National Recovery Plan for Malleefowl *Leipoa ocellata*

Government of South Australia

Australian Government

Northern Territory Government
Department of Natural Resources, Environment and the Arts

Department of Environment & Climate Change NSW

Department of Sustainability and Environment

Victoria The Place To Be

Parks Victoria

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Note: This recovery plan sets out the actions necessary to stop the decline of, and support the recovery of, the listed threatened species.

The plan has been developed with the involvement and cooperation of a broad range of stakeholders, but individual stakeholders have not necessarily committed to undertaking specific actions. The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved. Proposed actions may be subject to modification over the life of the plan due to changes in knowledge.

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Cover photograph: Malleefowl *Leipoa ocellata* by Sharon Gillam

Contents

Abbreviations and Acronyms

APL	Anangu-Pitjantjatjara Lands
APYLM	Anangu-Pitjantjatjara Yankunytjatjara Land Management (SA)
ARC	Australian Research Council
AWC	Australian Wildlife Conservancy
BA	Birds Australia
CALM	Department of Conservation and Land Management (WA) (now DEC)
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECC	Department of Environment and Climate Change, New South Wales (formerly Department of Environment and Conservation)
DEC NSW	Department of Environment and Conservation, New South Wales (now Department of Environment and Climate Change)
DEC WA	Department of Environment and Conservation, Western Australia (formerly CALM)
DEH	Department for Environment and Heritage (SA)
EPBC Act	Environment Protection and Biodiversity Conservation Act (1999)
GIS	Geographic Information System
GPS	Global Positioning System
FONEM	Friends of North Eastern Malleefowl (WA)
FoxTAP	Fox Threat Abatement Program (NSW)
ISP	Internet Service Provider
IUCN	International Union for the Conservation of Nature and Natural Resources (or World Conservation Union)
MPG	Malleefowl Preservation Group (WA)
NCMPG	North Central Malleefowl Preservation Group (WA)
NHT	Natural Heritage Trust
NP	National Park
NRETA	Department of Natural Resources, Environment and The Arts (NT)
NRM	Natural Resource Management
NSW	New South Wales
NT	Northern Territory
PIT	Passive Integrated Transponder
SA	South Australia
SAM	South Australian Museum
TSN	Threatened Species Network
VMRG	Victorian Malleefowl Recovery Group
WA	Western Australia

Summary

Current taxon status

Nationally, the Malleefowl *Leipoa ocellata* is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999* and this classification is consistent with international standards (IUCN 2001, criteria VU A1c,e and A2b,c,e). The Malleefowl occurs in all mainland states except Queensland and is recognised as threatened wherever it occurs. The species is listed as Critically Endangered in the Northern Territory, Endangered in New South Wales and Victoria, Vulnerable in South Australia, and as Fauna That Is Rare Or Is Likely To Become Extinct in Western Australia.

Habitat requirements and limiting factors

The Malleefowl is found in semi-arid to arid shrublands and low woodlands, especially those dominated by mallee and/or acacias. A sandy substrate and abundance of leaf litter are required for breeding. Densities of the birds are generally greatest in areas of higher rainfall and on more fertile soils where habitats tend to be thicker and there is an abundance of food plants. Much of the best habitat for Malleefowl has already been cleared or has been modified by grazing by sheep, cattle, rabbits and goats. The species has been shown to be highly sensitive to grazing by sheep, and is probably similarly sensitive to grazing by other introduced herbivores. The effect of fire on Malleefowl is severe, and breeding in burnt areas is usually reduced for at least 30 years. However, the deleterious effect of fire appears to be mitigated if fires burn patchily. Predation by the introduced fox is also thought to be limiting the abundance of Malleefowl and in many areas may be a major cause of decline. The degree of fragmentation of the remaining Malleefowl habitat is of particular concern and presents a major limiting factor to halting and reversing the decline of the species.

Recovery Plan Objectives

The primary objectives of this plan are to secure existing populations across the species' range and achieve de-listing of Malleefowl under the EPBC Act within 20 years.

