create synergies in the implementation of conservation action for Malleefowl throughout southern Western Australia.

This project was funded by the Commonwealth through a Natural Heritage Trust Cross-regional Component grant to the Avon Catchment Council (ACC). ACC contracted WWF Australia to deliver the project and they sub-contracted CSIRO to deliver the scientific component (January 2005).

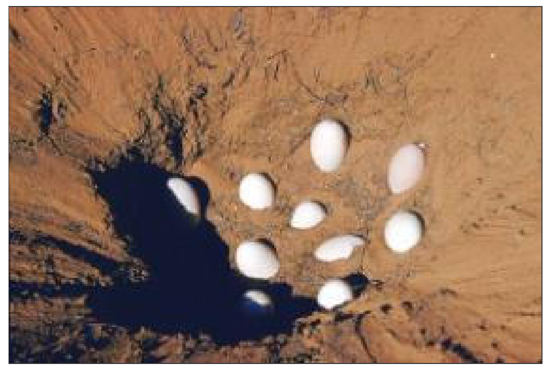
A decision by CSIRO Sustainable Ecosystems to withdraw from 'single species research' in February 2005 led to the transfer of the scientific component of the project to the newly formed Wildlife Research and Management (Dr Jeff Short). WR&M was contracted by WWF Australia to complete the delivery of the scientific component in August 2005.

## Conservation background

The Malleefowl *Leipoa ocellata* (Plate 1) belongs to the family Megapodiidae, the megapodes or mound builders. The group is unique amongst birds in that its members use external sources of heat to incubate their eggs.

Malleefowl are a threatened species under the Commonwealth *"Environment Protection and Biodiversity Conservation Act 1999"*. Malleefowl are listed in Western Australia as Fauna that is rare or is likely to become extinct under Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2005.

**Plate 1:** A Malleefowl at the mound; an incubation chamber containing Malleefowl eggs (Photos: courtesy of CSIRO Sustainable Ecosystems)



Benshemesh (2000) documented a contraction in the range of Malleefowl of about 50% within the past century, being most pronounced in arid areas and at the mesic peripheries of its former range.  Habitat loss due to land clearing was a major factor in declines, particularly on the mesic margins of their former range, and grazing by sheep, goats and rabbits have played a significant part (Frith 1962a, b).  The role of foxes was regarded as more controversial: "while some authors believe that fox predation is the main threat to Malleefowl populations and a major cause of their decline, others have considered Malleefowl populations resilient to high predation rates due to their life history and high fecundity." (Benshemesh 1997: 25).

Benshemesh  states that despite some uncertainties "there is no doubt that Malleefowl are currently threatened by a range of factors, and in many areas there has been such loss and fragmentation of their habitat that remaining populations are small and isolated, and prospects for their long-term conservation are poor. Detailed and extensive monitoring of Malleefowl populations in Victoria, South Australia and New South Wales has shown steep declines in breeding densities over the past decade, and the past five years in particular."

Benshemesh further notes "Malleefowl qualify as Vulnerable by current criteria for threatened species (IUCN 2001) as populations have declined by at least 20% over the past three generations (estimated as 15 years each), and it is likely that populations will decline by at least another 20% over the next three generations

(IUCN 2001, criteria VU A1c,e and A2b,c,e) . Further declines are expected both because many remaining populations are small and isolated, and because all populations are threatened by introduced competitors and predators and subject to recurrent catastrophic events of a scale that severely threaten the viability of populations and the quality of habitat."

Hence, Malleefowl are believed to have suffered substantial historical decline with further declines likely. However, it is not entirely clear whether the declines seen elsewhere in Australia have occurred in the Western Australian wheatbelt. Some experienced observers in the west have even suggested that the species may be increasing (Serventy and Whittell 1976).

Benshemesh states that "in the semi-arid zone where Malleefowl densities are highest, the clearing of habitat has been the major cause of the marked decline in the distribution of the species. Apart from removing much of the best habitat for the species, this clearing has fragmented the distribution of Malleefowl, and over much of its range the species now persists in small patches of habitat that are inadequate for its long-term conservation."

In Western Australia, there is a high level of interest in Malleefowl from community groups based in the wheatbelt. The members of these groups often have direct experience of Malleefowl in small remnants persisting after clearing. By Benshemesh's account, these populations may well be doomed.

However this view may be unduly pessimistic. Many aspects of landscape and habitat management may differ between the east and the west of Australia, including time since clearing, clearing patterns, fire history, remnant management, and attitudes towards exotic predators. Also the nature of the habitat, including the presence of a significant shrub understorey and the presence in many areas of poison peas (*Gastrolobium* spp.), may influence the favourability of post-clearing habitat.

## Objectives

Our aim was to provide a level of knowledge about the distribution and status of Malleefowl that would inform practical land management decisions at both the regional and local scale. We aimed to add value to the existing data on Malleefowl distribution, which was amassed over the prior decade by community groups in Western Australia, by collating, mapping and analysing.

Much of that existing data on Malleefowl consisted of presence-only records from the Western Australian Museum and from community recording. These data (because of the absence of absences!) had major deficiencies. Our objective was to find new and creative ways of using them to extract maximum value for conservation.

Our project had grown out of community interest and relied on community data. Farmers and land managers were strongly represented and most sightings were on private land.  Hence our aim was to maintain a landscape focus, rather than a protected area focus.

A key tool was the use of Geographic Information Systems (GIS) technology in spatial analysis, which allowed us to pursue a whole-of-landscape approach.  Our hope was to find new ways of utilizing these technologies to generate practical outcomes for management and to illustrate the value of such approaches.  We hoped their use would enable us to encourage new approaches to regional conservation that integrated on- and off-reserve conservation and provided the information to manage at a regional scale.  This in turn should lead to a significant improvement in the sustainable management of natural resources across the regions.

Finally, a key practical goal was to identify priority populations for Malleefowl conservation activities in Western Australia.

## Scope items

Key scope items identified in the contract are:

1. Engage with and provide support to community groups active in Malleefowl conservation , including training in database entry as required;
2. Collate existing sightings records;
3. Fill gaps in sightings record by survey;
4. Complete literature review of the ecology of Malleefowl;
5. Collate GIS layers of biophysical attributes;
6. Analyse sightings records;
7. Build regional model;
8. Develop spatially explicit population model;
9. Provide recommendations to link on and off-reserve conservation activities.

## Achievements

### 1. Community support and engagement

This component included four major areas:

1. Support for the MPG to continue with school visits to raise awareness of Malleefowl within their range;
2. Engagement with community groups involved in Malleefowl conservation;
3. Support for the MPG to upskill as appropriate; and
4. Creation of websites.

#### School visits

Wildlife Research and Management provided funds and direction to the MPG to consolidate on their existing school visit program and expand it to cover a wider area of the wheatbelt and south-west. Previously, it had focused largely on areas in the southern wheatbelt. School visits were organised around the "Malleefowl Magic" educational program, which teaches children about the life of Malleefowl in a fun and interactive manner. These school visits were known to stimulate interest in Malleefowl and often led to an increased number of sightings submitted from the area to the MPG. Hence, the location for many of the school visits was strategically chosen from areas within the wheatbelt where few records of sightings have been submitted in an effort to obtain more information about the distribution of Malleefowl.

Over the three year period, Susanne Dennings of the MPG presented the "Malleefowl Magic" educational program to 48 schools within the current or former range of the Malleefowl:

- **eight schools in the south-west**, including Augusta PS, Cowaramup PS, Karridale PS, Margaret River PS, Montessori PS (Margaret River), Nannup PS, Nyindamurra PS (Margaret River), and St Thomas More PS. Malleefowl packs were delivered to a further five schools including Bridgetown PS, Denmark PS, Northcliffe PS, Pemberton PS, and Walpole PS. All presentations were well received.
- **thirteen schools in the south coast region**, including Condingup PS, Esperance Christian PS, Esperance PS, Grass Patch PS, Jerdacuttup PS, Jerramungup PS, Munglinup PS, Our Lady Star Of The Sea PS (Esperance), Ravensthorpe PS and HS, Salmon Gums PS, Scaddan PS, and Wangatha Aboriginal School (Gibson).
- **four schools in the Merredin area** (North Merredin PS – two visits, South Merredin PS, Merredin High School and St Mary's Catholic PS). A Malleefowl Magic pack was also given to Westonia Shire NRM trainee Sara Bright to give to Westonia PS.
- **twenty three schools in the central and northern wheatbelt**, including Broomehill, Yealering, Tammin, Wyalkatchem, Wongan Hills, Cadoux,

Kalannie, Dalwallinu, Wubin, Coorow, Carnamah, Morawa, Perenjori, Latham, Buntine, Bencubbin, Mukinbudin, Westonia, Quairading, Babakin, Corrigin, Lake Grace and Dumbleyung. In addition, a community information evening was held in Wongan Hills.

**Figure 1:** South-western WA showing locations of school visits relative to the occurrence of Malleefowl.

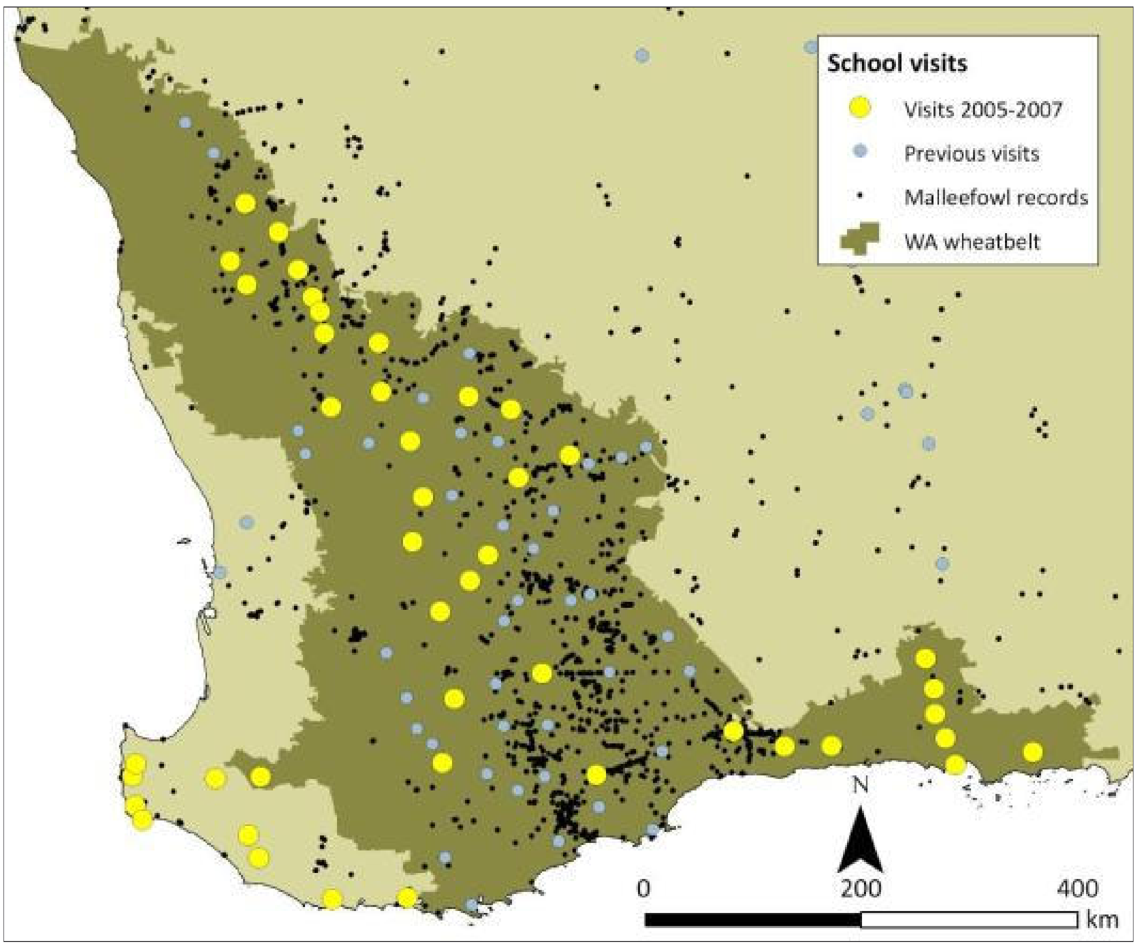


**Plate 2:** Susanne Dennings "nest making" with students at Southern Cross Primary School, as part of their Festival Day. Picture courtesy of Susanne Dennings.

**Plate 3:** Susanne Dennings and "Merve the Malleefowl" with students at Mount Margaret Primary School.

## Community involvement

Malleefowl Network

Both Blair Parsons and Jeff Short have regularly attended the WA Malleefowl Network meetings held bi-annually over the past three years. Blair typically provided an update on the progress of the scientific component of the project at these meetings. Both have had substantial input to the WA Malleefowl Action Plan, the revised National Malleefowl Recovery Plan, and Blair was on the organising committee for the National Malleefowl Forum held in Katanning in September 2007.

**Plate 4:** Participants at the Western Australian Malleefowl Network meeting March 2008. Back row from left: Gordon McNeil (NCMPG), Roger Forte (NCMPG), Dr Stephen Davies (chair and Curtin University), Dr Mike Bamford (Birds Australia), Blair Parsons (UWA/CSIRO); middle row: Wally and Sally Cail (NCMPG); and front row: Carl Danzi (WWFA co-ordinator) and Dr Jeff Short (WR&M).

Direct engagement with the MPG

Blair Parsons and/or Jeff Short have regularly participated in monthly MPG committee meetings over the three years of the project (Table 1).

During early June 2005, Blair Parsons in cooperation with the MPG, organised an information night for the community in Ongerup. Over 30 people attended, including community members, CALM staff from Albany, and the WA Malleefowl Network coordinator Alice Rawlinson. Both Blair and Jessica van der Waag (UWA PhD Student) gave presentations on their research with much positive feedback received from the group. During the meeting various issues related to the project were discussed including GIS training and provision of local knowledge by landholders in the area.

Jeff Short, Blair Parsons or both have attended each of the MPG's Annual General Meetings, held in Bullfinch (near Southern Cross) in 2004, Denmark in 2005, Ongerup in 2006 and Hyden in 2007. Blair presented an update of the project at the latter three meetings.

The Malleefowl Preservation Group continues to collect records of Malleefowl sightings (via their web page and from solicitations in *Malleefowl Matter*) and these are passed on to us.

### Direct engagement with community groups other than the MPG

Blair Parsons presented at an information session for the community in Wubin organised by the NCMPG in August 2005. Approximately 15 people attended including community members and the WA Malleefowl Network coordinator Alice Rawlinson. Blair gave a presentation on project research with much positive feedback received from the group. In addition, Blair conducted an information sharing session, where members of the NCMPG provided him with relevant data on Malleefowl in the area. The NCMPG showed Blair several Malleefowl monitoring sites.

During his stay, Blair accompanied the NCMPG on their annual fox baiting drive, which visited various towns in the area including Maya, Wubin, Gunyidi, Kalannie, and Pithara. This provided an opportunity for local landholders to share their knowledge on Malleefowl with Blair, including records of sightings of the species. Blair also accompanied Maya landholder Peter Waterhouse to his property to view known active mounds within a large bushland remnant located east of Maya.

**Table 1:** Engagement with the community groups between September 2004 and March 2008.

| Meeting | Date | Attendance |
|---|---|---|
| MPG Annual General Meeting - Bullfinch | Sep 2004 | 40 |
| MPG Annual General Meeting - Denmark | Sep 2005 | 60 |
| MPG Annual General Meeting - Ongerup | Sep 2006 | 50 |
| MPG Annual General Meeting - Hyden | Sep 2007 | 50 |
| MPG Information night | Jun 2005 | 30 |
| NCMPG Information session | Aug 2005 | 30 |
| MPG meetings | monthly | 5-10 |
| WAMN meetings | bi-annually | 10-20 |
| National Malleefowl Forum | Sep 2007 | 80 |

### Upskill groups in database and GIS

We have provided database and GIS training to a MPG committee member. Other members have been given an informal introduction to the database. In addition, a user-friendly interface was designed for the database where sightings records are stored and MPG members have been trained in basic data entry or have worked with WR&M staff to enter data at the Ongerup office of MPG. In general the community group was happy to 'delegate' much of the task of data entry and management to WR&M. Attempts to solicit community volunteers to take a greater role were unsuccessful (for example, an advertisement placed in an edition of Malleefowl Matter by MPG).

### Creation of websites

Two websites summarising the project and its objectives were created. A project description can be found on the WR&M website at http://www.wildliferesearchmanagement.com.au/Malleefowl.htm. This report will be added to the Wildlife Research and Management web site.

A brief description of Blair Parsons' PhD project, which comprises much of the work associated with the overall project, can be found at http://www.animals.uwa.edu.au/pgweb?displaytype=Student_info&id=532.

## 2. Collate existing sightings records

At the commencement of this project it was evident that there was a large amount of data on the occurrence of Malleefowl in the Western Australian wheatbelt – but this data was fragmented between many sources and in great need of collation. One important source of data was that of the MPG in Ongerup, a group that had been collecting sightings data since the mid-1990s. However, much of this data was in a raw form, on stored paper sheets and often with a written description of location that could not necessarily be translated easily into latitude and longitude. Our goal was to work with the MPG to collate all available data, but with a focus on adding value to the existing data held by the group. Over time this goal broadened to include the compiling of location data for Malleefowl from other community groups in the wheatbelt.

The task of collating data began with developing a spatially linked relational database to allow storage and manipulation of data. This database was linked to a GIS system (ArcView) allowing for the verification and correction of misplaced or inaccurate data.

We worked with the MPG to organise and collate their records and to support them in collecting further data from community members. This required:

- Verifying the accuracy of records and correcting if necessary. We sought data to an accuracy of 250-500m;
- Culling of records where descriptions or locations were too vague (for example, we identified 142 records that did not have detailed descriptions and a further 49 records that were too vague to allow for correction to take place). Records beyond the wheatbelt (another 44) were collated also but the level of locational accuracy was not assessed.
- Continuing to accept further sightings in paper and electronic format via the MPG website and add these data points to the database at periodic intervals.
- A further call to members for data via the March 2005 edition of *Malleefowl Matter*. This was a call for information about the presence of Malleefowl in an area where there was an obvious gap in the distribution. This included an area surrounding Gairdner (near the south coast and to the west of Fitzgerald River National Park). People who had seen Malleefowl were asked to provide information on any birds seen in this location.

Blair Parsons, Bruce Turner (CSIRO) and Dr Jeff Short worked with community members to translate data sheets into electronic format. Alan Dennings from the MPG invested a vast amount of time in translating written descriptions of location to latitude and longitude. The combination of his local knowledge and use of Magellan 'DiscoverAus' software allowed precise determinations. Other key volunteers included Susanne Dennings and Claudine Deering.

The verification and correction of the sightings records was an important but extremely labour-intensive process. It required each point to be displayed using the GIS and its location details checked to confirm whether it was in the correct position or not. Given that this dataset was the point of origin for much of the analysis that was to take place during the life of the project it was critical that the process be accurate and rigorous. Examples of error that existed within the dataset included:

- Human error during data entry;
- Error due to use of coarse resolutions (i.e. 32° 15′ is recorded instead of 32° 15′ 25.4″);
- Error due to vagueness of location descriptions.

Blair Parsons further investigated the accuracy of records derived from other sources. There included records from other agencies, community groups, and the literature. The verification process used an array of resources including various vegetation and land tenure layers displayed in a GIS as well as mapping packages containing detailed cadastral information. Web searches and the use of online Atlases (e.g. SkyView orthophoto viewer http://www.landonline.com.au/skyviewwa/content/asp/skyviewwa_index.asp?product_group_id=78, Western Australian Atlas http://www.walis.wa.gov.au/walis/content/wa_atlas_popup2.html#) were also incorporated into the process. The majority of these data were accurate to 300 m.

Sightings data continued to be submitted to the MPG and Alan Dennings determined latitude and longitude for these sightings using computer mapping software. An increase in the reporting of Malleefowl sightings was experienced after a call for further data was included in the March 2005 edition of *Malleefowl Matter*. Approximately 20 sightings per month have been recorded since March 2005, contributing to the already large body of data available for analysis. We continued to accept new records until January 2006.

Despite this wealth of data, there was a bias towards the southern wheatbelt where most of the MPG members reside. In an effort to remove some of this bias, Blair Parsons approached the North Central Malleefowl Preservation Group (NCMPG) and Friends of North Eastern Malleefowl (FONEM) to gain access to their sightings and mound data. Mick Davis from FONEM provided 55 accurate records from the Mukinbudin area, and NCMPG provided 61 records from Wubin and surrounds. In addition, NCMPG provided data for over 120 mounds located within the Dalwallinu Shire. These data were entered into the database, plotted using a GIS and checked for accuracy. They provided valuable information for the central and northern wheatbelt, areas that were previously under-represented.

**Table 2:** Number of records of sightings of Malleefowl compiled from various sources. The database contained a total of 2861 records of sightings of Malleefowl at December 2005.

| Data Source | Community/agency | Count |
|---|---|---|
| Malleefowl Preservation Group | community | 1281 |
| Western Australian Museum | agency | 630 |
| Department of Environment and Conservation | agency | 411 |
| Birds Australia (Atlas 1 data) | agency | 135 |
| Birds Australia (Atlas 2 data) | agency | 95 |
| Structured surveys (this study) | community | 65 |
| North Central Malleefowl Preservation Group | community | 61 |
| Friends of North-eastern Malleefowl | community | 55 |
| Bird Atlas of South-western WA | agency | 51 |
| Literature | agency | 43 |
| Personal observation (Blair Parsons and Leslie Brooker) | community | 34 |
| **Total by community** | **-** | **1496** |
| **Total by agency** | **-** | **1365** |

All of these data have been verified and organised into a useable format. Key attributes such as breeding status, bird size, and habitat type have been extracted from general comments fields and placed into new fields, allowing them to be used in analysis.

**Figure 2:** A plot of the spatial distribution of sightings of Malleefowl for south-west Western Australia.

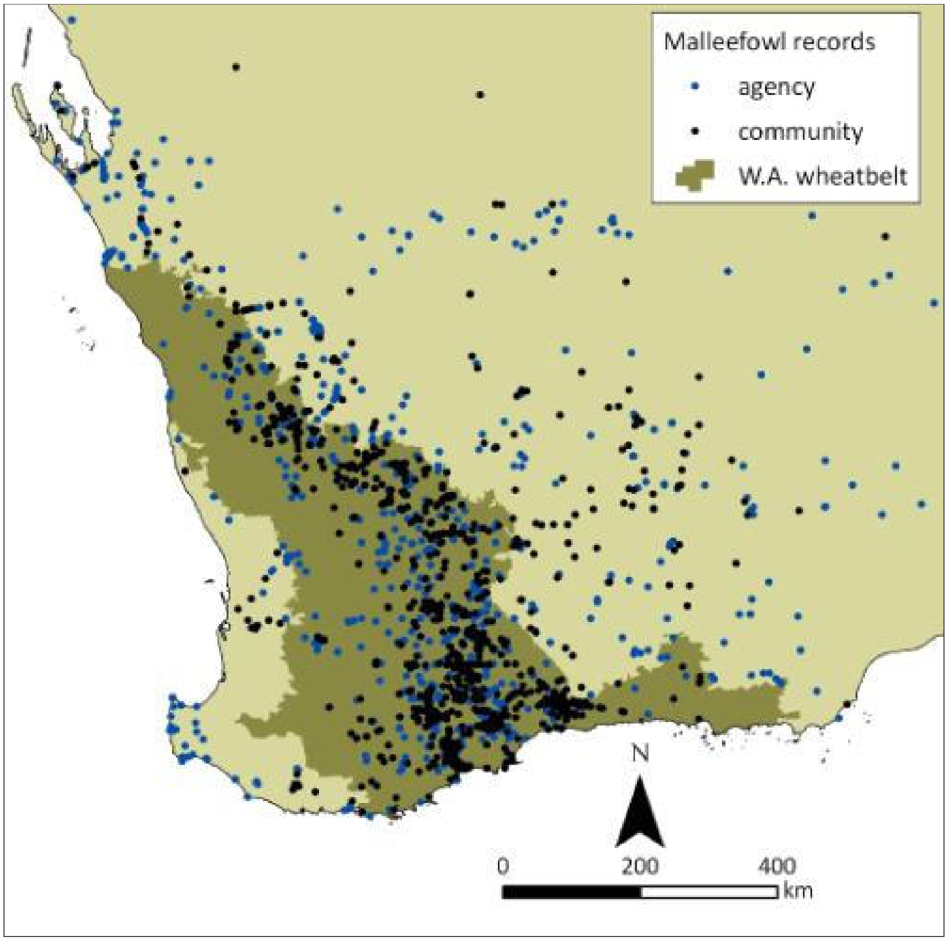
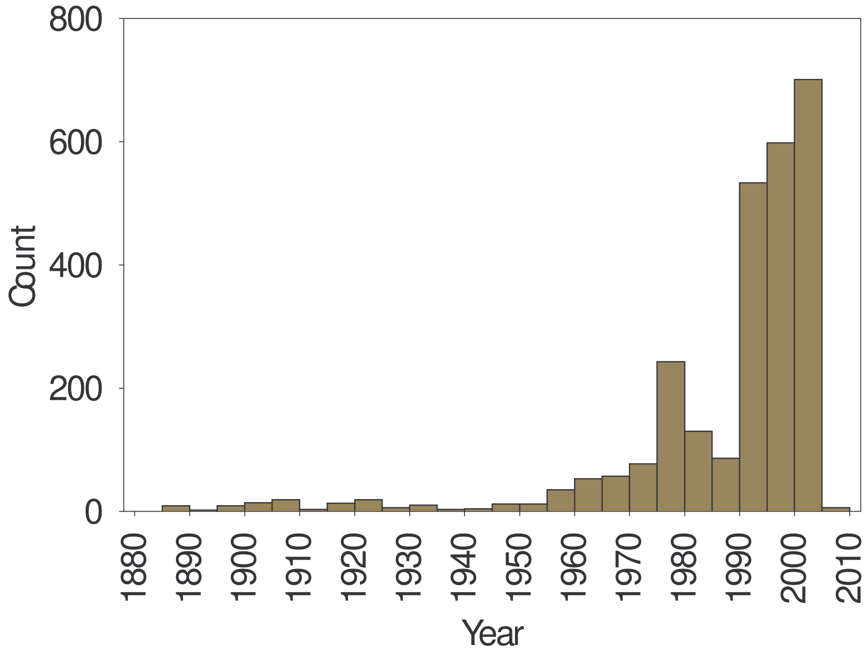


**Figure 3:** A plot of the distribution of sightings of Malleefowl over time.




Temporal changes in sightings rate

The key feature of Figure 3 is the strongly accelerating growth in sightings records beginning in the mid-1950s, with a minor peak in the late 1970s and a major peak between 1990 and 2005. There is a general view that Malleefowl are on a long-term declining trend and that this trend continues despite a cessation of land clearing in the wheatbelt (Benshemesh 2000, Garnett and Crowley 2000) in direct contrast to the trend of observations. How do we reconcile this disparate information?

Listed below are a number of factors might that may have influenced sighting rates:

1. The rate of sightings might match population growth in regional Western Australia. This might suggest a rate of sighting peaking in c. 1970 and declining thereafter.
2. The rate of sightings may be linked to clearing history with many sightings during periods of land clearing. If so sightings should have peaked in 1960s and declined thereafter.
3. The rate of sightings might reflect the rise and fall in Malleefowl numbers in response to the impact of rabbits on the availability of food resources for Malleefowl. In this case there might be a step down in sightings in response to the arrival of rabbits in the south-west *c.* 1900 and a step up in sightings in the mid-1950s linked to the loss of rabbits to myxomatosis.
4. The rate of Malleefowl sightings may track abundance of Malleefowl subject to the primary influence of foxes. If this is the case, then there should have been a step decrease in Malleefowl sightings in the mid-1920s associated with the colonisation of the south-west by foxes. The introduction of myxomatosis

in the mid-1950s and the replacement of "one-shot" oats by rabbit flea in *c.* 1970 (Christensen 1980) would have had a major impact on the primary prey of foxes but the impact on Mallefowl as secondary prey would be more ambiguous. The introduction of broad-scale baiting of CALM (DEC) reserves (Western Shield) from 1996 would have resulted in an increase in sightings rate.

5. A major change in the relative profitability of wool and wheat in the early 1970s led to a quantum shift in agricultural enterprises in some areas, moving more strongly into wheat and placing less reliance on stock for wool. This led to a decrease in overall sheep numbers in the wheatbelt. This may have led to more benign land management for Malleefowl (i.e. less pressure to graze remnants and more likely to have crop around remaining remnants to provide food for Malleefowl). This might have led to a surge in sightings since the mid-1970s.
6. There has been a step-change (reduction) in winter rainfall in the Western Australian wheatbelt over the past 30 years. This may have reduced overall productivity leading to a decline in Malleefowl or may have had an indirect effect via a change in fire frequency. This would lead to an expected reduction in sightings in the past 30 years.
7. The sightings rate might be linked to the rise in profile of the bird (and birds generally) and the growth in community interest and communication technology. Therefore, sightings records should have peaked associated with major bird surveys in the late 1970s and 1990s and also risen sharply following the formation of the MPG and other groups from *c.* 1992.

The peaks and troughs in Malleefowl sightings appear strongly linked to changing effort rather than Malleefowl abundance. The graph cannot be taken as an index of density or abundance of the species as this would assume a constant effort over time. The minor peak in the late 1970s corresponds to Birds Australia's Atlas 1 surveys of 1977-1981 and the Western Australian Museum surveys of wheatbelt reserves in the mid-1970s. The major peak coincides with the rise of community groups and their organised reporting schemes in the 1990s.

Is there an explanation for the dips and bumps in earlier years or is any trend swamped by variable effort over time? We collated sightings to 5-year periods centred on major ecological events and compared 25 year periods (5 x 5 years) on either side of significant ecological events to establish if there was a step change in reporting rates. Results are detailed in Table 3.

Significant changes in sightings rate were evident during the period of early settlement of the wheatbelt commencing *c.* 1900 (3-fold increase), the arrival of foxes in the south-west *c.* 1923 (>2-fold decrease), and the 90% reduction in rabbits due to the introduction of myxomatosis in the early 1950s (9-fold increase). There was no decrease in sighting rate attributable to the arrival of rabbits *c.* 1905. This broadly overlaps the period of initiation of agricultural expansion and the likely step increase in the number of contacts between early settlers and Malleefowl.

The enormous changes in observer effort commencing in the mid-1970s and continuing through to the present largely swamp the impact of later events. The likely increase in foxes from the late 1960s and the substantial drop in rainfall would be expected to have negative impacts on Malleefowl numbers. However, numbers of sightings have grown strongly since mid-1950s. The spike in reporting at the beginning of the 1900s, coinciding with the beginning of the phase of agricultural expansion further reinforces the role that changing effort plays in reporting rates.

**Table 3:** Reporting rates for Malleefowl in relation to major ecological events.

| Ecological event | Mean sightings $yr^{-1}$ before | Mean sightings $yr^{-1}$ after | Expected effect | Actual effect | Test | Significance |
|---|---|---|---|---|---|---|
| Settlement of the wheatbelt from 1900 | 0.88 | 2.72 | Positive | Positive 3-fold | $F_{1,8} = 6.93$ | P = 0.030* |
| Arrival of rabbits in the south-west *c.* 1905 | 1.36 | 2.40 | Negative | Positive | $F_{1,8} = 1.56$ | P = 0.247, n.s. |
| Arrival of the fox in 1922-23 | 2.84 | 1.20 | Negative | Negative >2-fold | $F_{1,8} = 6.32$ | P = 0.036* |
| Arrival of myxomatosis in *c.* 1952-53 and subsequent major reduction in rabbits | 1.44 | 13.00 | Positive | Positive 9-fold | $F_{1,8} = 7.87$ | P = 0.023* |

## 3. Fill gaps in sightings record via survey

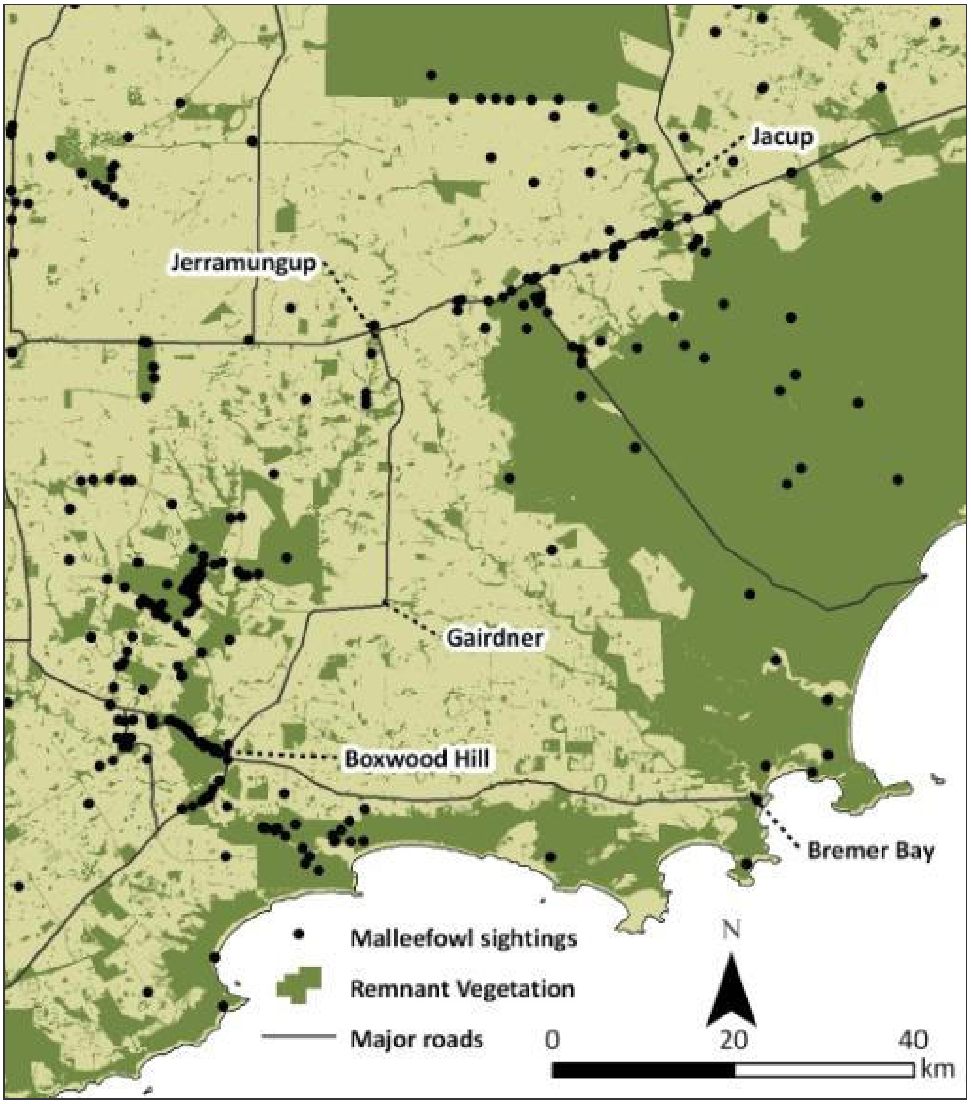
A major problem with the Malleefowl sightings dataset is that records are largely presence only, rather than presence / absence. Records were not collected in a systematic way, either spatially or temporally, but rather have been gathered from opportunistic sightings. The 2800+ dataset of Malleefowl sightings is biased by varying effort in time and space. The dataset allows us to say where Malleefowl do occur, but not to confidently say where they don't occur.

Attempts were made to strengthen the dataset by surveying areas of the Western Australian wheatbelt where there may have been a lesser level of effort. This included:

- Sourcing data from various Malleefowl groups in the northern and central wheatbelt (see above);
- Targeted field visits to areas where there were obvious gaps in distribution;
- Targeted postal and follow-up phone surveys of landholders in areas where sightings were lacking.

A survey of land managers and natural resource management officers (NRMOs) commenced in December 2005 aiming to determine whether "holes" in the sightings data (i.e. areas of apparent absence) were genuine or not and to understand why these patterns of Malleefowl occurrence existed. For example, in the 20 km circle centred on Wubin, 24 sightings of Malleefowl had been recorded whereas in the equivalent 20 kilometre surrounding Watheroo, just 60 kilometres to the west, only one sighting had been recorded. Similarly, in the 20 kilometres surrounding Ongerup, 56 sightings of Malleefowl had been recorded whereas in the 20 kilometres surrounding Gairdner, 50 kilometres to the south-east, only six had been recorded. The absence of sightings may have indicated a true absence of Malleefowl or it could simply have been that observers were sparse in these areas or had not reported the presence of Malleefowl. Similarly, areas with an abundance of records may simply have been areas where there were many committed observers reporting their sightings to community groups.

**Figure 4:** A map showing a conspicuous lack of Malleefowl sightings for Gairdner and surrounds, compared with neighbouring Boxwood Hill.