Specific Objectives:

MANAGING POPULATIONS

1: Reduce permanent habitat loss

2: Reduce the threat of grazing pressure on Malleefowl populations

3: Reduce fire threats

4: Reduce predation

5: Reduce isolation of fragmented populations

6: Promote Malleefowl-friendly agricultural practices

7: Reduce Malleefowl mortality on roads

PLANNING, RESEARCH, AND MONITORING

8: Provide information for regional planning

9: Monitor Malleefowl and develop an adaptive management framework

10: Determine the current distribution of Malleefowl

11: Examine population dynamics: longevity, recruitment and parentage

12: Describe habitat requirements that determine Malleefowl abundance

13: Define appropriate genetic units for management of Malleefowl

14: Assess captive breeding and re-introduction of Malleefowl

15: Investigate infertility and agrochemicals

COMMUNITY INVOLVEMENT AND PROJECT COORDINATION

16: Facilitate communication between groups

17: Raise public awareness through education and publicity

18: Manage the recovery process

Estimated cost of recovery

This recovery plan outlines actions for improving the conservation status of Malleefowl for a five-year period. Cost estimates have been provided for each action, with the exception of Actions 1-7, which form part of broader conservation programs, or are dependent on identification of priorities at regional and local scales (see Action 8.1). Over one third of the projected costs may be covered by voluntary contributions from community groups involved in a range of activities. Asterisks indicate where volunteer contributions (VC) are likely to be greatest.

Five year Budget ($000s).

Action		Yr1	Yr2	Yr3	Yr4	Yr5	*Total*	*VC*
8.1	Prepare regional conservation plans	0	0	56.6	0	0	*56.6*	*
9.1	Analyse and review monitoring, and develop adaptive management	54	64	0	0	0	*118.0*	*
9.2	Monitor breeding densities	208	178	178	178	178	*920.0*	***
9.3	Fox control (8 sites)	57.4	57.4	57.4	57.4	57.4	*287.0*	*
9.4	Facilitate and coordinate monitoring efforts	49.7	16.3	16.3	11.8	11.8	*105.9*	*
10.1	Distribution of Malleefowl in remote areas	79.1	70.1	35.6	35.6	35.6	*256.0*	
10.2	Distribution of Malleefowl in settled areas	67.6	25.5	0	0	0	*93.1*	*
11.1	Feasibility of PIT readers	19.6	0	0	0	0	*19.6*	*
11.2	Monitor population turnover	75.0	16.8	16.8	16.8	16.8	*142.2*	***
11.3	Monitor recruitment	28.9	30.9	18.4	18.4	18.4	*115.0*	**
12.1	Habitat requirements	84.9	0	0	0	0	*84.9*	*
13.1	Genetic units for management	20.5	37.6	0	0	0	*58.1*	
14.1	Review role of captive breeding	18.0	0	0	0	0	*18.0*	
15.1	Assess infertility	7.2	0	0	0	0	*7.2*	
16.1	National forum and newsletter	32.0	2.0	2.0	32.0	2.0	*70.0*	**
17.1	Raise awareness	16.0	4.0	4.0	4.0	4.0	*32.0*	**
18.1	Manage recovery process	10.0	10.0	10.0	10.0	10.0	*50.0*	*
	TOTAL	827.9	512.6	395.1	364	334	*2433.6*	

Part A Species information and general requirements

Species

The Malleefowl *Leipoa ocellata* Gould 1840 belongs to the family Megapodiidae, the megapodes or mound builders. The group is usually considered amongst the Galliformes (del Hoyo *et al.* 1994), or as a sister group to this order (Jones *et al.* 1995) and is unique amongst birds in that its members use external sources of heat to incubate their eggs (Clark 1964). The family comprises only seven genera and 22 species, all of which are confined to the islands of south-east Asia and the south-west Pacific, and Australia (Jones *et al.* 1995).

The Malleefowl is the most southerly distributed of three species of megapode that occur in Australia. It is restricted to the mainland and differs from all other extant megapodes in that it inhabits semi-arid and arid habitats rather than damp forests. These dry regions are not conducive to the incubation methods typically employed by megapodes (Frith 1956a), such that the Malleefowl has developed the most sophisticated and elaborate technique of incubation of the family (see Frith 1955; 1956b, 1959, 1962b).