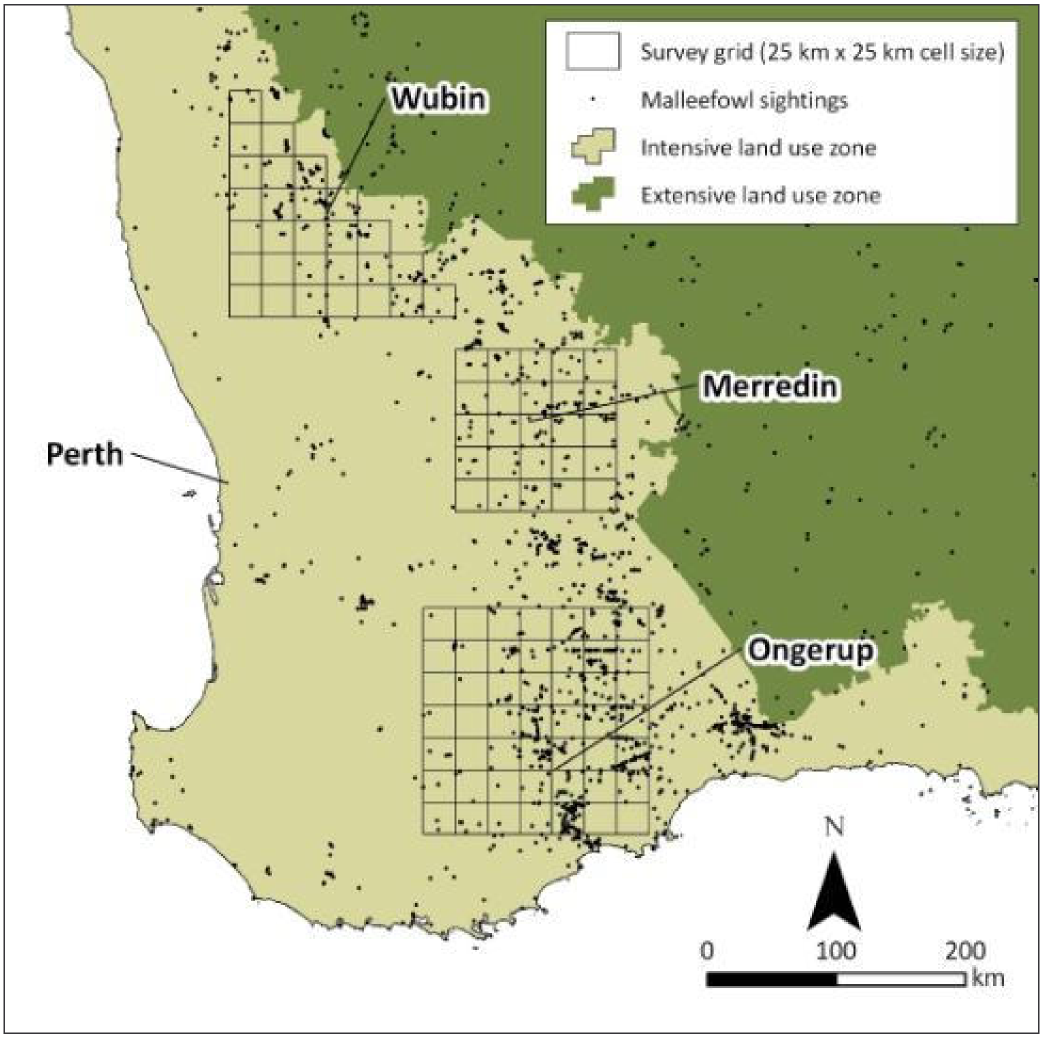



For example, we conducted a trip to Jacup (between Fitzgerald River National Park and Lake Magenta Nature Reserve) in June 2005 where there were few or no Malleefowl records. Upon visiting two landholders to the south and east of Lake Magenta it was found that Malleefowl were present throughout the area and we were able to identify many new areas of Malleefowl presence.

A postal survey was distributed to land managers and NRMOs in grids centred on Ongerup, Merredin and Wubin. These three grids covered 63,750 km$^2$, some 31% of the wheatbelt. Particular emphasis was placed on obtaining information from apparent areas of absence within close proximity of known areas of Malleefowl activity. The intention was to establish if this was a true reflection of the distribution of Malleefowl, or was an artefact of differential effort.

In all, the survey was sent to over 133 participants in the WA wheatbelt. Responses were obtained from 53 landholders; a return rate of nearly 40%. The end result of this postal survey was a presence/absence dataset covering nearly 64,000 $km^2$.

**Figure 5: The location of grids used in our postal/phone survey of Malleefowl occurrence.**




Intensive field survey of Malleefowl continued in late 2006 and 2007. This work provided further information on presence and absence but was targeted at gaining an understanding of the patchiness of Malleefowl distribution within the Western Australian wheatbelt at the scale of individual remnants. We sought to understand why Malleefowl occurred in some bushland remnants but not in others nearby. Information relating to the physical attributes of the habitat of Malleefowl (e.g. vegetation type, composition and structure, soil type and qualities) was collected. Vegetation surveys were conducted at three random quadrats (50 m x 50 m) in each remnant to assess habitat structure, quality and composition. Additional information relating to the management of habitat (e.g. grazing, fire history, and predator baiting regimes) was collected by meeting with landholders and agency staff and conducting semi-structured interviews.

The intensive field survey program initially focused on areas of the northern wheatbelt, including Wubin, Nugadong, Buntine, and Latham. Here 25 sites were visited. Subsequent surveys focused on the central wheatbelt (Merredin, Koonadgin, Bodallin, Wadderin, Doodlakine and South Tammin - 19 sites) and the southern wheatbelt (Ongerup/Pingrup – 13 sites).

## 4. Literature review

We reviewed the literature on Malleefowl ecology and distribution, landscape processes, and threatening processes relevant to the Western Australian wheatbelt. We also reviewed articles discussing modelling techniques suitable for analysing our dataset. The literature database for this review contained 458 records. An annotated list of scientific references relevant to Malleefowl distribution and ecology can be found in the Appendix. Table 4 summarises some of the key threatening processes identified in the literature.

Much effort was invested in researching spatial modelling techniques that were of relevance to this study. In addition to reviewing the literature, expert opinion was sought from various people including Dr Terry Walshe (UWA), Dr Lesley Gibson (DEC), and Drs Mike Austin, Nick Nicholls and Tony Arthur (CSIRO) who had considerable experience in ecological modelling. Furthermore, significant effort was put into investigating the use of various software applications for mapping and modelling to be undertaken in this project (e.g. GRASP (Generalised Regression And Spatial Prediction), R statistical software environment, PRIMER, BIOCLIM, and ArcGIS).

**Table 4:** Key factors impacting on Malleefowl occurrence.

| Factor | Description |
|---|---|
| Substrate | Densities are determined by soil type and its effect on understorey shrubs, as well as drainage capacity (Frith 1959); Malleefowl tend to prefer a relatively light soil (Frith 1962). |
| Vegetation type | Densities are higher in areas with dense shrub undergrowth or complete canopy; and one or more abundant *Acacia* shrubs (Frith 1962); Malleefowl nest in occasional clearings of impenetrable thickets within mulga (Kimber 1985). |
| Grazing | Grazing typically reduces density by 85-90%. Sheep graze on understorey, including *Acacia* shrubs, leading to rapid loss of herbs and seeds (Frith 1962). Malleefowl limited by food available, sheep and rabbits "enter into direct competition with the birds for food" – herbs and fallen *Acacia* seed. Destroy *Acacia* seedlings decreasing food supply (Frith 1962). Stock grazing may impact not only through competition for food (as suggested by Frith), but by opening up habitat and increasing vulnerability to predation; and by extending the time spent foraging exposing to greater threat from predation (Priddel and Wheeler 1996). |
| Fragmentation | A 92% reduction in area (from 22 to 1.8 $km^2$) produced only a 70% reduction in numbers (Frith 1973) – birds were able to utilize resources of the paddock. Observations of Malleefowl regularly feeding into paddocks on a regular basis in small remnants in the wheatbelt (< 200 ha) – extra resources may lift the carrying capacity of remnant (pers. obs.). However, recent extinctions have occurred in small nature reserves (162 ha and 145 ha) in NSW (Priddel and Wheeler 1994). |
| Drought | Rate of increase weakly related to rainfall with positive rates of increase at > 550 mm (cf long-term average of 487 mm). Malleefowl often failed to complete nests and to lay in low rainfall years (Priddel and Wheeler 2003). Compounding effect of drought, with breeding failure and adult mortality with losses not made up in subsequent years due to poor recruitment. (Priddel and Wheeler 2003). |
| Foxes | Priddel and Wheeler (1994, 1996, 1997, and 2003) reported fox predation on Malleefowl at all stages of their life cycle from eggs, newly-hatched, juveniles, sub-adults and adults; in contrast there is the view that Malleefowl |

| | |
|---|---|
| | are resilient to high predation rates due to their life history and high fecundity (Benshemesh 1997: 25); for summary of arguments see Short (2004). |
| Fire | Positive correlation between density of Malleefowl and time post-fire (assume largely linked to food availability, availability of litter for nesting, canopy for roosting, and the presence of a vegetation mid-storey to limit predation from birds of prey). Benshemesh (1992) noted that Malleefowl breeding densities were highest in vegetation with more complete canopy cover, a measure closely correlated to greater fire age. In mallee in eastern Australia, 60 yrs or greater is estimated to be an appropriate minimum fire interval with the maximum interval remaining unknown (Woinarski 1989, Benshemesh 1990, 1992). Clarke (2005) emphasised the importance of areas unburnt for > 40 years in south-east Australia. Priddel (1989) suggests the need for a mosaic of various ages within each mallee reserve. This helps prevent widespread wildfire which would create vast expanses of even-aged mallee coppice. |
| Rainfall | High-value mallee occurs in high rainfall areas of NSW (Priddel 1989). |

## 5. Collate GIS layers of biophysical attributes

The compilation and collation of biophysical spatial data required identifying appropriate GIS layers and sourcing them from the various agencies including Department of Agriculture, Department of Environment and Conservation, Australian Bush Heritage, Landgate, and CSIRO Mathematics and Information Sciences. These included:

- Climatic data (for all of Australia);
- Soil-landscape subsystems (for all of Southwest WA);
- Vegetation cover (for all of Southwest WA);
- Pre-clearing vegetation (for all of Southwest WA);
- Vegetation change 1988-2004 (for all of Southwest WA);
- Fire history mapping (Lake Magenta/Dunn Rock/Lake Bryde/Breakaway Ridge Nature Reserves in the south; Charles Darwin Reserve and Mount Gibson Sanctuary in the north);
- Land tenure (e.g. DEC managed lands, unmanaged reserves, unallocated crown land);
- Cadastre (e.g. property boundaries, roads, shire and locality boundaries); and
- Detailed vegetation mapping (Fitzgerald Biosphere and several major reserves);

These data are held on disk by Wildlife Research and Management, with Blair Parsons as custodian. Much of it is publicly available and therefore can be used in the future by WWF Australia or others but some is under licence. The value is in the analysis of this data in combination with the Malleefowl data.

## 6. Analyse sightings records

The collated Malleefowl records were a rich source of data and were subjected to a range of analyses. These included:

- Bioclimatic analysis;
- Changing distribution of Malleefowl over time;
- Habitat preference of Malleefowl at multiple scales;
- Occurrence in small remnants; and
- Fire frequency and the rate of recovery of Malleefowl habitat from fire.

These are discussed below.

### Bioclimatic analyses

This analysis sought to investigate and quantify climatic variation within the range of the Malleefowl, which covers approximately half of the Australian continent, spanning 37 degrees of longitude and 16 degrees of latitude. Because of the vast extent of this range, it is likely to encompass a substantial variation in climate, as well as a variety of habitats and land uses.

There have been many studies of the ecology of Malleefowl over the past 50 years, but all have been in south-eastern Australia, within the easternmost third of its range. One goal was to establish whether ecological findings from studies in eastern Australia can be applied to Western Australia.

In all, > 4000 records of Malleefowl occurrence across Australia were used in analysis. Records were derived from:

- the Western Australian sightings database compiled for this project, being the collation of community and institutional records (e.g. MPG, Department of Environment and Conservation, WA Museum, etc);
- an existing national sightings database of presence-only records (Benshemesh 2000); and
- data from long-term studies and monitoring sites in Eastern Australia (Frith 1959; Booth 1985; Brickhill 1987; Brandle 1990; Benshemesh 1992; Cutten 1998; and Priddel and Wheeler 2003).

We made use of the software package BIOCLIM (Houlder *et al.* 2000), a climatic modelling program, to determine whether climate within the range of Malleefowl in Western Australia is comparable to that in eastern Australia. This can be used to predict the climatic envelope for a species based on available location records. A key advantage of BIOCLIM is that it only requires presence data as opposed to presence / absence data.

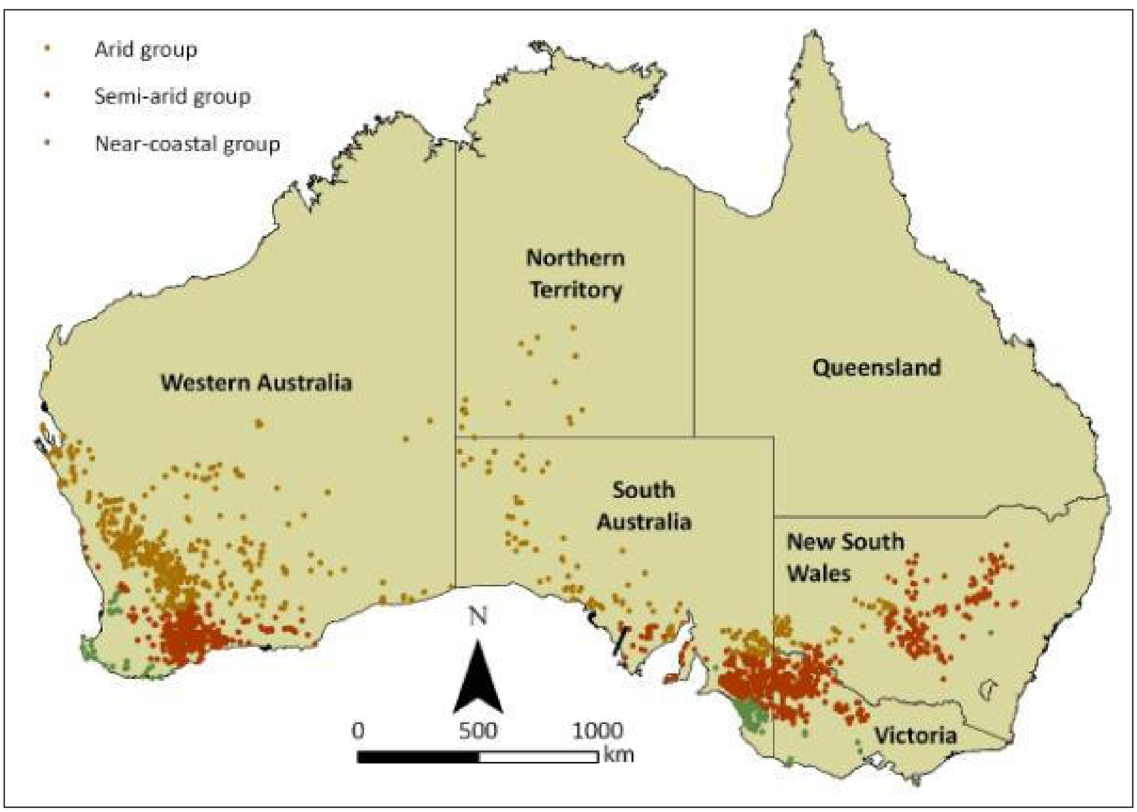
We sought to answer the following questions:

- What is the extent of climatic variation within the known range of Malleefowl in Australia and, what climatic factors are important in determining the occurrence of the species?
- Are there climatically distinct groups of sightings records within the known range of Malleefowl in Australia?
- What are the relative impacts of various climate change projections on the predicted future range of Malleefowl in Western Australia?

Results indicated that the climatic conditions experienced by Malleefowl did vary considerably across its range. Three climatic groupings were identified:

- an arid group (encompassing the northern and central Western Australia wheatbelt and pastoral areas of New South Wales and South Australia);
- a semi-arid group (encompassing the southern wheatbelt, Victoria, central New South Wales and southeast South Australia); and
- a near-coastal group (records from the deep south-west of Western Australia and deep south-east of South Australia only).

**Figure 6:** The geographic occurrence of three climatic groupings of Malleefowl records.




The range of Malleefowl in the central and northern wheatbelt and the far south-west of Western Australia have climatic conditions that are distinct from other areas within the range of the species in Western Australia. The climate experienced by

Malleefowl in Western Australia tended to be warmer and drier than in eastern Australia with higher levels of radiation and lower levels of moisture. The Western Australian climate also tended to exhibit a higher degree of seasonality in its rainfall (i.e. more distinct seasons such as dry summers and wet winters).

Past ecological studies from south-eastern Australia were conducted on populations of Malleefowl in the semi-arid climatic group. This group also contains records from the southern wheatbelt of Western Australia. Recent work by Jessica van der Waag in and around Ongerup falls within this climatic group. No ecological studies have been conducted in the group that covers the north and central wheatbelt of Western Australia or the deep south-west: the arid and near-coastal climatic groups.

Analysis of the likely response of Malleefowl to various predicted scenarios of climate change suggested a significant contraction from areas in the arid interior towards more mesic areas in the south-west. This included a significant southwards latitudinal contraction within the Western Australian wheatbelt.

A manuscript was submitted to the *Journal of Biogeography* in 2007 and a revised manuscript is in preparation for submission to an alternate journal. The manuscript is:

Parsons, B., Short, J., and Roberts, J.D. (in preparation). Climatic variation within the range of a widespread species: an analysis of the distribution of Malleefowl (*Leipoa ocellata*) in Australia using bioclimatic modelling.

### Changing distribution over time

This analysis sought to quantify the extent of decline of Malleefowl over time in the Western Australian wheatbelt. Early accounts suggest Malleefowl were common across their range in Western Australia but had reduced in number during the mid-twentieth century. Some published accounts (Benshemesh 2000) suggest a 45% decline. Others (Serventy and Whittell 1976) suggest an increase.

We made assessments:

- for all of Western Australia using the method of Benshemesh (2000) and a greatly expanded presence-only dataset; and
- for the Western Australian wheatbelt using an improved methodology and data from three grids centred on Wubin, Merredin, and Ongerup, spanning an area of *c.* 64,000 km$^2$.

The key inputs to the latter analysis were:

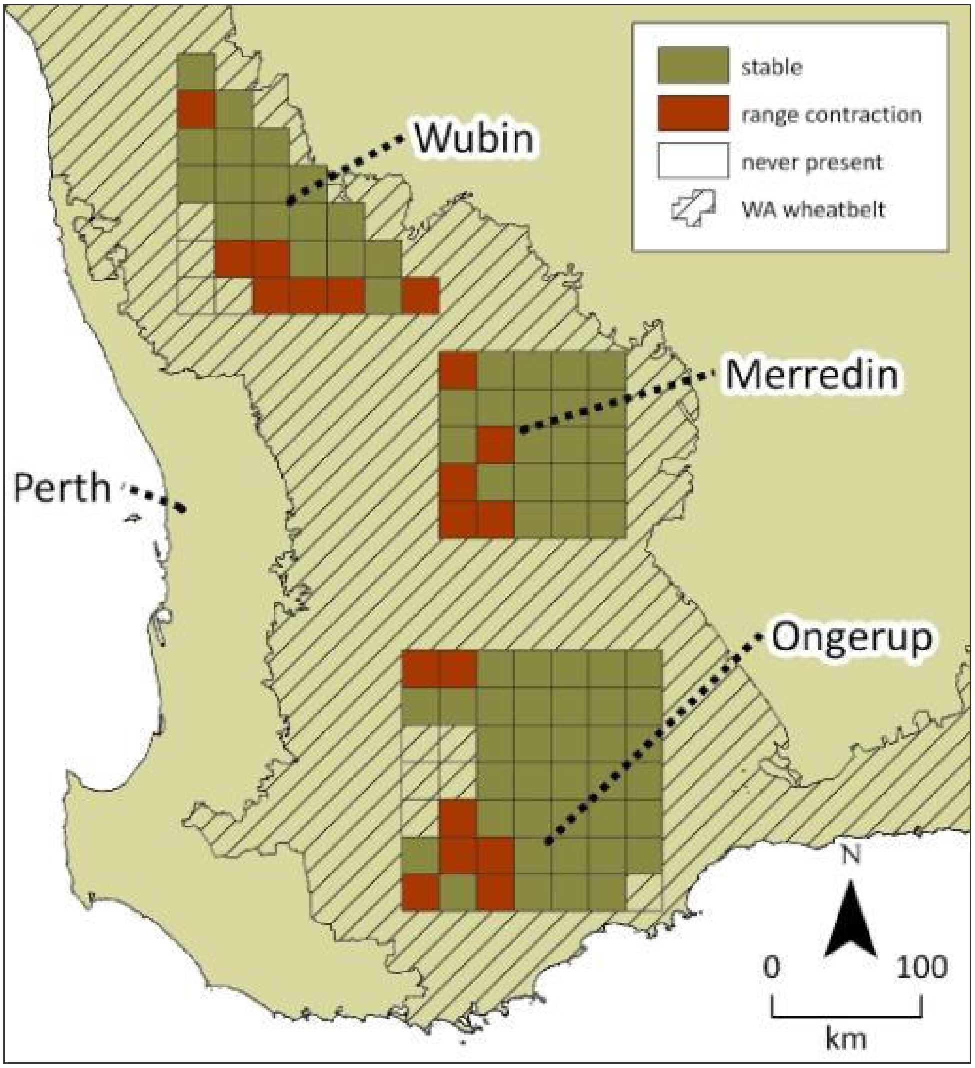
- Presence data for Malleefowl derived from a collation of community and institutional (WA Museum, Department of Environment and Conservation, etc) records;
- Absence data generated from the interviews of long-term residents (via postal and phone surveys) within our grids; and
- Environmental variables (e.g. vegetation extent, clearing history, wheat and sheep density).

The aim of this analysis was to determine whether there has been a contraction in the range of Malleefowl over time and what the reasons for this might be.  We split the sightings data for all of WA into pre- and post-1981 and that for the WA wheatbelt into pre- and post-1989.

Findings suggest that that the range of Malleefowl has contracted within Western Australia with contractions most evident at the south-west (near-coastal) and eastern (arid) extremes of its historical range.  Comparisons of the expanded data set with that of the National Recovery Plan (Benshemesh 2000) show that the decline of Malleefowl is less than that documented previously.

Within the Western Australian wheatbelt, Malleefowl were historically present in areas dominated by mallee and shrub/thicket vegetation and largely absent from areas dominated by woodland or heath associations.  This is broadly in keeping with their present distribution.  Malleefowl decline in the wheatbelt region was negatively correlated with the amount of vegetation in an area and positively with the number of years that land has been under agricultural production, suggesting that they are vulnerable to processes of degradation associated with land clearing and agricultural expansion.  The decline of Malleefowl was correlated with the amount of sheep present in an area, suggesting either that sheep are having negative effects on Malleefowl habitat; or that where sheep numbers are lower, wheat cropping (a known source of food) is more prevalent, which may benefit the species.

**Figure 7:** Malleefowl status (i.e. stable or range contraction) within 25 km x 25 km cells within the Western Australian wheatbelt.



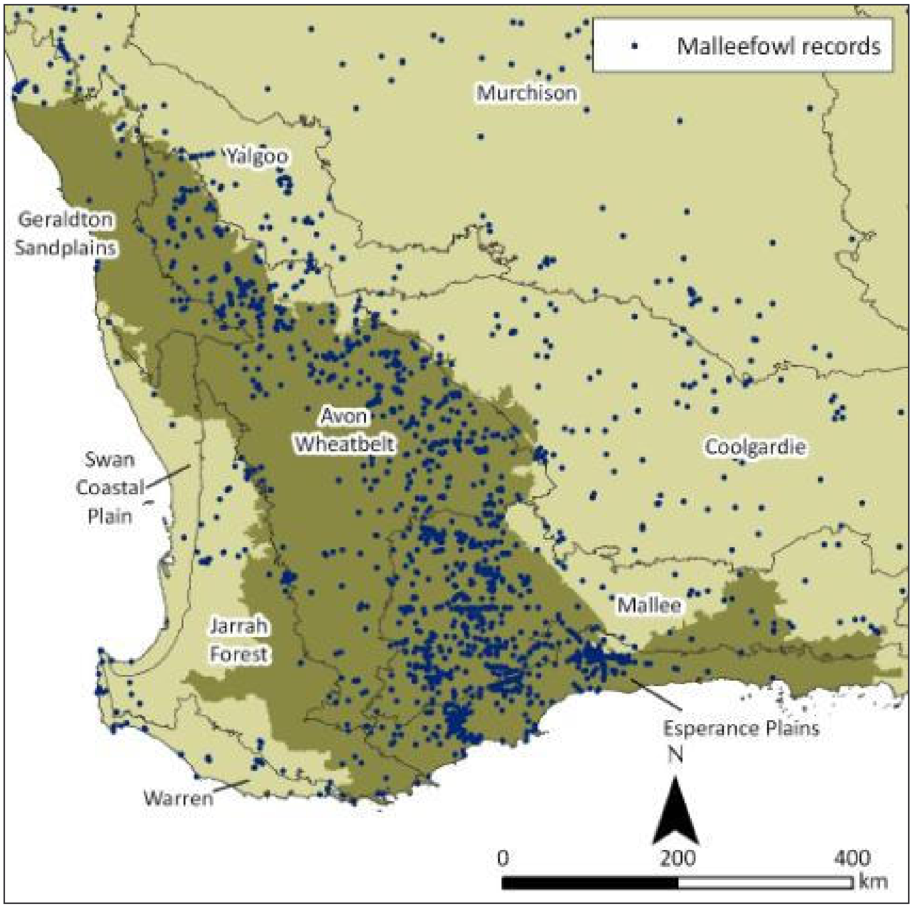

A manuscript has been submitted to and accepted by the journal *Emu*. The manuscript is:

Parsons, B., Short, J., and Roberts, J.D. (2008). Malleefowl (*Leipoa ocellata*) range contraction in Western Australia: a comparative assessment using presence-only and presence-absence datasets. *Emu* **108** (3), in press.

### Habitat preference

Malleefowl occur broadly across the southern half of Australia occupying at least 32 IBRA regions (Benshemesh 2000). The bulk of records of Malleefowl in south-west Western Australia fall within the Avon Wheatbelt, Mallee, and Esperance Plains IBRA regions, with lesser numbers in Geraldton Sandplains, Yalgoo, Murchinson, Coolgardie, Swan Coastal Plain, Jarrah Forest, and Warren (Figure 8). Detailed studies of habitat of this species have been confined to just five of these IBRA regions, all in eastern Australia. The climate of much of the range of Malleefowl in the northern wheatbelt of Western Australia is distinct from that in the east (see above) and this is reflected in different habitat use and land use. Equivalent climatic areas in the east are largely used for extensive pastoralism rather than cropping.

**Figure 8:** The spatial distribution of Malleefowl records across IBRA regions within south-west Western Australia.




We sought to develop models of habitat preference of Malleefowl for the Western Australian wheatbelt. These models were developed at two scales – regional and sub-catchment. It was hoped that this dual approach would facilitate decisions at these two scales, allowing prioritisation of conservation actions (e.g. where best to invest scarce conservation dollars, where local on-ground works might best be employed).

The key inputs to the regional scale analysis were:

- Presence data for Malleefowl derived from a collation of community and institutional records (MPG, WA Museum, Department of Environment and Conservation, etc);
- Absence data generated from the New Atlas of Australian Birds (Barrett *et al.* 2003) using cells (1 $km^2$) with > 25 bird records (excluding nocturnal birds, birds of prey, and waterbirds) but with no record of Malleefowl and > 2 km from any Malleefowl presence location.
- Nineteen explanatory variables including measures of climate, soil, and

vegetation type and extent.

Analysis was by generalised additive models (GAM) to select variables and to explore the shape of the response variables and generalised linear models (GLM) models to develop a predictive relationship.

At a regional scale, the distribution of Malleefowl within the Western Australian wheatbelt was associated with landscapes that had lower rainfall, greater amounts of mallee and shrubland, with those areas of habitat occurring as large remnants (> 500 ha), and, lighter soil surface textures. Malleefowl occurrence was best predicted at broad scales (> 5 km) suggesting the species is able to move between remnants that are separated by distances less than this.

At a finer scale, Malleefowl occurrence was associated with mallee/shrubland and thicket vegetation and sandy soil types (excluding deep sands, which typically support *Banksia* woodlands and kwongan heath). Woodland represented poor habitat for the species.

A manuscript has been submitted to the *Journal of Applied Ecology*. The manuscript is:

Parsons, B., Short, J., and Roberts, J.D. (submitted). Using community knowledge to predict the occurrence of Malleefowl (*Leipoa ocellata*) in the Western Australian wheatbelt. *Journal of Applied Ecology*.

### Occurrence in small remnants

Malleefowl occur widely across Australia but have suffered declines, particularly in agricultural landscapes in eastern Australia (Priddel and Wheeler 1994). The species remains prevalent throughout much of the Western Australian wheatbelt, but reasons for their relative abundance in this region compared to similar landscapes in eastern Australia are not fully understood. However, despite being widespread in the Western Australian wheatbelt, their distribution is patchy at the scale of individual remnants. This is exemplified by their presence at the Foster Road remnant at Ongerup, but absence from the nearby Tieline Road remnant. For local management and on-ground works to be effective, an understanding of the factors governing Malleefowl distribution at the scale of individual remnants is required.

We sought to describe the management regimes and site-specific habitat characteristics of small remnants occupied by Malleefowl in the Western Australian wheatbelt. We measured and described habitat (vegetation and soil) features and management regimes for 57 remnants (25 occupied, 32 unoccupied) distributed widely across the wheatbelt. Our dataset included:

- Detailed vegetation and soil measurements from three quadrats (50 m x 50 m) within each remnant;
- Information regarding management (e.g. grazing, fire regime, predator control) from semi-structured landholder interviews; and

- Information regarding Malleefowl occurrence over time for each remnant from semi-structured landholder interviews.

We explored which factors were most closely associated with the occurrence of Malleefowl within small remnants. Analysis involved contrasting occupied and unoccupied remnants using ordination (principle components analysis). It was hoped that this would provide much needed insight for on ground action (e.g. corridor design, selection of remnants for protection).

Small remnants in the Western Australian wheatbelt were largely ungrazed, owing to the presence of poison pea (*Gastrolobium* spp.). Similarly, very few remnants were burnt. Most remnants were baited for foxes but much of this baiting occurred in a sporadic manner, both across time and space.

Analysis revealed that Malleefowl tend to occur in remnants that contain a greater amount of litter and food shrubs (e.g. *Acacia, Gastrolobium* spp.). Remnants containing a greater density of tall shrubs (> 1.5 m) were also more likely to be occupied by Malleefowl. Remnants varied considerably with respect to the amount of sedges, grasses, soil gravel content, and medium shrub density but these factors were not related to Malleefowl occurrence.

**Plate 5:** A comparison of "favourable" (top) and "less favourable" (bottom) Malleefowl habitat. The habitat in the top photograph is favourable because it possesses more tall shrubs, litter and food shrubs (e.g. *Acacia* spp).

### Role of fire

This analysis sought to assess the threat posed by fire to Malleefowl within the Western Australian wheatbelt. Previous accounts have listed wildfire as a primary threat to the persistence of Malleefowl (Benshemesh 2000) and have suggested that Malleefowl require long unburnt habitat (> 60 years post-fire, Benshemesh 1992).

Our analysis of the impact of fire on Malleefowl involved two discrete parts:

- Describing the temporal pattern of regeneration of vegetation following fire in two key habitats for Malleefowl; and
- Assessing the relative frequency and extent of fire in small remnants, large remnants, and pastoral areas beyond the wheatbelt.

#### Regeneration of key habitats after fire

This component focused on understanding the effect of fire on the two key Malleefowl habitats in the Western Australian wheatbelt - mallee and *Acacia* shrublands. Two areas were selected for analysis: an area in the north that was primarily *Acacia* shrubland; and an area in the south that was predominantly mallee. The area in the north was made up of two pastoral stations 350 km north-east of Perth that had been destocked: Mt Gibson Sanctuary managed by Australian Wildlife Conservancy; and Charles Darwin Reserve managed by Bush Heritage Australia. The area in the south contained several nature reserves in the Great Southern region including Lake Magenta, Dunn Rock, Lake Bryde and Breakaway Ridge Nature Reserves. These sites were selected for study because they possessed rich and varied fire histories and had vegetation that was typical of areas where Malleefowl persist within the wheatbelt.

Up to five transects were placed within comparable vegetation communities in each of the fire age classes available (range 1968-2004). At each transect, vegetation complexity, cover, and litter cover were measured.

Our results indicated that the post-fire response of these Malleefowl habitats differed. Mallee developed a complex understorey and generous litter layer after about 15 years post-fire and these important features were maintained beyond 45 years. *Acacia* shrublands took longer to develop a litter layer and this layer tended to diminish after about 25-30 years post-fire. Similarly, shrubby understorey diminished after approximately 25 years. This suggested that in *Acacia* shrublands, resources for Malleefowl will likely decrease over the long term if fire is eliminated from the system.

**Plate 6:** Mallee habitat of differing post-fire age. The vegetation in the top photograph was last burnt prior to 1960 (i.e. >45 yrs old); the bottom was last burnt in 1989 (18 years old).

**Plate 7:** *Acacia* shrubland habitat of differing post-fire age. The vegetation in the top photograph was last burnt prior to 1960 (i.e. >45 yrs old); the bottom was last burnt in 1995 (12 years old).

Frequency and extent of fire

We mapped the distribution of fires in areas of known Malleefowl occurrence using remote sensing. This process resulted in a quantification of how much Malleefowl habitat had been burnt in the last 15 years and allowed a comparison of the frequency and extent of fires in habitat in farmland, large reserves, and in pastoral areas.

A key aim was to assess the relative importance of remnant vegetation on farmland for Malleefowl conservation relative to the more extensive and continuous habitat in the major reserves within the wheatbelt and on adjoining pastoral and vacant crown land.

The difference between successive satellite images (LANDSAT TM, biannual from 1988-2004) was examined using ArcGIS to identify fire events within native vegetation. The frequency of fires was collated for three spatial groups: 1) small remnants (100 – 500 ha); 2) large remnants and reserves (> 500 ha); and 3) continuous vegetation adjacent to the wheatbelt.

**Plate 8:** An example of a fire as detected by remote sensing. The satellite image on the left shows a fire scar for a large remnant of vegetation. The image on the right shows the scar detected using remote sensing of the satellite image.

Our findings suggest that fire frequency is related to the size of the remnant in which it occurs. For example, fire is infrequent in small remnants in the wheatbelt and when a fire does occur, only a small portion of the remnant is burnt. In larger remnants and reserves, fire is moderately common and greater proportions of such remnants are burnt. Fires in the pastoral zone and in vacant crown land adjacent to the wheatbelt are most common. Often the fire events observed in large remnants and continuous vegetation were much larger (mean area = 26 900 ha, range = 7 – 393 000 ha), whereas those for small remnants were all minor (mean area = 80 ha, range = 10 – 264 ha). This suggests that the vulnerability of Malleefowl to fire differs depending on the size of the remnant, being greatest in large areas of continuous habitat.

The contemporary fire regime in the Western Australian wheatbelt differs from that of the past. Currently, very little fire occurs whereas in the immediate past large, widespread fires were common and associated with clearing of land for agriculture (Burrows *et al.* 1987, McCaw and Hanstrum 2003). Prior to settlement, fire regimes were likely to exist as fine scale mosaics, maintained by Aboriginal communities (Hallam 1979).

A manuscript detailing this work is currently in preparation and will be submitted to journal in mid 2008:

Parsons, B. (in prep). Are contemporary fire regimes a threat to the persistence of Malleefowl (*Leipoa ocellata*) in the Western Australian wheatbelt? *Austral Ecology*.

### Summary of analyses

A summary of the major analyses conducted is given in Table 5. This shows the dataset used for each analysis, the type of analysis, the range of explanatory variables employed, and the key outcomes.

**Table 5: Summary of major analyses conducted as part of this project.**

| Analysis | Dataset | Explanatory variables | Type of analysis | Key outcomes |
|---|---|---|---|---|
| Bio-climatic | Whole of Australia presence-only records (4129 records) | 35 bioclimatic variables (temperature, precipitation, radiation, and moisture). | BIOCLIM | Three major climate groups through range of Malleefowl: arid group; semi-arid group; near-coastal group. All groups occur in Western Australia. |
| Historical decline | Presence data for all of WA (3466 records); Presence data for wheatbelt grids plus absence data from targeted surveys of long-term residents. | 7 landscape-scale variables, including history and length of land use, sheep density, area under crop, human density, and extent of woody vegetation (excluding areas at risk of salinity). | Assessment of occupancy of 100 x 100 km cell size for WA; Assessment of occupancy of 25 x 25 km cell size for c. 30 % of WA wheatbelt; GAM model to explain decline versus no decline using 7 variables. | Decline of Malleefowl less than previously given, particularly in wheatbelt. Contraction in range associated with extent of land clearing (positive), years of agricultural use and number of sheep in the landscape (positive). |
| Habitat preference (regional scale) | Presence data for WA wheatbelt; Absence data generated from Atlas 2 data. | 19 explanatory variables (climate, soil, and vegetation extent) at 1 $km^2$ resolution. | GAM models to select variables and explore shape of response and GLM models to develop a predictive relationship. | Malleefowl associated with greater amounts of mallee and shrubland within 5 km radius, lower rainfall, smaller distances to nearest 500 ha remnant, and lighter soil textures. |
| Habitat preference (sub-catchment scale) | Presence data by sub-catchments in WA wheatbelt (177 of 788 had Malleefowl presence). | Categorical variables of vegetation type and soil-landscape mapping at sub-catchment scale. | Descriptive analysis and chi square goodness of fit tests to establish whether Malleefowl records at random with respect to environmental variables | Mallee, shrubland and thicket vegetation and sandy soil types (sandy duplex and sandy earth, but not deep sands) favoured. Woodland was not a favoured habitat. |
| Occurrence in individual remnants | Detailed landholder knowledge of Malleefowl occurrence in 56 remnants throughout wheatbelt. | Fine scale, field measurements of vegetation and soil; landholder surveys regarding management and history. | Descriptive comparison and exploration using ordination. | Small remnants containing Malleefowl are typically not threatened by grazing or fires. Most are only sporadically baited for foxes. Malleefowl tend to occur in remnants with more litter, food shrubs, and tall shrub cover. Remnants with a substantial sedge or grass cover tend to remain unoccupied. |

| | | | |
|---|---|---|---|
| Fire | Satellite imagery at 2-year intervals since 1988;<br>Fire maps and vegetation and litter assessments of sites of different fire age. | Descriptive comparison. | Fire frequency a function of remnant size;<br>Two major habitats for Malleefowl recover at different rates from fire, but both more quickly than estimates from the eastern states. |

## 7. Build regional model

The analysis of habitat preference of Malleefowl for the Western Australian wheatbelt described above provides the opportunity to build a regional model. The key inputs to this analysis were presence data for Malleefowl derived from a collation of community and institutional records (contemporary records only: 1990-2005), and absence data generated from the New Atlas of Australian Birds (1998-2002) as described above. After a rigorous screening of the available data we were left with a final dataset of 869 presences and 876 absences with which to construct the model of best fit.