Taxonomy

The Malleefowl is the only species in the genus *Leipoa*. Some authors describe two subspecies or races of the species: a darker western form (*ocellata*), and an eastern form (*rosinea*) (Matthews 1912; Macdonald 1973). However, recent genetic analyses suggest there are no distinct subspecies or races (S Donnellan pers comm.) and none are currently recognised (Christidis & Boles 2008).

Conservation status

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

- In the Northern Territory, Malleefowl is listed as <u>Critically Endangered</u> under the *Territory Parks and Wildlife Conservation Act 2000* and the species may be extinct (Blakers *et al.* 1984; Kimber 1985), although recent unconfirmed reports suggest it may still occur in the south-west region.
- In New South Wales, Malleefowl is listed as <u>Endangered</u> under the *Threatened Species Conservation Act 1995.*
- In South Australia, Malleefowl is listed as <u>Vulnerable</u> under the *National Parks and Wildlife Act 1972 – Schedule 8.*
- In Victoria, Malleefowl is listed under the *Flora and Fauna Guarantee Act 1988,* and is regarded as <u>Endangered</u> (Victorian Department of Sustainability and Environment 2003).

- In Western Australia, Malleefowl is listed as Fauna that is rare or is likely to become extinct under Schedule 1 of the *Wildlife Conservation (Specially Protected Fauna) Notice 2005.*

Malleefowl have declined greatly over the past century, and several detailed studies have examined their conservation ecology in south-eastern Australia. These studies have provided much information on the habits and requirements of the species and threats to its conservation. Nonetheless, there is insufficient information available to accurately assess the conservation status of Malleefowl across Australia except in broad terms. This is primarily because little is known of the population dynamics of the species, or its current distribution and population trends in many areas. Despite these 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, SA and NSW have shown steep declines in breeding densities over the past decade, and the past five years in particular (Priddel & Wheeler 2003; Gates 2004; Benshemesh 2005).

In addition to the national and state listings, Malleefowl qualify as Vulnerable by international criteria for threatened species (IUCN 2001, criteria VU A1c,e and A2b,c,e). Further declines are expected because many remaining populations are small and isolated; are threatened by introduced competitors and predators; and are subject to recurrent catastrophic events that severely threaten habitat quality and the viability of populations.

International obligations

The species is not listed under any international agreements.

Affected interests

Malleefowl have a huge potential range and occur on a variety of land tenures primarily comprising Aboriginal land; State and Federal Government controlled land in the form of national parks and reserves and uncommitted/unallocated Crown Land; pastoral leases; and private land.

All of these land managers will be involved in the implementation of this plan to some degree. Planned recovery actions include employment of traditional owners in both survey and monitoring on Aboriginal lands where Malleefowl may occur, and the recording of traditional knowledge of where the birds may occur. Private landholders and leaseholders will be encouraged to report sightings and other information with wildlife authorities or with local Malleefowl volunteer groups.

Numerous community groups have been formed throughout southern Australia to help conserve the Malleefowl. Total membership of these groups numbers over 1000, of which well over 100 are active in the field. These volunteer groups are well organised and active throughout the range of the species, with the exception of central Australia and central NSW. Their role in survey, monitoring, predator control, forming landscape linkages and education has been instrumental in the conservation of Malleefowl, and this important contribution is encouraged in this plan. State and Federal government agencies including regional NRM boards will be involved in every stage of implementing the plan.

Role and interests of Indigenous people

The preservation of Malleefowl in central Australia is important both to the species' conservation, and because Malleefowl feature in Aboriginal mythology and are associated with certain 'Dreaming' sites and trails in central Australia. On Aboriginal land in both SA and WA, Malleefowl occur at low densities, and the challenges to their conservation are very different from those in the south. The recovery effort will benefit greatly from Aboriginal involvement due to the traditional knowledge, skill, and management practices of Aboriginal people in these areas, and their proximity to sites of interest.

In particular, the plan aims to involve Aboriginal communities by:

- encouraging traditional land management, particularly in regard to fire;
- soliciting sightings;
- involving Indigenous communities in survey and monitoring; and
- providing community education and information in regard to Malleefowl and the recovery process.

While a number of actions include Aboriginal involvement, it should be noted that the capacity of Aboriginal people to contribute is dependent on there being adequate infrastructure and project management expertise in place on Aboriginal Lands. While some programs and structures (e.g. community ranger programs) are in place to provide this support, they are not well established in all areas and often lack secure funding and operational capacity.