Analysis was by generalised additive models (GAM) to select variables and to explore the shape of the response variables and generalised linear models (GLM) models to develop a predictive relationship.

The model with the lowest residual deviance (Table 6) took the following form:

*Malleefowl presence/absence* is a function of $\log(a) + b + c + d + d^2$

where a = *mallee/shrub within surrounding circle of radius 5 km* (MALSHR5K), b = *mean annual rainfall*, c = *distance to nearest 500 ha remnant* (DIST500HA), and d = *surface texture* (SURTEX).

**Table 6:** GLM model of Malleefowl occurrence (869 presences, 876 absences, deviance explained = 48.9%).

| Term | Estimate | Standard Error | P |
|---|---|---|---|
| Constant | $2.53 \times 10^{0}$ | $5.03 \times 10^{-1}$ | < 0.001 |
| Mean Annual Rainfall | $-1.22 \times 10^{-2}$ | $1.07 \times 10^{-3}$ | < 0.001 |
| DIST500HA | $-1.43 \times 10^{-4}$ | $1.49 \times 10^{-5}$ | < 0.001 |
| MALSHR5K | $2.39 \times 10^{0}$ | $1.45 \times 10^{-1}$ | < 0.001 |
| SURTEX | $1.03 \times 10^{-2}$ | $1.60 \times 10^{-3}$ | < 0.001 |
| $SURTEX^2$ | $-1.98 \times 10^{-5}$ | $3.07 \times 10^{-6}$ | < 0.001 |
| | | | |
| Null deviance | 2419 | | |
| Degrees of freedom | 1744 | | |
| Residual deviance | 1183 | | |
| Residual d.f.: all variables | 1739 | | |

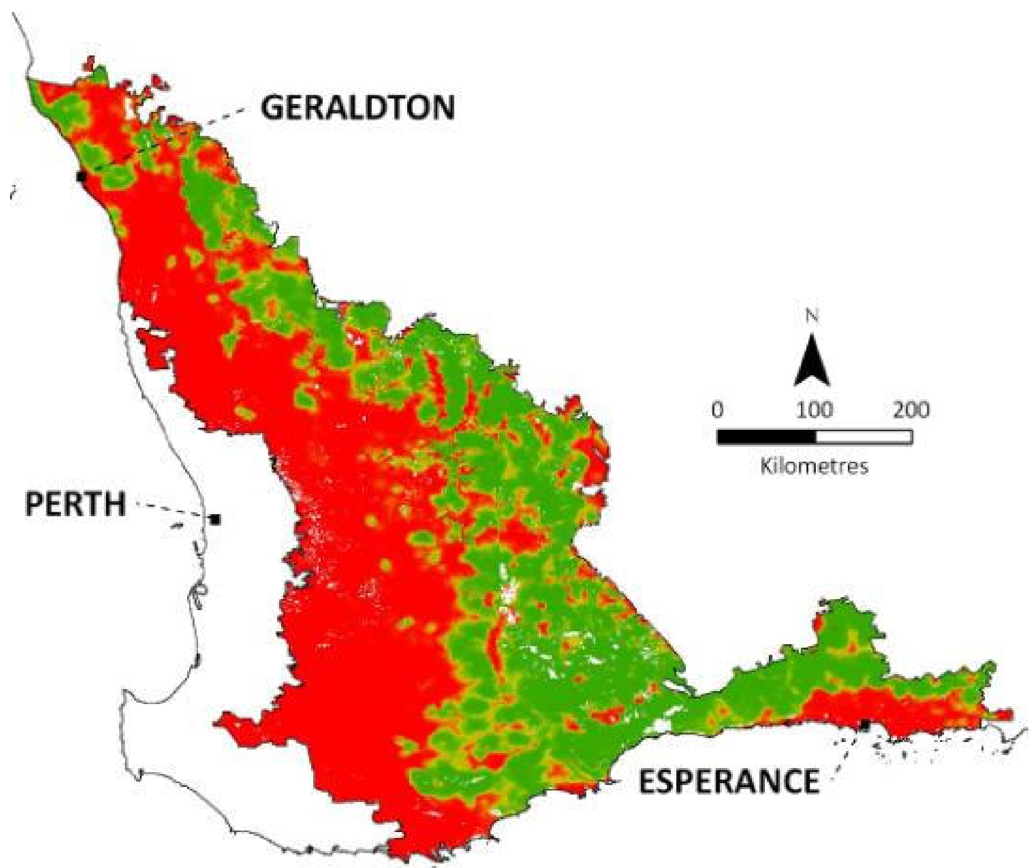
This GLM model allowed us to create spatial predictions of Malleefowl occurrence by deriving a probability of occurrence of Malleefowl (with upper and lower 95% confidence intervals) for all cells within the wheatbelt using a GIS.

This regional model identified 8 689 500 ha of the wheatbelt as having a 50% or greater chance of containing a Malleefowl presence. At the upper and lower 95% confidence limits, this area could be as large as 15 605 200 ha or small as 577 700 ha, respectively. If we restrict the above calculations to areas of remnant vegetation only and exclude farmland, we find that the model predicts 2 016 000 ha of remnant vegetation as having a 50% or greater chance of containing Malleefowl, with 2 752 600 ha and 370 600 ha representing upper and lower 95% confidence intervals, respectively. Of the 2 016 000 ha identified above, approximately 55% is part of the public estate (e.g. reserves, unallocated crown land, unmanaged reserves) with approximately 45% on private lands. Remnant vegetation formally reserved as part of the conservation estate (i.e. managed by the Western Australian Department of Environment and Conservation) makes up approximately 36% of the area predicted.

These mean spatial predictions are shown in Figure 9. This indicates the importance of the eastern half of the wheatbelt as core habitat for Malleefowl and indicates the high relative amount of habitat in the southern wheatbelt. The summary figures above indicate the vital role that remnant bushland on private land have in the overall conservation of the species in Western Australia.

They are also suggestive of the importance of the unfragmented bushland to the immediate east of the wheatbelt and beyond our study area.

**Figure 9:** The mean spatial prediction plot of the GLM model (red and green areas signify low and high probability of Malleefowl occurrence, respectively).



## 8. Develop spatially explicit population model

The aim of this section was to build a regional GIS-based population model of Malleefowl distribution and abundance that was a synthesis of:

- the extensive existing literature on the distribution and abundance of Malleefowl;
- the structured mound counts conducted by the community groups within the WA Malleefowl Network; and
- the regional model derived from community sightings (presence data) and Atlas lists of > 25 species but excluding Malleefowl (absences) given above.

This approach is more speculative and less rigorous than the preceding work. A key difference with the preceding section is that we are attempting to determine the density (abundance) of Malleefowl (rather than a probability of occurrence) to provide a first attempt to assess regional and local viability of Malleefowl.

Some of the key questions that might be informed by such an approach include:

1. What is a best estimate of the current population of Malleefowl?
2. What is a best estimate of the pre-clearing population of Malleefowl?
3. Where are the areas of greatest densities? Do 80% of the population occur in 20% of the area? If so which areas?
4. What is the relative distribution and abundance of Malleefowl between nature reserves and farmland remnants? How important are farmland remnants?
5. What is the relative distribution of Malleefowl between the 3-5 biggest nature reserves and the smaller nature reserves?
6. Is rainfall a key driver of regional abundance?
7. What result would a change in management produce? For example:
    - an increase in revegetation efforts within areas of Malleefowl occurrence;
    - an increase in farmer participation in predator control activities
    - a halving of fire frequency in big nature reserves;
8. How effective is increasing connectivity via revegetation compared to other management alternatives?

This model provides us with a tool to allow us to manipulate management actions spatially across south-west Western Australia and assess the relative impact of such actions. It also provides a tool to assess the size of concentrations of Malleefowl within the landscape to identify those that may be less than some arbitrary threshold of numbers (and hence viability).

We took a triage approach to determine where priority Malleefowl habitat exists within the Western Australian wheatbelt, to make a crude estimate at population sizes, and to make an estimate of the viability of populations also.

*Establishing a density of Malleefowl in the Western Australian wheatbelt*

Published estimates of the density of Malleefowl in eastern Australia (Table 7) appear to vary with rainfall and habitat. High quality mallee habitats in high rainfall areas (> 400 mm per annum) typically have densities of 3.4 to 9.4 per square kilometre. Low rainfall mallee, often with a *Triodia* understorey, typically have lower densities (typically 2 – 2.5 per $km^2$).

There is some suggestion of inflated densities post-clearing (four-fold increase in density around Griffith immediately following clearing (Frith 1973)) and the suggestion of long-term declines (a halving of density) in highly fragmented sites subject to grazing, vegetation disturbance from harvest of broombush understorey, and high fox densities (Priddel and Wheeler 2003)).

Priddel and Wheeler's (2003) study indicates a 1:1 relationship between the number of active mounds and the breeding pairs of birds in a remnant.

Mound counts from the Western Australian wheatbelt (Tables 8 and 9) gave an average of 1.8 active mounds per $km^2$ in mallee and 1.1 active mounds per $km^2$ in shrubland habitats. This translates to a density of 3.6 breeding adults per $km^2$ in mallee and 2.2 per $km^2$ in shrubland. The mallee values are consistent with moderate quality habitat in eastern Australia; the shrubland values with estimates from drier locations in eastern Australia.

There was no apparent trend of mound counts with rainfall (Figure 10), in contrast to suggestions from the eastern states (Table 7). The major discernible trend was a highly significant difference in density (6-fold) between wheatbelt and pastoral areas. Areas beyond the wheatbelt are typically subject to higher levels of grazing by rabbits, kangaroos, goats and sheep, a greater fire frequency and a more open understorey habitat (increasing the risk from aerial and ground predators).

**Table 7:** Estimates of density of Malleefowl in a range of habitats and management regimes.

| Number of birds | Method | Location / habitat | Area (ha) | Density /km² | # of active mounds/ km² | Reference |
|---|---|---|---|---|---|---|
| 74 | Colour banded | Griffith, NSW – pre-clearing | 2200 | 3.4 | | Frith (1973) |
| 22 | Colour banded | Griffith, NSW – post clearing | 180 | 12.2 | | Frith (1973) |
| | | Bull and whipstick mallee near Griffith | | 5 | | Frith (1962) |
| | | Open mallee with porcupine grass (NSW) | | 2.5 | | Frith (1962) |
| | | Dense mallee with closed canopy and shrub layer (higher rainfall), NSW | | 9.4 | | Frith (1962) |
| 32 | Colour banded | Yalgogrin, NSW (high rainfall mallee – 487 mm pa) | 558 | 5.7 | 2.9 | Priddel and Wheeler (2003) |
| 14 | Colour banded | Yalgogrin, NSW (after 12 yr decline) | " | 2.5 | 0.9 | Priddel and Wheeler (2003) |
| | | Small remnants with old growth habitats (some lightly grazed), SA | | 2-4 | | Brickhill (1987) |

| | | | | |
|---|---|---|---|---|
| Old growth mallee | | 3.2 | | Franklin (1993) |
| Low rainfall mallee, SA | 400 | 2.2 | 1.1 | Brickhill (1985), (1987) |

**Table 8:** Mound counts in the southern wheatbelt of Western Australia (predominantly mallee), showing the density of active mounds.

| Location | Site ID | Mean annual rainfall (mm 1977-2007) | Area (ha) of remnant | Year of data | Rainfall (year of survey) | Area monitored (ha) | Active mounds | Total mounds | Active/sq km | Total/ sq km | Ratio of total: active | Mean active mounds/ sq km |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Corackerup | WA11 | 408 | 4334 | 1993 | 499.6 | 300 | 5 | 26 | 1.67 | 8.67 | 5.20 | |
| | | | | 1995 | 413.7 | 300 | 5 | 26 | 1.67 | 8.67 | 5.20 | |
| | | | | 1997 | 443.6 | 300 | 4 | 20 | 1.33 | 6.67 | 5.00 | |
| | | | | 1998 | 481.0 | 300 | 4 | 13 | 1.33 | 4.33 | 3.25 | |
| | | | | 1999 | 366.5 | 300 | 8 | 31 | 2.67 | 10.33 | 3.88 | |
| | | | | 2000 | 361.1 | 300 | 9 | 28 | 3.00 | 9.33 | 3.11 | |
| | | | | 2001 | 465.1 | 300 | 3 | >9 | 1.00 | n.a. | n.a. | |
| | | | | 2002 | 228.4 | 300 | 3 | 20 | 1.00 | 6.67 | 6.67 | |
| | | | | 2003 | 540.1 | 300 | 2 | 35 | 0.67 | 11.67 | 17.50 | |
| | | | | 2006 | 300.3 | 370 | 10 | 38 | 2.70 | 10.27 | 3.80 | |
| | | | | 2007 | 397.0 | 370 | 5 | 45 | 1.35 | 12.16 | 9.00 | 1.67 |
| Peniup | WA13 | 405 | 6500 | 1995 | 406.2 | 300 | 4 | 14 | 1.33 | 4.67 | 3.50 | |
| | | | | 1996 | 277.5 | 300 | 3 | 13 | 1.00 | 4.33 | 4.33 | |
| | | | | 1998 | 477.8 | 300 | 1 | 14 | 0.33 | 4.67 | 14.00 | |
| | | | | 1999 | 358.8 | 300 | 1 | 10 | 0.33 | 3.33 | 10.00 | |
| | | | | 2000 | 356.2 | 300 | 4 | 20 | 1.33 | 6.67 | 5.00 | |
| | | | | 2001 | 470.6 | 300 | 1 | 13 | 0.33 | 4.33 | 13.00 | |
| | | | | 2002 | 221.5 | 300 | 2 | | 0.67 | | | |
| | | | | 2003 | 540.6 | 300 | 1 | | 0.33 | | | |
| | | | | 2004 | 298.6 | 300 | 1 | | 0.33 | | | |
| | | | | 2005 | 514.8 | 300 | 2 | 11 | 0.67 | 3.67 | 5.50 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2007 | 390 .0 | 300 | 3 | 13 | 1.00 | 4.33 | 4.33 | 0.70 |
| Foster Road | WA12 | 363 | 136 | 1994 | 216.9 | 136 | 7 | 27 | 5.15 | 19.85 | 3.86 | |
| | | | | 1995 | 371.2 | 136 | 8 | 27 | 5.88 | 19.85 | 3.38 | |
| | | | | 1996 | 313.9 | 136 | 7 | 27 | 5.15 | 19.85 | 3.86 | |
| | | | | 1997 | 373.2 | 136 | 6 | > 12 | 4.41 | | | |
| | | | | 1998 | 436.3 | 136 | 6 | 23 | 4.41 | 16.91 | 3.83 | |
| | | | | 1999 | 370.8 | 136 | 6 | 12 | 4.41 | 8.82 | 2.00 | |
| | | | | 2001 | 386.2 | 136 | 4 | 42 | 2.94 | 30.88 | 10.50 | |
| | | | | 2002 | 260.9 | 136 | 5 | | 3.68 | 0.00 | 0.00 | |
| | | | | 2007 | 371 | 136 | 6 | 25 | 4.41 | 18.38 | 4.17 | 4.49 |
| Hills | WA14 | 359 | 150 | 1995 | 337.9 | 150 | 2 | 8 | 1.33 | 5.33 | 4.00 | |
| | | | | 1998 | 437.0 | 150 | 2 | 9 | 1.33 | 6.00 | 4.50 | |
| | | | | 1999 | 369.6 | 150 | 0 | 4 | 0.00 | 2.67 | | |
| | | | | 2000 | 282.1 | 150 | 0 | 10 | 0.00 | 6.67 | | |
| | | | | 2002 | 251.9 | 150 | 0 | 7 | 0.00 | 4.67 | | |
| | | | | 2007 | 356 | 150 | 0 | 20 | 0.00 | 13.33 | | 0.44 |
| | | | | | | | | sum | | | | 7.30 |
| | | | | | | | | mean | 1.71 | | | 1.83 |

**Table 9:** Mound counts in the northern wheatbelt of Western Australia (predominantly shrubland thicket), showing the density of active mounds.

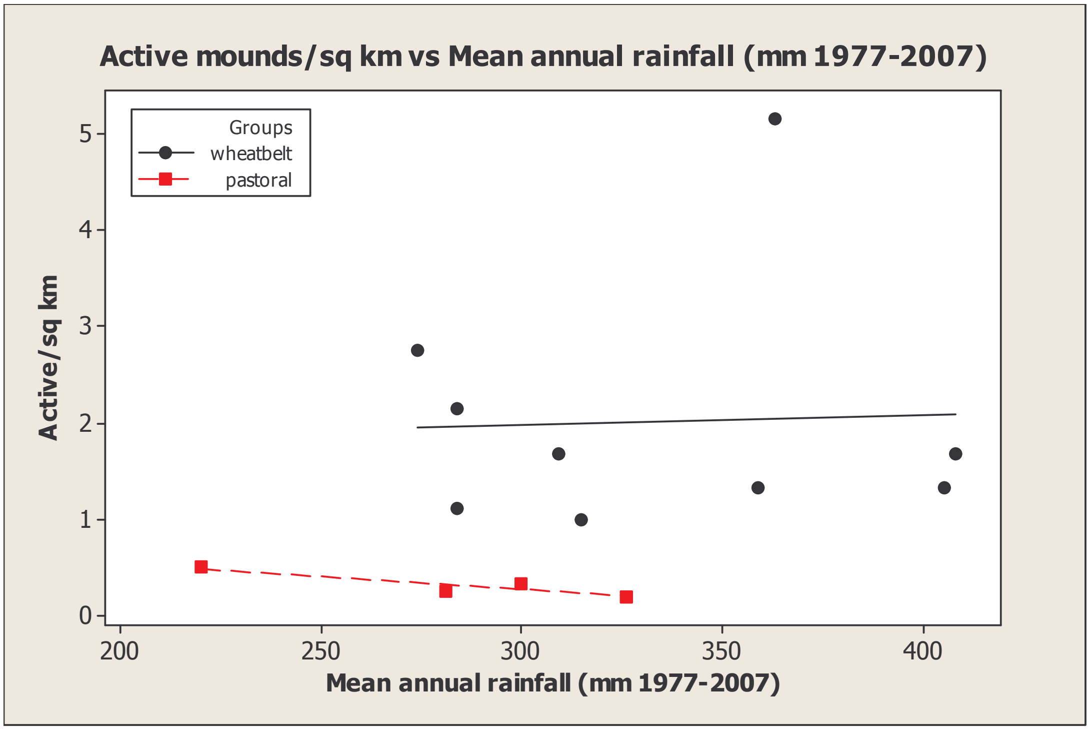
| Location | Site ID | Mean annual rainfall (mm 1977-2007) | Area (ha) of remnant | Year of data | Rainfall (year of survey) | Area monitored (ha) | Active mounds | Total mounds | Active / sq km | Total / sq km | Ratio of total: active | Mean active mounds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Old Well (Maya) | WA02 | 315 | 152 | 1998 | 332.6 | 100 | 1 | 5 | 1.00 | 5.00 | 5.00 | |
| | | | | 1999 | 593.3 | 100 | 3 | 14 | 3.00 | 14.00 | 4.67 | |
| | | | | 2004 | 322.3 | 100 | 3 | 14 | 3.00 | 14.00 | 4.67 | |
| | | | | 2007 | 203 | 100 | 0 | 37 | 0 | 37.00 | - | 1.75 |
| Nugadong (Milton McNeil Reserve) | WA01 | 274 | 448 | 1995 | 325.8 | 400 | 11 | 42 | 2.75 | 10.50 | 3.82 | |
| | | | | 1998 | 262.0 | 400 | 10 | 45 | 2.50 | 11.25 | 4.50 | |
| | | | | 2000 | 344.7 | 400 | 10 | 45 | 2.50 | 11.25 | 4.50 | |
| | | | | 2001 | 221.0 | 400 | 10 | 42 | 2.50 | 10.50 | 4.20 | |
| | | | | 2003 | 249.7 | 400 | 1 | 42 | 0.25 | 10.50 | 42.00 | |
| | | | | 2005 | 255.4 | 400 | 1 | 46 | 0.25 | 11.50 | 46.00 | |
| | | | | 2006 | 275 | 400 | 0 | 46 | 0 | 11.50 | - | |
| | | | | 2007 | 233 | 400 | 0 | 46 | 0 | 11.50 | - | 1.34 |
| Eaton's | WA05 | 309 | 92 | 2004 | 308.4 | 60 | 1 | 10 | 1.67 | 16.67 | 10.00 | |
| | | | | 2006 | 257 | 60 | 1 | 9 | 1.67 | 15 | 9.00 | |
| | | | | 2007 | 201 | 60 | 0 | 8 | 0 | 13.33 | | 1.11 |
| Reudavey's | WA07 | 284 | 231 | 2005 | 279.8 | 186 | 4 | 34 | 2.15 | 18.28 | 8.50 | |
| | | | | 2006 | 299 | 200 | 0 | 42 | 0 | 21 | | |
| | | | | 2007 | 219 | 200 | 0 | 42 | 0 | 21 | | 0.72 |
| Carter's | WA04 | 284 | 216 | 2004 | 264.4 | 180 | 2 | 32 | 1.11 | 17.78 | 16.00 | |
| | | | | 2005 | 279.8 | 180 | 2 | 32 | 1.11 | 17.78 | 16.00 | |
| | | | | 2006 | 299 | 200 | 1 | 41 | 0.5 | 20.5 | | |
| | | | | 2007 | 219 | 200 | 0 | 39 | 0 | 19.5 | | 0.68 |
| | | | | | | | | mean | 1.18 | | | 1.12 |

**Table 10:** Mound counts beyond the wheatbelt of Western Australia (predominantly ungrazed by domestic stock), showing the density of active mounds.

| Location | Site ID | Mean annual rainfall (mm 1977-2007) | Area (ha) of remnant | Year of data | Rainfall (year of survey) | Area monitored (ha) | Active mound s | Total mound s | Active/s q km | Total / sq km | Multiple | Mean active mounds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eyre (Microwave Tower) | WA18 a | 309 | na | 1990 | 313 | 300 | 1 | 22 | 0.33 | 7.33 | 22 | |
| | | | | 1991 | 223 | 300 | 0 | 22 | 0.00 | 7.33 | | 0.17 |
| Eyre (Bird Observatory) | WA18 b | 326 | | 1990 | 335 | 1000 | 2 | 21 | 0.20 | 2.10 | 10.5 | |
| | | | | 1991 | 236 | 1000 | 6 | 22 | 0.60 | 2.20 | 3.66667 | |
| | | | | 1992 | 504 | 1000 | 3 | 22 | 0.30 | 2.20 | 7.33333 | |
| | | | | 1993 | 377.8 | 1000 | 3 | 22 | 0.30 | 2.20 | 7.33333 | |
| | | | | 1994 | 250.9 | 1000 | 3 | 22 | 0.30 | 2.20 | 7.33333 | |
| | | | | 1995 | 321.9 | 1000 | 5 | 22 | 0.50 | 2.20 | 4.4 | |
| | | | | 1996 | 304.8 | 1000 | 2 | 22 | 0.20 | 2.20 | 11 | 0.34 |
| Eyre | WA18 c | 326 | na | 2005 | 279.5 | 1162 | 2 | 63 | 0.17 | 5.42 | 31.5 | |
| | | | | 2006 | 361.4 | 1162 | 1 | 63 | 0.09 | 5.42 | 63 | 0.13 |
| Mt Gibson Minesite | WA08 | 281 | na | 2005 | 272.0 | 200 | 0 | 6 | 0.00 | 3.00 | > 3 | 0 |
| Mt Gibson Iron | na | 281 | na | 2004 | 252.4 | 1948 | 5 | 41 | 0.26 | 2.10 | 8.2 | |
| | | | | 2005 | 273.6 | 3540 | 10 | 56 | 0.28 | 1.58 | 5.6 | 0.27 |
| White Wells (Aust Bush Heritage) | na | 282 | na | 2005 | 271 | 292 | 1 | 21 | 0.34 | 7.19 | 21 | 0.34 |
| Eurardy | WA22 | 291 | na | 2007 | 215 | 209 | 0 | 0 | 0.00 | 0.00 | | 0 |
| Mt Jackson | WA17 | 281 | | 2004 | 263 | 270 | 0 | 36 | 0.00 | 13.3 3 | | |
| | | | | 2005 | 214 | 620 | 82 | 80 | 0.32 | 12.9 0 | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2006 | 413 | 1013 | 18 | 118 | 0.79 | 11.65 | 40.0 | |
| | | | | 2007 | 244 | 1207 | 4 | 87 | 0.33 | 7.21 | | 0.36 |
| Peron | | 220 | na | 2006 | 85.0 | 200 | 1 | 2 | 0.50 | 1.00 | 2.0 | 0.5 |
| Mean (pastoral) | | | | | | | | | 0.28 | | | 0.23 |

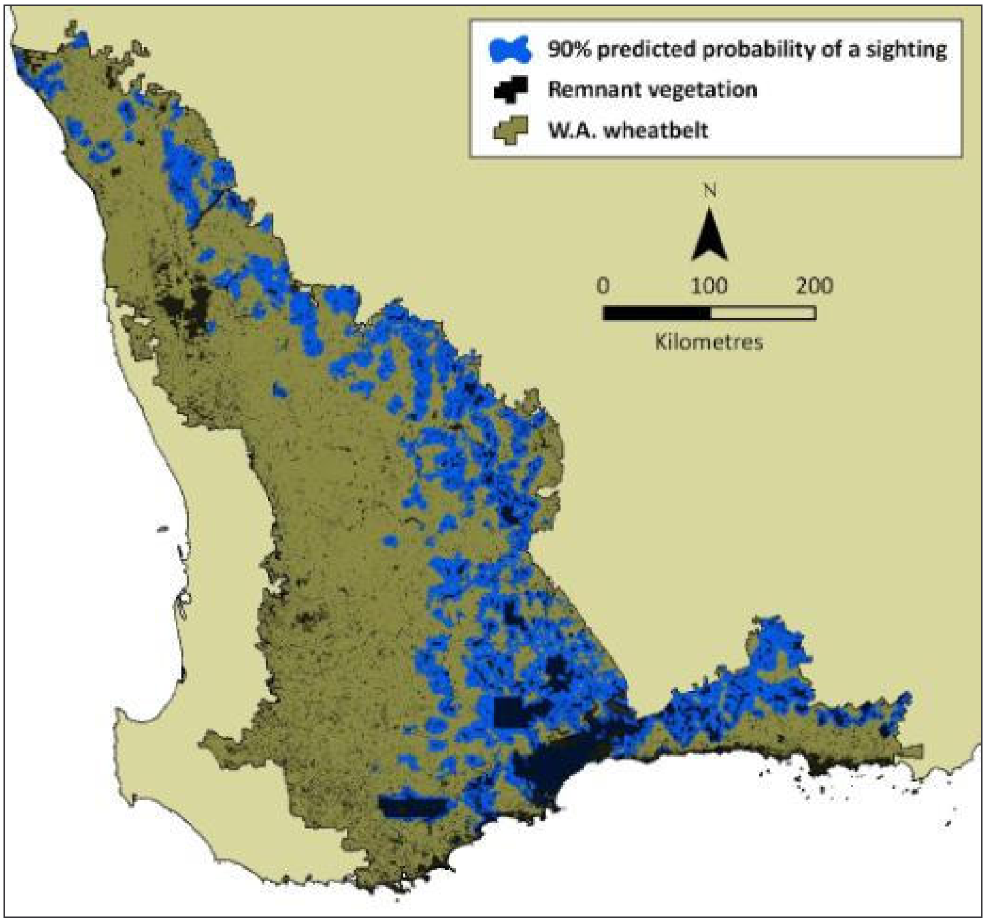
**Figure 10:** The relationship between number of active mounds per square kilometre and rainfall for sites in Western Australia.



*Identifying 'neighbourhoods' of inter-connected Malleefowl habitat*

We used the regional model (Section 7 above) to identify all areas within the Western Australian wheatbelt that had at least a 90% chance of containing a Malleefowl sighting (over a 15 year period – because the model was built using data from 15 yrs). We plotted these areas spatially using a 90% isobar, resulting in the identification of 385 discrete neighbourhoods within the study area (Figure 11).

**Figure 11 :** Areas of inter-connected Malleefowl habitat ('neighbourhoods') within the WA wheatbelt.




We then estimated the likely density of Malleefowl within these neighbourhoods by using the collated mound data from Western Australia, informed by the ratio of breeding pairs to active mounds given in the literature (Table 7). We investigated the relationship between mound density and annual rainfall, mound density and land use, and derived separate density estimates for mound counts in the north (predominantly *Acacia* shrubland and thicket) and those in the south (predominantly mallee).

We arbitrarily divided neighbourhoods on the triage principle into those we perceived to be:

1. Relatively secure (those with an estimate of > 300 breeding birds);

2. At risk and high priority for management action (those with an estimated 100 – 300 birds); and

3. At great risk but likely requiring too great an input of management effort to maintain long-term viability (those neighbourhoods with < 100 birds).

We examined in detail the attributes (e.g. amount of habitat, reserves, time span for sightings data, estimated breeding population, proximity to other neighbourhoods or location adjacent to the pastoral zone) of each neighbourhood in these three classes.

*Results*

Fourteen neighbourhoods were identified as containing at least 100 breeding birds within them (Figure 12). These 14 neighbourhoods were dominated by one large neighbourhood that extended from Beacon in the north-eastern wheatbelt to the south coast and east to Scaddan (north of Esperance). It contains many key reserves including Lake Magenta Nature Reserve, Dunn Rock Nature Reserve, Dragon Rocks Nature Reserve, Fitzgerald River National Park, Stirling Ranges National Park, as well as many substantial areas of remnant vegetation including private and unallocated crown land. The attributes of this and the other neighbourhoods are summarised in Table 11. This neighbourhood was estimated to contain about 34,000 birds, or greater than 86% of the wheatbelt population. In contrast, its proportion of total sightings was around 55%.

Of the 13 remaining neighbourhoods, six were estimated to be viable (≥ 300 breeding birds), and a further seven "at risk" (100 -300 breeding birds). The attributes of each neighbourhood are given in Table 12. The mean population of the viable neighbourhoods was about 525 breeding birds. Collectively these six neighbourhoods (Mt Gregory, Canna, Buntine, Tarin Rock, Kau Rock and Boyatup North) made up about 8% of the estimated Malleefowl population.

The seven "at risk" populations had on average about 130 breeding birds each (or collectively < 3% of the estimated wheatbelt population). The 371 `non-viable areas' had on average only four breeding birds each.

In addition to the 14 areas given in Table 11, we have identified five other areas that fall outside the modelled neighbourhoods but have well known populations of Malleefowl. These could be taken to be a deficiency in the model or to represent genuine examples of sub-populations at high risk. These are:

- Dryandra State Forest – an extensive area of woodland habitat with long-term predator control;

- Foster Rd remnant, north of Ongerup – a small and isolated remnant that has received great focus due to the history of the MPG. It has a high concentration of birds;
- Dongolocking Reserve – multiple sightings were reported from CALM (DEC) in the mid 1990s but nothing since;
- Caron (south of Perenjori) – too isolated and small, but is situated on a highway so generates a lot of sightings; and
- a private remnant north-west of Narembeen (name of owner withheld) with a known population – too isolated and small.

*Limitations of the model*

It is important to be aware of the limitations of the model:

- Assumes any habitat other than mallee and shrubland are not Malleefowl habitat (cf, for example, known population at Dryandra State Forest in woodland);
- Assumes all mallee and shrubland are Malleefowl habitat ( cf. areas of such habitat to the north of Geraldton and to the east of Esperance where there are few sightings – these areas may not be suitable for Malleefowl);
- The 90% cut-off value is arbitrary, but we trialled an 80% value and this showed little additional area around existing neighbourhoods; and
- Assumes all habitats are ungrazed and long unburnt (as density estimates derived from such habitat in monitored grids). While this is true for many of the areas we have examined it is unlikely to be true for all areas.

**Figure 12:** The 14 neighbourhoods with an estimated population of 100 or more birds.

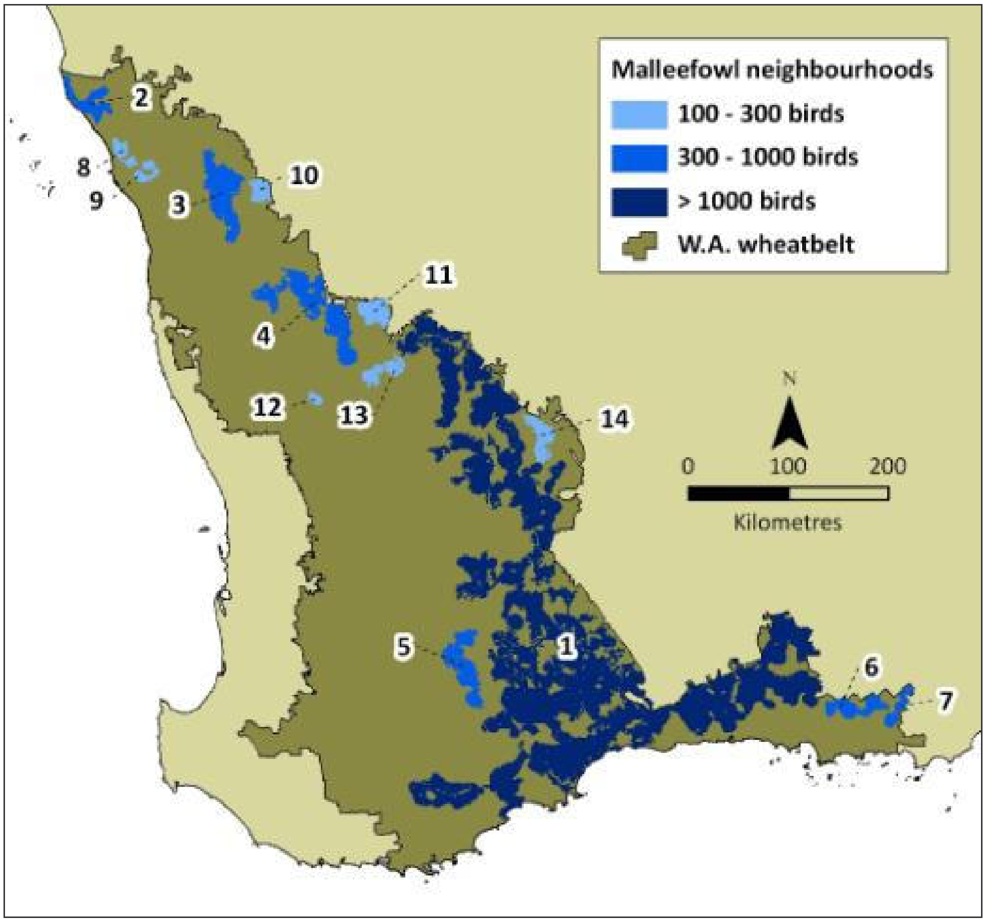


**Table 11:** Mean values for attributes of neighbourhoods with a > 90% probability of sighting Malleefowl as derived from the regional model

| Neighbourhood | Count | Mean area (ha) | Mean area of remnant vegetation (ha) | Mean area of habitat (mallee and shrub thicket) (ha) | Mean area of DEC estate (ha) | Mean area of all reserves (ha) | Mean # of sightings within neighbourhoods (total) | Estimated mean population of breeding Malleefowl in neighbourhoods | Estimated minimum total breeding population of Malleefowl |
|---|---|---|---|---|---|---|---|---|---|
| Largest neighbourhood | 1 | 3,970,800 | 1,349,482 | 992,316 | 688,486 | 1,187,450 | 834 (834) | 33,633 | 33,633 |
| Other viable (≥ 300 birds) | 6 | 134,333 | 28,238 | 18,626 | 9,879 | 14,098 | 23 (140) | 526 | 3,153 |
| At risk (100-300 birds) | 7 | 43,914 | 7,113 | 5,154 | 1,057 | 2,757 | 3 (24) | 133 | 934 |
| Non-viable (< 100 birds) | 371 | 1,601 | 249 | 129 | 45 | 102 | < 1 (68) | 4 | 1,348 |
| Low probability area (< 90 % predicted prob. of occurrence) | 1 | 14,946,552 | 2,208,696 | 256,098 | 617,340 | 1,407,325 | 432 (432) | | ? |
| Total | | | | | | | | | 39,068 |

**Table 12:** Attributes of viable and at risk Malleefowl neighbourhoods (> 90% probability of Malleefowl sighting). The fragmentation index is the area of all remnant vegetation within a neighbourhood divided by the number of remnants that intersect that neighbourhood i.e. the higher the number, the less fragmented the habitat within the neighbourhood is.

| # | Status | Name | Area of remnant veg (ha) | Malleefowl habitat (%) | Proportion in reserves (%) | Proportion as farm remnants (%) | Frag. Index | Nearest neighbourhood/ uncleared land | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Viable | Main | 1,349,483 | 74 | 88 | 12 | 107 | n/a | Contains many key reserves, spans much of eastern wheatbelt |
| 2 | Viable | Mt Gregory | 21,140 | 67 | 31 | 69 | 41 | 2 km (Kalbarri National Park) | Marginal habitat of coastal *Acacia rostellifera* thickets |
| 3 | Viable | Canna | 36,591 | 79 | 10 | 90 | 22 | 3 km (9 - Gutha East) | Mosaic of shrub thickets with York Gum in valleys |
| 4 | Viable | Buntine | 36,514 | 57 | 34 | 66 | 28 | abuts pastoral country | Contains NCMPG monitoring sites and Buntine and several other substantial nature reserves |
| 5 | Viable | Tarin Rock | 21,503 | 50 | 99 | 1 | 34 | 12 km (1 – Main) | Contains Tarin Rock and North Tarin Rock Nature Reserves; primarily mallee scrub |
| 6 | Viable | Kau Rock | 36,447 | 76 | 92 | 8 | 151 | abuts unallocated crown land | Contains Kau Rock, Burdett South and Beaumont Nature Reserves, primarily mallee scrub |
| 7 | At risk | Boyatup North | 17,234 | 56 | 42 | 58 | 59 | abuts unallocated crown land | Contains several nature reserves, is at extreme east of wheatbelt |
| 8 | At risk | Nanson | 6,956 | 79 | 16 | 84 | 25 | 4 km (8 – Wicherina) | Mixed thickets with jam scrub and York Gum on low lands |
| 9 | At risk | Wicherina | 6,905 | 67 | 42 | 58 | 29 | 4 km (7 – Nanson) | Jam scrub with some scrub heath and thickets, contains large crown reserve (2 500 ha) |
| 10 | At risk | Gutha East | 6,264 | 88 | 4 | 96 | 32 | abuts pastoral country | Mixed *Acacia*/*Melaleuca*/*Allocasuarina* thickets |
| 11 | At risk | Goodlands | 7,501 | 74 | 37 | 63 | 30 | abuts pastoral country | Contains Goodlands Nature Reserve; mostly *Acacia* and *Allocasuarina* thickets |
| 12 | At risk | Wongan Hills | 4,592 | 74 | 94 | 6 | 79 | 37 km (4 – Buntine) | Includes Wongan Hills Nature Reserve; primarily mallee and *Allocasuarina* thickets |
| 13 | At risk | Badgerin | 4,873 | 69 | 34 | 66 | 16 | 1 km (1 – Main) | Includes Badgerin Rock and Mollerin Nature Reserves;primarily mallee and *Allocasuarina* thicket |
| 14 | At risk | Moorine Rock | 12,702 | 64 | 19 | 81 | 45 | 1 km (1 – Main) | Primarily *Acacia*, *Melaleuca* and *Allocasuarina* thicket |

## 9. Provide recommendations to link on and off reserve conservation activities

In Section 7 we have seen that Malleefowl have a 50% or greater chance of occupying some 2 million hectares of remnant bushland in the Western Australian wheatbelt. Some 36% is in the Department of Environment and Conservation estate, 19% in other reserves, and 45% on farmland. Hence the long-term fate of Malleefowl in the wheatbelt is tightly linked to the attitudes and actions of both institutional managers and farmers.