As major stakeholders in Malleefowl conservation, Aboriginal landholders and traditional owners will be invited onto the recovery team and be part of the decision making process.

The requirements of the *Native Title Act 1993* only apply to land where Native Title rights and interests may exist. When implementing any recovery actions in this threatened species plan where there has been no Native Title determination, or where there has been no clear extinguishment of Native Title, there needs to be consideration of the possibility that Native Title may continue to exist. Generally the *Native Title Act 1993* requires certain procedures to be followed prior to undertaking activities - known as future acts that may include certain recovery actions in this plan - which may affect Native Title rights and interests. This threatened species plan is released and will be adopted subject to any Native Title rights and interests that may continue in relation to the land and/or waters.

Nothing in the plan is intended to affect Native Title. The relevant provisions of the *Native Title Act 1993* should be considered before undertaking any future acts that might affect Native Title. Procedures under the *Native Title Act 1993* are additional to those required to comply with the *Aboriginal Heritage Act 1998*.

Benefits to other species or communities

Malleefowl share their habitat with numerous threatened species of mammals, birds, reptiles and plants that would also benefit from management actions that secure habitat; reduce grazing pressure, fox abundance, and the extent of fires; and increase the connectivity of habitat fragments. In particular, Malleefowl are one of a suite of threatened mallee birds that are listed under the EPBC Act including the Black-eared Miner *Manorina melanotis*, Red-lored Whistler

Pachycephala rufogularis, Mallee Emu-wren *Stipiturus mallee*, Regent Parrot (eastern) *Polytelis anthopelus monarchoides* and Western Whipbird *Psophodes nigrogularis oberon* and *P. n. leucogaster*. Recovery plans have been prepared for some of these species (Baker-Gabb 2001, 2004) and management recommendations in these are in accord with those for Malleefowl. Malleefowl also share their habitat with a number of near threatened (Garnett & Crowley 2000) and state-listed birds including the Striated Grasswren *Amytornis striatus striatus* (listed as Vulnerable in NSW and Victoria and Rare in SA), Chestnut Quail-thrush (eastern) *Cinclosoma castanotus castanotus* (Endangered in NSW and Victoria and Vulnerable in SA), Bush Stone-curlew *Burhinus grallarius* (Endangered in NSW and Victoria and Vulnerable in SA), and Crested Bellbird (southern) *Oreoica gutturalis gutturalis* (Near Threatened in Victoria). Some of these species might also benefit from the increased community participation, and the infrastructure used to monitor Malleefowl may also be useful to monitor the abundance of other species.

Social and economic impact

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

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

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

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

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

Part B Distribution and location

Distribution

The original distribution of Malleefowl covered much of the southern half of the continent from the west coast to the Great Dividing Range in the east (Blakers *et al.* 1984) and was widespread in every mainland state except Queensland (Appendix II). The species occurred in more than a quarter of the 80 major biogeographic regions of Australia (as defined by Thackway & Cresswell 1995; Environment Australia 2000), and ranged as far north as the Tanami Desert in the Northern Territory (Kimber 1985), and to within 60 km of Melbourne in the south (Campbell 1884; Campbell 1901; Mattingley 1908). While there have been various searches of historical records for the original distribution of Malleefowl (Blakers *et al.* 1984; Kimber 1985; Gara 1989), little systematic effort has been made to record Aboriginal knowledge (but see Kimber 1985; Copley & Williams 1995; Richards & Short 1996; Copley *et al.* 2003). This traditional knowledge includes accounts of the bird's range, habits and habitat requirements, and is fast disappearing. A preliminary list of Aboriginal names for Malleefowl is presented in Appendix I, and it is hoped that this may encourage further work in this field.

Within the past century the range of Malleefowl has contracted, particularly in arid areas and at the periphery of its former range. Of 194 one-degree grid cells across Australia in which the species has been recorded at some time in the past (Appendix II), nearly half (47%) have had no Malleefowl records since before 1992, and 30% have had no Malleefowl records since before 1981. In particular, declines were apparent in arid areas and the species may be extinct in the NT where the species was last recorded in 1965. Since 1981, the species' range appears to have contracted by 22% in eastern Australia (NSW and VIC), 26% in SA, and 28% in WA (Appendix II). Parsons *et al.* (2008) have examined the contraction in the range of Malleefowl in WA using a much larger dataset and have provided similar estimates for the contraction of the species' range in that state since 1981 (30%), but also warn that estimates of range contraction using presence-only data such as these may be unreliable in remote areas as there is a high likelihood of the species being present but undetected.