There are both significant differences and similarities in how these two groups currently manage the land under their control (see Table 13) and both can be informed by the research undertaken in this study.

*Grazing*

Nature Reserves are free of domestic stock, as are many private remnants due to the risk posed by poison plants *Gastrolobium* spp. and the comparatively recent role of Landcare in fostering a greater conservation ethic among farmers. However, while our limited surveys have shown a low rate of utilization of remnant vegetation on farms for stock, this conclusion may not have generality across the wheatbelt. There is a need for a comprehensive survey of wheatbelt remnants to establish the extent to which they are or are not grazed.

Uncontrolled browsing of feral goats in the pastoral lands adjacent to the northern wheatbelt is a significant problem. Some major neighbouring landholders (Australian Wildlife Conservancy, Australian Bush Heritage, Ninghan Station) are attempting to deal with this in a co-ordinated way. Goats, with their preference for browsing and their tendency to remove virtually all foliage below 1.8 m (Henzell 2008), are likely to have a devastating impact on Malleefowl populations. This is exacerbated by their high numbers and rate of increase (75% increase per annum in the absence of control measures: Henzell 2008).

Rabbits are not typically controlled in farm remnants or in nature reserves. Most land managers seem to rely largely on disease and/or foxes to exert control.

There is typically no control of kangaroo numbers in nature reserves; in contrast, farmers often reduce the density of kangaroos in remnants, particularly when they venture onto adjoining croplands.

*Fox control*

The impact of foxes on Malleefowl remains controversial. Note, the differing points of view on foxes and fox control espoused by Priddel and Wheeler (1994, 1996, 1997, and 2003), cf. Frith (1962a, b) and Benshemesh (1997). See Short (2004) for a summary of the arguments.

There are two independent initiatives active in the Western Australian wheatbelt, one driven by the Department of Environment and Conservation, the other by farmers. These are:

- Fox baiting of major reserves under the Western Shield program conducted by the Department of Environment and Conservation. Baiting of the larger reserves is at a frequency of four times per annum (Armstrong 2003). This fox control is directed largely at the conservation of threatened mammals but may provide a windfall benefit to ground-nesting birds. This baiting only occurs in two nature reserves known to contain Malleefowl – Lake Magenta Nature Reserve and Dryandra Woodland.

- Regional fox control – Red Card for the Red Fox (http://www.thewest.com.au/default.aspx?MenuID=146&ContentID=63169). Major perceived problems include patchy uptake by farmers at a regional level, the ineffectiveness of a single annual baiting, and the small scale of the cull relative to the size of the fox population.

A major difference suggested by our study is linking these two efforts more closely through an awareness of the "neighbourhoods" typically centred on one or many major DEC reserves.

*Fire regimes*

Immediate fire suppression is the dominant policy of fire management throughout the wheatbelt in an effort to minimise damage to life and property. The effectiveness of this policy appears to vary with remnant size being most effective with small remnants and least effective within the large tracts of contiguous bush to the east of the wheatbelt.

Hussey and Baxter (2006) talk about the use of fire for "ecological renewal" in small remnants in the wheatbelt. They suggest the time for this might be when > 50% of understorey shrubs are dying or dead. They favour an attempt to create a mosaic of vegetation of different ages to maximise the resources for fauna and to make the remnant more resilient to further fire. They suggest a fire interval that is least twice as long as it takes the slowest maturing plant in the community to flower and produce seed and before older plants are no longer able to reproduce. They emphasise the dangers of invasion of the remnant by weeds such as exotic grasses and crop weeds, particularly if remnants are burnt in winter to minimise potential threat to property.

Hussey and Baxter (2006) suggest a fire interval of > 40 years for Malleefowl to give sufficient time to allow build up of leaf litter for nesting.

Department of Environment and Conservation fire plans seek to protect and minimise risk to life and property, but also acknowledge "the importance of ecological factors in managing a diverse native flora and fauna to meet the objective of minimising risk of species loss" (McClusky *et al.* 2003).

The requirements of Malleefowl are used to set fire intervals in wheatbelt reserves in Western Australia. These are derived from studies in eastern Australia that suggest burnt country does not support Malleefowl for 10-15 years after fire due to the inadequate litter supplies for nest construction (Cowley *et al.,* 1969 cited in Benshemesh 2000), and that even 20-30 years after a fire, breeding densities are about one third of those in long-unburnt habitats. The optimal fire frequency for Malleefowl conservation seems to be in excess of 60 years (Benshemesh, 1992).

Fire policy varies with reserve size (McClusky *et al.* 2003). This is based on the belief that the chance of a fire completely burning all vegetation in a small-sized remnant is far greater if a fire occurs, although the overall frequency of fires in such areas may be low (McClusky *et al.* 2003: 38). Such a fire in a small and isolated remnant is likely to cause local extinction of Malleefowl (Benshemesh, 2000).

Hence, the policy for reserves < 500 ha is fire exclusion. The small size of these reserves makes the risk of successfully completing a prescribed burn to selected areas of a reserve without burning the entire reserve too great. For larger reserves (> 5000 ha), a fire model is applied that divides each reserve into three successional age classes – early, mid and late, with the aim of retaining at least 20% of a reserve and/or the major vegetation communities in one of the three classes. This requires decisions to be made on what age that vegetation communities move from early to mid and from mid to late successional age classes. This is dependent on the vegetation community. For mallee woodland in the Mallee II Bioregion, McClusky *et al.* (2003) give 0-15 years as the ages of early succession (based on the age that majority of mallee species will set enough seed for regeneration), 15-60 years as the ages of mid-succession (with 60 considered the age when eucalypt species associated with mallee woodlands reach maturity), and 60-100 years as the ages of late succession (100 being the age when many mallee woodland species reach senescence).

Goals for larger reserves include that no more than 30% of the reserve burn at any one time and that a fire interval of > 30 years is maintained (McClusky *et al.* 2003). Burrows *et al.* (1987) suggest a similar regime for Dryandra Forest (avoiding frequent fire that might eliminate fire sensitive species and favouring a fire interval of 20-60 years).

*Fragmentation*

Despite the history of extensive clearing of the wheatbelt over the last 100 years, there remains an extensive north-south linkage of habitat in the eastern wheatbelt that appears to form a single interconnected neighbourhood (Neighbourhood 1 of Figure 12). Effort must be invested to ensure there is no slow attrition of connectivity within this extensive area over time. This means fostering and protecting existing connections.

Neighbourhood 1, as well as neighbourhoods 4, 6, 7, 10, and 11 are physically linked to the extensive tracts of uncleared land to the east of the wheatbelt (both pastoral and crown land). Hence, a large proportion of the remaining range of Malleefowl in south-west Western Australia appears sufficiently interconnected to allow movement and recolonisation.

In addition, there appears to be an effective east-west link for Malleefowl from the Stirling Ranges National Park through to Fitzgerald River National Park and the extensive woodlands to the east (the 'Gondwanan' linkage).

The scale of the wheatbelt makes management intervention on any meaningful scale through revegetation extraordinarily difficult. Hence, very strategic actions of revegetation are needed. Table 12 indicates that the gaps between adjoining neighbourhoods or between neighbourhoods and uncleared land to the east are often as small as 3-4 kilometres, and provide obvious choices for manageable intervention.

*Climate change*

Malleefowl appear relatively well placed to deal with climate change because of the extensive retention of habitat along a north-south continuum (neighbourhood 1 (Main) and the north-south extent of uncleared bushland to the east of the wheatbelt). Both include extensive areas of land in the private (farmland, pastoral) versus public estate (nature reserves and crown land).

This should allow Malleefowl to persist in the southern part of their range whatever the outcome of climate change over coming decades.

The neighbourhood concept we have espoused in Section 8 above emphasises the link between on- and off reserve conservation strategies. The major reserves typically form the nucleus of neighbourhoods, but their extent and connection are due to the surrounding remnants on farmland and the vegetation retained as roadside or other corridors. This interconnection between the private and public estate is vital to the long-term conservation of the Malleefowl in the wheatbelt.

*Integration of management effort*

The WA Malleefowl Network has been a positive initiative that has worked to link community groups across the wheatbelt with an interest in Malleefowl conservation, and to link these with NGOs (such as WWFA) and the Department of Environment and Conservation (with statutory authority for management and conservation of Malleefowl).

The value of a participatory approach involving all stakeholders is exemplified by the outcomes of this study. These are based on a solid foundation of community-sourced observational and survey data and historical knowledge. This rich source of information, coupled with agency data, allowed for the progression of knowledge regarding the ecology and conservation of malleefowl, which can be used by key stakeholders (i.e. community groups, farmers, State agencies) in the on-ground management of malleefowl. By incorporating data and knowledge of the community into research, this study has highlighted the value of a participatory approach, rather than `knowledge transfer' from the scientific community to end users (i.e. landholders and land managers). It has also highlighted the vital role that the community plays in ecological research (Pearson, 1992; Lunney and Matthews, 2001; Goffredo *et al.*, 2004) and land management in agricultural landscapes.

This community participation needs to be fostered and encouraged. The vital importance of farm remnants in providing habitat for Malleefowl and in creating interconnected neighbourhoods with DEC reserves mean that farmers are a key stakeholder in any solution.

Our model of Malleefowl `neighbourhoods' provides the basis for a strategic and objective approach to making decisions about local and regional priorities for on-ground support for Malleefowl that cross the private and public estate.

**Table 13:** Typical on and off reserve management activities for Malleefowl

| Threat | On-reserve | Off-reserve |
|---|---|---|
| Fire | Fire suppression – effectiveness greater in smaller reserves; less effective in larger reserves | Fire suppression effective |
| Grazing - sheep | Total exclusion | Exclusion variable, probably linked to district stocking rates, remnant size and presence/absence of poison plants |
| Grazing - goats | Variable control of goats in northern parks and nature reserves, particularly beyond the wheatbelt. | Absent |
| Grazing - kangaroos | No control | Reduction in kangaroo grazing pressure by shooting is common |
| Grazing - rabbits | Little or no control other than via myxomatosis and rabbit calici virus | Little or no control other than via myxomatosis and rabbit calici virus |
| Foxes | Quarterly baiting of large reserves; Annual baiting of mid-size reserves; No baiting of most wheatbelt reserves and the large unfragmented areas east of the wheatbelt | Annual regional baiting (Red Card for the Red Fox) and some targeted baiting of known Malleefowl habitat, but probably of limited effectiveness due to low frequency and patchy coverage |
| Fragmentation | None or limited | Corridors to connect isolated remnants; provision of supplementary food (inadvertent) around small remnants an important resource, particularly as remnants are often long unburned and so may be less productive |

## Conclusions and Recommendations

Dr Harry Frith of CSIRO Wildlife Research, made a detailed study of Malleefowl in the New South Wales wheatbelt in the 1950s. The study began in 1954 in a large area (>1,300 ha) of high quality and continuous mallee, but by 1957 some 78% of the habitat had been cleared for farming (Frith 1973). Malleefowl persisted for a time in the tiny remaining remnant of that past mallee, but are now locally extinct (Priddel and Wheeler 1999).

Much of the high quality mallee in eastern Australia has now been cleared and the remaining expansive areas (in central NSW and north-western Victoria) are subject to large scale burns and the ever-present foxes. Beyond the wheatbelt, much of their remaining habitat is browsed by stock, resulting in an opening up the habitat and removal of food plants of the Malleefowl. The species is perceived to be at considerable risk throughout its eastern range.

There have been no formal studies of the species in Western Australia, but all the same threatening processes operate and there is no reason to believe that the species isn't similarly threatened. This conclusion is reflected in its State listing. It is perceived to be at risk of extinction under the WA State Act.

However, a closer look at the Western Australian situation gives cause for guarded optimism – perhaps the dire story of the eastern states is not entirely replicated here.

*Positive indications*

1. Serventy and Whittell perceived the species to be increasing in the Western Australian wheatbelt due to enhance food supply;
2. The large number of contemporary sightings of Malleefowl and their broad spatial extent across the known range of the species in Western Australia (this study) suggest a species that is holding its own;
3. Remnants are often ungrazed by stock in Western Australia because of the presence of poison plants, *Gastrolobium* (this study);
4. Remnant vegetation is typically left as discrete areas in contrast to the often variegated landscape of scattered eucalypts that characterises clearing patterns in Eastern Australia;
5. Clearing in the eastern half of the WA wheatbelt has left substantial areas of retained vegetation and reasonable extent of linking vegetation (this study: e.g. Neighbourhood 1 of Figure 12);
6. Habitat favoured by Malleefowl (this study: mallee, shrubland) has not been favoured for clearing in Western Australia due to poor agricultural productivity and the presence of poison plants;

7. There has been a demonstrated long-term persistence of Malleefowl in small wheatbelt remnants such as Foster Road at Ongerup (Table 8), in contrast to their demise in Frith's study area in eastern Australia (Pulletop NR and other nearby small reserves between 80 and 160 ha: Priddel and Wheeler 1999).

8. Low incidence of fire in wheatbelt remnants and a low probability of the entire remnant burning due to effective fire suppression by farmers (this study, in direct contrast to comments in the literature);

9. Small remnants on farms are important habitat for Malleefowl in Western Australia and an important element of their survival in these remnants is the tolerance of farmers of Malleefowl making use of the resources of the adjoining paddocks. This high level of tolerance of farmers to use of paddocks (young crop) by Malleefowl is in direct contrast to their attitudes to kangaroos;

*Cautions*

1. There are considerably uncertainties in the interpretation of sightings data;

2. The precautionary principle suggests it is better to err on the side of threat to encourage further action;

3. The growing problem of climate change and the known susceptibility of Malleefowl to drought.

We conclude that the long-term prognosis for Malleefowl in the Western Australian wheatbelt is much brighter than elsewhere in its range and that its status here is much more secure than previous published studies have indicated. However, their continued persistence cannot be taken for granted, requiring overall neutral or positive environmental trends over time throughout the wheatbelt for it to persist. These environmental trends relate strongly to maintenance of overall connectivity of the landscape and the maintenance of habitat quality within remnants (chiefly by the exclusion of grazing).

*Recommendations*

1. More strategic approach to revegetation based on regional model of Section 8;

2. Wheatbelt–wide survey to establish the extent of grazing of farm remnants by stock;

3. Development of a GIS layer for habitat connectivity for the wheatbelt to assist spatial interpretation of isolation and fragmentation;

4. Continue to promote community and farmer involvement in the long-term conservation of Malleefowl;

5. Further research on "ecological renewal" of fire with respect to Malleefowl food plants and appropriate fire intervals for Malleefowl habitat. This might include a study of differential use of habitat in Lake Magenta Nature Reserve in response to varied local fire history;

6. Lobby for greater conservation security for the extensive areas of Crown land to the east of the wheatbelt (Great Western Woodlands) as a major resource for Malleefowl and a counter to climate change because of its north-south extent;

7. More research on the first four years in the life cycle of Malleefowl , particularly with respect to dispersal and survival;

8. A study of fragmentation as an asset to Malleefowl rather than a cost (cf Benshemesh 2000), due to the close juxtaposition of food and shelter provided by cropping alongside ungrazed bushland remnants.

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Frith, H.J. (1962a). Conservation of the mallee fowl, *Leipoa ocellata* Gould (Megapodiidae). *CSIRO Wildlife Research* **7**, 33-49.

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Priddel, D. and Wheeler, R. (1996). Effect of age at release on the susceptibility of captive-reared malleefowl *Leipoa ocellata* to predation by the introduced fox *Vulpes vulpes*. *Emu* **96**, 32-41.

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Priddel, D. and Wheeler, R. (2003). Nesting activity and demography of an isolated population of Malleefowl (*Leipoa ocellata*). *Wildlife Research* **30**, 451-464.

Saunders, D.A. and Ingram, J.A. (1995). *Birds of Southwestern Australia: an atlas of changes in the distribution and abundance of wheatbelt avifauna.* Surrey Beatty and Sons, Chipping Norton, NSW.

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Short, J. (2004). Conservation of the Malleefowl: are there lessons from the successful conservation of native mammals by intensive fox control? In '*Proceedings of the National Malleefowl Forum 2004'.* Pp. 54-68. (Victorian Malleefowl Recovery Group, Inc., Melbourne.