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

Over the past decade, and past five years in particular, continuing declines in breeding densities have been demonstrated through monitoring programs over large areas of habitat managed for conservation in Victoria, SA and NSW (Gates 2004; Benshemesh 2005, Benshemesh *et al*. 2007).

Habitat critical for survival

The Malleefowl is found principally in the semi-arid to arid zone in shrublands and low woodlands dominated by mallee (Frith 1962a, b) and associated habitats such as Broombush *Melaleuca uncinata* (Woinarski 1989a; Woinarski 1989b) and Scrub Pine *Callitris verrucosa*. Malleefowl also occur in Red Ironbark *E. sideroxylon* woodland at the eastern limit of their distribution (Korn 1989), and in Brown Stringybark *E. baxteri/E. araneosa* woodland in the south of Victoria and South Australia. In Western Australia they are also found in some shrublands dominated by acacia, and occasionally in woodlands dominated by eucalypts such as Wandoo *E. wandoo*, Marri *Corymbia calophylla* and Mallet *E. astringens* (Storr 1985, 1986, 1987; Storr & Johnstone 1988; Benshemesh & Malleefowl Preservation Group 2001; Sanders *et al.* 2003).

In central Australia, Malleefowl occurred through large areas of mulga *Acacia aneura* (Frith 1962a; Kimber 1985). Mulga has recently been split into several species, and of those in the Great Victoria Desert the birds seem to prefer the smaller Desert-mulga *Acacia minyura* (G. Wikilyiri pers. comm., R. Kankanpakantja pers. comm.; J. Benshemesh pers. obs.). Of the four sites at which the ranging of Malleefowl has been studied in Desert-mulga in the Anangu-Pitjantjatjara/Yankunytjatjara Lands (APYL) in the north-eastern Great Victoria Desert, the birds used adjacent sandplain areas for foraging (Benshemesh 1997a, and unpublished) where foods were more common. Malleefowl also occur in denser mallee (Red Mallee *E. socialis,* Sharp-cap Mallee *E. oxymitra*, and Blue Mallee *E. gamophylla*) although by southern standards these habitats are very open. Typically, these mallee areas have an understorey of Hard/Lobed Spinifex *Triodia basedowii* or other *Triodia* species, and shrub thickets on the ridges where Umbrella Bush *Acacia ligulata* and other seed-bearing shrubs are often common.

The habitat requirements of Malleefowl anywhere in Australia are poorly understood and have as yet received limited study due to the difficulty of efficiently assessing the abundance of the birds at different sites. A sandy substrate and abundance of leaf litter are clear requirements for the construction of the birds' incubator-nests (Frith 1959, 1962a). Densities of the birds are generally greatest in areas of higher rainfall and on more fertile soils (Frith 1962a; Benshemesh 1992a; Copley & Williams 1995) and where shrub diversity is greatest (Woinarski 1989b). However, the floristic and structural requirements of the species are not well understood and have been examined in only two studies of limited scope.

Frith (1962a) measured the breeding density of Malleefowl in four general classes of mallee in New South Wales and found densities were highest in a habitat class characterised by numerous food plants (especially leguminous shrubs and herbs), a dense canopy, and open ground layer. Apart from rainfall and habitat type, sheep grazing seemed the best explanation for different breeding densities: Malleefowl densities in grazed areas were about a tenth those of ungrazed areas.

Benshemesh (1992a) examined Malleefowl breeding densities at 12 sites in Victoria in relation to habitat structure and the density of food plants. Dense canopy cover was the most important feature associated with high breeding densities. The abundance of those shrubs that may provide an important food source, such as acacias, was poorly correlated with breeding density, suggesting that this resource was not limiting the populations examined. Fire history was also important: the birds preferred old growth (i.e. long unburnt) mallee.

Neither of these studies was of sufficient scope to adequately describe the habitat features that are important for Malleefowl across their range, or to identify with any accuracy sites that might currently harbour populations of the birds or may be suitable for their re-introduction.