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# Appendices

A. Outputs

B. Annotated bibliography

## A. Outputs

### Scientific articles:

Parsons, B.C., Short, J.C., and Roberts, J.D. (2007). Here today, gone tomorrow? Quantifying the decline in occurrence of Malleefowl (*Leipoa ocellata*) in Western Australia? In '25 years of Landscape Ecology: Scientific Principles in Practice'. (ed. by Bunce, R.G.H., Jongman, R.H.G., Hojas, L., and Weel, S.) pp. 50-51. IALE, Wageningen, The Netherlands.

Parsons, B.C., Short, J.C., and Roberts, J.D. (2008). Contraction in range of Malleefowl (*Leipoa ocellata*) in Western Australia: a comparative assessment using presence-only and presence-absence datasets. *Emu* **108** (3), in press.

Parsons, B.C., Short, J.C., and Roberts, J.D. (in prep). Are contemporary fire regimes a threat to the persistence of Malleefowl (*Leipoa ocellata*) in the Western Australian wheatbelt?

Parsons, B.C., Short, J.C., and Roberts, J.D. (in prep). Climatic variation within the range of a widespread but declining species: an analysis of the distribution of Malleefowl (*Leipoa ocellata*) in Australia using bioclimatic modelling.

Parsons, B.C., Short, J.C., and Roberts, J.D. (submitted). Using community observations to predict the occurrence of Malleefowl (*Leipoa ocellata*) in the Western Australian wheatbelt. *Journal of Applied Ecology*

### Magazine/newsletter articles

"Malleefowl – an iconic species driving landscape change": article in *Malleefowl Matters*, December 2004.

"Documenting the decline of Malleefowl in the Western Australian wheatbelt using community collected data": article in *Malleefowl Matters*, January 2006.

"Community collected sightings data are driving Malleefowl science: research in the WA wheatbelt": article in *Around the Mounds*, February 2006.

"Diagnosing the decline of Malleefowl using sightings data": article in *Western Wildlife*, April 2006.

“Here today, gone tomorrow? Quantifying Malleefowl decline in the WA wheatbelt”: article in *Malleefowl Matters*, January 2007.

“Here today, gone tomorrow? Quantifying Malleefowl decline in the WA wheatbelt”: article for *North Central Malleefowl Preservation Group Newsletter*, January 2007.

“Malleefowl in the fragmented Western Australian wheatbelt: spatial and temporal analysis of a threatened species”: article in the Megapode Specialist Group Newsletter, July 2007.

“Landholder knowledge of Malleefowl in the WA wheatbelt”: article in *Around the Mounds*, August 2007.

“The National Malleefowl Forum – a brief summary”: article in *Malleefowl Matters*, October 2007.

"Fire in Malleefowl habitat in the Western Australian wheatbelt": article in *Malleefowl Matters*, March 2008.

### *Presentations*

Talk by Blair Parsons at an MPG community information evening in Ongerup (June 2005)

Talk by Blair Parsons at a NCMPG community information session in Wubin (August 2005)

Talk by Blair Parsons at the Malleefowl Preservation Group Annual General Meeting in Denmark (September 2005)

Talk by Blair Parsons at the University of Western Australia as part of School of Animal Biology postgraduate seminar series (September 2005)

Talk by Blair Parsons at the University of Western Australia as part of School of Animal Biology postgraduate seminar series (June 2006)

Talk by Blair Parsons at the Malleefowl Preservation Group Annual General Meeting in Ongerup (September 2006)

Presentation by Blair Parsons at the Birds Australia Annual Congress in Albany (October 2006)

Talk by Blair Parsons at CSIRO Sustainable Ecosystems in Canberra (December 2006)

Talk by Blair Parsons at the University of Western Australia as part of School of Animal Biology postgraduate seminar series (May 2007)

Presentation by Blair Parsons at the International Association for Landscape Ecology World Congress in the Netherlands (July 2007)

Talk by Blair Parsons at the Malleefowl Preservation Group Annual General Meeting in Hyden (August 2007)

Presentation by Blair Parsons at the National Malleefowl Forum and First Western Australian Megapode Symposium in Katanning (September 2007)

Presentation by Blair Parsons at the Ecological Society of Australia Annual Congress in Perth (November 2007)

Talk by Blair Parsons at CSIRO Centre for Environment and Life Sciences as part of the Agricultural Sustainability Initiative seminar series (December 2007)

## *B. Annotated bibliography*

### Western Australian Malleefowl distribution – a selection from the historical literature

Ashby, E. (1921). Notes on the supposed "extinct" birds of the south-west corner of Western Australia. *Emu* **20**, 123-124.

The author provides details of Malleefowl occurrence at Cape Naturaliste, near Margaret River in south-west Western Australia. The effect of frequent fire on coastal vegetation is described (a reduction in height four feet high to around 18 inches), with a suggestion that this has negatively affected Malleefowl.

Carnaby, J.C. (1933). The birds of the Lake Grace district. *Emu* **33**, 103-109.

"Few only seen at Lake Grace but very plentiful north, south and east. It used to be very commonly distributed all over the upland country (highlands of sandplain), and old nesting mounds may be seen on cleared ground where wheat is now grown."

Carter, T. (1917). On the birds of Dirk Hartog Island and Peron Peninsula. *Ibis* **10**, 572-573.

The author mentions the abundance of Malleefowl in coastal scrubs north of Carnarvon (north-western limit of its range) in 1887. An abundance of Malleefowl is also noted in 1877 in dense mallee scrub and thickets along a telegraph line from the Wooramel River to Flint Cliff telegraph station (on Hamelin Pool Station) and 20-30 miles south of there.

Crossman, A.F. (1909). Birds seen at Cumminin Station, Western Australia. *Emu* **9**, 84-90.

The author describes vast sand plains covered with "practically impenetrable scrub", that were considered to be "the haunts of kangaroo, emu, malleefowl, and other game." Crossman noted an apparent decline in the abundance of malleefowl, as judged by an abundance of disused nests in the area. He also noted the presence of a recently active malleefowl mound in soft soil in gimlet woodland.

de Rebeira, C.P.S. and de Rebeira, A.M. (1977). Birds. In '*The Natural History of the Wongan Hills*'. (ed. by Kenneally, K.F.) pp. 77-96. Western Australian Naturalists Club, Perth.

The authors detail Malleefowl occurrence in the Wongan Hills area. "Provided there is no further habitat destruction, with support from sympathetic landowners, this species is now in no danger and will continue as a breeding resident in the Hills."

Ford, J.R. and Stone, P.S. (1957). Birds of the Kellerberrin/Kwolyin district, Western Australia. *Emu* **57**, 9-21.

Implicates the red fox in decline of Malleefowl in the Kellerberrin and Kwolyin districts. "It still survives in a number of localities which include the "Yerrapin Estate" about ten miles north of Shackleton, where the species has been known to breed on several occasions."

Gould, J. (1865). *Handbook to the birds of Australia.* Lansdowne Press, Melbourne, Vic.

Describes the occurrence, breeding habits and habitat of Malleefowl at Wongan Hills. "They were built in precisely the same situations that I have seen them in other parts of the continent, that is, in a sandy scrubby country, the site of the mound being in some little open glade, in the very thickest part of the scrub."

"The farthest point north at which I have seen the breeding-places of this bird is Gantheaume Bay (Kalbarri)."

Leake, B.W. (1962). *Eastern Wheatbelt Wildlife*. B.W. Leake, Perth, WA.

The author describes his personal experiences with Malleefowl in detail, with an emphasis on the central wheatbelt, an area where the birds have declined. Describes a substantial decline in Malleefowl abundance after three years of dry conditions (1877-79).

"The gnow came into the York district in considerable numbers about the year 1865…I found where they had been seeking the seeds of a jam tree on a ridge of Mount Brown, and on the low ranges adjoining Cut Hill."

"I never saw any nests of the gnows nearer than about 50 miles from York, near Coraling, beyond Dangin."

Makes mention of mounds located in thick scrub along the edge of salt lakes nr Yorkrakine 50 miles east of Northam. Malleefowl were numerous along the edge of a chain of salt lakes at Tammin/Mt Caroline.

Milligan, A.W. (1904). Notes on a trip to the Wongan Hills, Western Australia, with a description of a new *Ptilotis*. *Emu* **3, 4**, 217-226, 2-11.

Re; Wongan Hills - "Our great disappointment was to find that the Gnous…had abandoned the locality." The author suggests that frequent fire and drought may be responsible for absence of Malleefowl.

Ogilvie-Grant, W.R. (1910). On a collection of birds from Western Australia with field notes by Mr G.C. Shortridge - Part II. *Ibis* **4**, 156-191.

"The Ocellated Megapode, known as the 'Gnou' by the natives and 'Mallee-hen' by the colonists, is fast disappearing, although its old nesting mounds are to be found almost everywhere. It seems now to be entirely extinct in the west (on the Gascoyne River) and, although existing as far inland as Kalgoorlie, has become very rare in the central districts."

Serventy, D.L. and Whittell, H.M. (1976). *Birds of Western Australia.* University of Western Australia Press, Perth.

"During the last three decades (1940s to 1970s) there has been a significant increase in the numbers of Malleefowl in the south-west of Western Australia and the birds have been reported from a wide area in the wheatbelt whence they had hitherto been considered to have vanished or become very scarce."

## Malleefowl ecology – selected references

Barker, R.D. and Vestjens, W.J.M. (1989). *The food of Australian birds. I, Non-Passerines / by R.D. Barker and W.J.M. Vestjens.* CSIRO Division of Wildlife and Rangelands Research, Lyneham, A.C.T.

Provides an account of Malleefowl diet: Food plants include *Cassia, Cassytha, Beyeria, Owenia, Acacia, Pittosporum, Eriostemon* and *Santalum*. Animal items include cockroaches, ants and *Hymenoptera*.

Benshemesh, J. (1992). The Conservation Ecology of Malleefowl with Particular Regard to Fire. Ph.D thesis. Monash University, Clayton, Vic.

The author provides a comprehensive examination of the ecology of Malleefowl, with particular emphasis on the effect of fire on Malleefowl, behavioural observations, nesting density and success, and survival and movement of chicks.

Benshemesh, J. (1997). *Review of Malleefowl Monitoring Data in Victoria*. Flora and Fauna Technical Report No 148. Department of Natural Resources and Environment, East Melbourne, Victoria.

In this report the author suggests that Malleefowl populations may be resilient to high predation rates by introduced predators such as foxes due to their life history and high fecundity.

Benshemesh, J. (2000). *National Recovery Plan for Malleefowl.* Department for Environment and Heritage, Adelaide, S.A.

This publication represents the most current and comprehensive published account regarding Malleefowl. It contains a thorough summary of ecological and biological knowledge, current status, recovery objectives and recovery actions. A revised plan is in draft and is scheduled to be released in the near future.

Booth, D.T. (1985). Ecological Physiology of Malleefowl (*Leipoa ocellata*). PhD thesis. University of Adelaide, Adelaide, S.A.

Provides useful information on home range, mound density and effects of drought on Malleefowl.

Booth, D.T. (1987). Home range and hatching success of Malleefowl, *Leipoa ocellata* Gould (Megapodiidae), in Murray mallee near Renmark, S.A. *Australian Wildlife Research* **14**, 95-104.

Provides information on the home range of Malleefowl . For example, in low rainfall mallee the home range of Malleefowl was approximately 4 $km^2$ with considerable overlap between individuals, resulting in 1.1 pairs per $km^2$.

Brandle, R. (1990). *Malleefowl mound distribution and status in an area of the Murray Mallee of South Australia; a baseline report.* Nature Conservation Society of South Australia Inc., South Australia. 57 pp.

The author provides information on mound distribution and density in the mallee of South Australia. The overall density was 1.8 mounds per $km^2$.

Brickhill, J. (1987). The Conservation Status of Malleefowl in New South Wales. M. Nat. Res. Sci. thesis. University of New England, Armidale, NSW.

A comprehensive examination of Malleefowl ecology in New South Wales. The thesis includes information of the distribution and abundance of Malleefowl in NSW, their diet, fecundity and breeding success, and habitat quality.

Cutten, J.L. (1998). *Distribution and Abundance of Malleefowl (Leipoa ocellata) in the Murray Mallee and South East Regions of South Australia.* Nature Conservation Society of South Australia Inc., Wayville, South Australia.

Provides an estimate of Malleefowl distribution and abundance in south-east South Australia using a combination of landholder surveys and existing infromation. This report provides useful information of vegetation types for the Murray mallee and south-east regions.

Frith, H.J. (1959). Breeding of the mallee fowl, *Leipoa ocellata* Gould (Megapodiidae). *CSIRO Wildlife Research* **4**, 31-60.

This paper covers a variety of topics regarding Malleefowl breeding biology and ecology including mound distribution and habitat (soil) preferences, breeding and egg laying behaviour, and incubation.

Frith, H.J. (1962). Conservation of the mallee fowl, *Leipoa ocellata* Gould (Megapodiidae). *CSIRO Wildlife Research* **7**, 33-49.

A key paper on Malleefowl research. This account summarises much of the early research conducted by Frith in central NSW in the 1950s. The paper covers habitat requirements, grazing impacts, impact of land clearing, impact of foxes, and Malleefowl diet.

Frith, H.J. (1962). *The Mallee-Fowl: the Bird that Builds an Incubator*. Angus and Robertson, Sydney.

A book detailing the biology of Malleefowl. Provides valuable pioneering information on habitat preferences, the effect of foxes, and recommendations for conservation. Intended for scientific and non-scientific audiences alike.

Frith, H.J. (1973). *Wildlife Conservation*. Angus and Robertson Pty Ltd, Sydney, NSW.

This book covers a wide range of conservation issues. Regarding Malleefowl, the author suggests that the number and local distribution of Malleefowl are ultimately determined by the soil type and its effect on the understorey shrubs, as well as drainage capacity.

Griffiths, F.J. (1954). Survey of the lowan for mallee-fowl in New South Wales. *Emu* **54**, 186-189.

Details a survey conducted in New South Wales for Malleefowl. This paper implicates land clearing and fox predation in the decline of Malleefowl in NSW. The author also suggests that hunting of Malleefowl for food may be partly responsible

Harlen, R. and Priddel, D. (1996). Potential food resources available to Malleefowl *Leipoa ocellata* in marginal mallee lands during drought. *Australian Journal of Ecology* **21**, 418-428.

This paper provides and excellent account of Malleefowl diet. The authors found Malleefowl to feed on a wide range of food items including leaves, buds, flowers, fruits and seeds of numerous shrubs and herbs, and on many species of invertebrates that these plants harbour. They suggest that seeds of *Acacia* and other legumes form a major component of the Malleefowl diet, particularly during summer.

Morris, K.D. (2000). Fauna translocations in Western Australia 1971-1999: an overview. In '*Biodiversity and the reintroduction of native fauna to Uluru-Kata Tjuta National Park'*. (Ed. Gillen, J.S., Hamilton, R., Low, W.A., and Creagh, C.) pp. 64-74. Bureau of Rural Science, Kingston, ACT.

Details the reintroduction of Malleefowl to Francois Peron National Park in Shark Bay, Western Australia. In 1996 and 1997, 105 eggs were collected from 18 active mounds from the wheatbelt, Kalbarri National Park and Nanga Station and artificially incubated at captive breeding facilities. Sixty seven birds, between 6-12 months were released in 1997 and 1998. Birds were intensively monitored for 6 months, with subsequent monitoring including track counts, incidental bird sightings and mound monitoring. The survival rate over first six months was estimated at 90% and birds had appeared to have dispersed widely. Active mounds have been detected and some chicks were sighted after the 2002-03 season, as well as sub-adult birds and un-banded birds.

Priddel, D. and Wheeler, R. (1994). Mortality of captive-raised Malleefowl, *Leipoa ocellata*, released into a mallee remnant within the wheat-belt of New South Wales. *Wildlife Research* **21**, 543-552.

Details the release of captive-reared Malleefowl into an isolated remnant in NSW. Most birds died after several days, with the vast majority killed by predators, including foxes. The authors suggest that the red fox is currently the greatest threat to Malleefowl persistence.

Priddel, D. and Wheeler, R. (1996). Effect of age at release on the susceptibility of captive-reared Malleefowl *Leipoa ocellata* to predation by the introduced fox *Vulpes vulpes*. *Emu* **96**, 32-41.

Details the release of captive-reared Malleefowl into Yathong Nature Reserve. Younger birds (3-5 mths) suffered substantially higher mortality than older birds (14-28 mths).

Priddel, D. and Wheeler, R. (1997). Efficacy of fox control in reducing the mortality of released captive-reared Malleefowl, *Leipoa ocellata*. *Wildlife Research* **24**, 469-482.

The authors showed that captive reared Malleefowl released into fox-baited areas survived better than birds released into areas not subjected to baiting. Despite control, foxes continued to be the primary cause of mortality in the released populations. It has yet to be established that fox control can reduce mortality to a level sufficient to facilitate the recovery of populations.

Birds fared much better in areas of dense mallee vegetation as (unbroken canopy, dense understorey) opposed to more open or discontinuous habitat. A fifth of all birds were killed by raptors. This was also related to the structure of the vegetation.

Priddel, D. and Wheeler, R. (2003). Nesting activity and demography of an isolated population of Malleefowl (*Leipoa ocellata*). *Wildlife Research* **30**, 451-464.

Summarises a 12 year study of Malleefowl at Yalgogrin (558 ha): a remnant of native vegetation in central NSW completely surrounded by large expanses of agricultural land. The remnant suffered multiple disturbances such as grazing, harvesting of mallee vegetation and some felling of trees (typical of most remnants).

The paper covers various aspects of Malleefowl ecology including feeding behaviour, recruitment, longevity, mound distribution, and the impact of various threats including fire, grazing and predation.

Priddel, D., Wheeler, R., and Copley, P. (2007). Does the integrity or structure of mallee habitat influence the degree of Fox predation on Malleefowl (*Leipoa ocellata*)? *Emu* **107**, 100-107.

In this paper, the authors examined the survival of Malleefowl in undisturbed mallee habitat within reserves in South Australia. Fox predation was the major cause of mortality, accounting for at least 30%, and perhaps as much as 96%, of all deaths. The study suggested that understorey structure had no influence on the degree of predation and that Malleefowl populations across Australia are threatened by foxes, placing the species at risk of extinction.

Short, J. (2004). Conservation of the Malleefowl: are there lessons from the successful conservation of native mammals by intensive fox control? In '*Proceedings of the National Malleefowl Forum 2004*'.Pp. 54-68. Victorian Malleefowl Recovery Group, Inc., Melbourne.

The author examines the primary causes for decline in Malleefowl by drawing parallels with mammal declines in Australia. A demonstration of the importance of fox control in reintroduction projects confirms its importance in ongoing Malleefowl management. The author also emphasises that fox control alone will not be enough to halt declines; management of grazing and fire regimes is also of great importance.

Woinarski, J.C.Z. (1989). The vertebrate fauna of broombush *Melaleuca uncinata* vegetation in northwestern Victoria, with reference to effects of broombush harvesting. *Australian Wildlife Research* **16**, 217-238.

Investigates the impact of cutting of broombush on Malleefowl, and the impact of fire also. Malleefowl densities were highest in long unburnt with no birds found in areas burnt less than eight years ago.