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

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

Malleefowl habitat and fire

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

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

Secondly, fire in the mallee typically kills and removes all parts of vegetation above the surface and thus fire has a major influence on the structure and floristic composition of habitats occupied by Malleefowl. The effects of fire on Malleefowl populations appear to be severe and long-lasting. After extensive fires Malleefowl may not breed for up to 17 years (Tarr 1965; Cowley *et al.* 1969), possibly due to a shortage of litter material for nesting, or greater exposure to predators (Priddel & Wheeler 1997). Nonetheless, there are several records of

Malleefowl breeding within six years of habitat being burnt (Benshemesh 1996b; Benshemesh & Burton 1997b), although this appears an exception rather than the norm (pers. obs.). Somewhat ironically, the accumulated litter that is used in nesting is also a major fuel-bed in most mallee habitats (Noble 1984), so that even in years of average rainfall some mallee habitats may be able to sustain large fires every 10-20 years (Leigh & Noble 1981).

Numerous authors have suggested that fire may benefit Malleefowl in the longer term as relatively short-lived shrubs, such as acacias, increase in abundance after fire and are food sources for the birds. However, this does not appear to be the case. Benshemesh (1990; 1992a) found breeding densities at four sites burnt 20-30 years previously to be only about one third that of neighbouring sites that had remained unburnt for at least 40 years, and this probably reflected the species' habitat requirements. Woinarski (1989a; 1989b) also observed fewer birds in habitat burnt within the past 40 years than in long-unburnt (60-80 years) habitat. As Woinarski's study involved counting birds rather than estimating breeding densities, his results further suggest that substantial non-breeding populations do not exist in younger age-classes of mallee. More recently, Clarke (2005) used habitat suitability modelling to examine fire history preferences of Malleefowl and other threatened mallee birds within reserve systems in the Murray mallee of NSW, SA and Victoria. This study used recent sightings of Malleefowl and GIS data to develop a statistical model of the preferences of the species and also found that there was a strong preference by Malleefowl for older age classes (>20 years) and avoidance of younger classes.

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

While large-scale fires are deleterious to Malleefowl populations in the short and long-term, the effect of fire is mitigated if fires burn patchily. Birds in a radio-tracking study in Victoria survived in relatively small unburnt patches by utilising the burnt habitats for foraging, and the unburnt habitats for roosting, nesting, and daytime shelter (Benshemesh 1990; 1992a). Unburnt patches were only about a tenth the average home-range size of Malleefowl in that study. Breeding density was greatly reduced by the fire, but the breeding success within the islands was similar to before the fire. Twelve years after the fire, Malleefowl breeding densities had returned to within 80% of their original density (Benshemesh 1997b), and continued to increase until 16 years after the fire when breeding density peaked at 60% above those before the fire. The population then crashed following a severe drought and stayed low for several years (Benshemesh 2005). While this example lends some support to the notion that limited and patchy burns might actually improve habitat for Malleefowl (Brickhill 1987b), similar increases have not been shown for other partially burnt areas of similar age. Thus, a habitat enhancement effect of mosaic burns has yet to be clearly demonstrated in mallee for any size or pattern of fire. However, as fuel beds in mallee tend to accumulate with increasing time since fire, a mosaic of different aged habitats may be beneficial to Malleefowl by interrupting the continuity of fuel and slowing the spread of large wildfire.

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

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

Mapping of habitat critical to the survival of the species and identification of important populations

Maps based on records from state fauna atlases, museums, Birds Australia and volunteer groups are provided in Appendix II.

Malleefowl occur in a wide range of habitat types and habitat critical to the survival of the species is known only in broad terms. Nonetheless, mappable habitat models have recently been developed by Clarke (2005) for Malleefowl and other threatened species in the Murray Mallee of eastern Australia including the Murray-Sunset and Big Desert/Wyperfeld reserve complexes (Vic), Riverland (formerly Bookmark) Biosphere Reserve (SA), Ngarkat Conservation Park (SA) and Lower Murray-Darling Basin (NSW). These models used recent Malleefowl sightings and GIS data on landforms, habitat type and fire history to develop statistical and spatially explicit maps of the broad habitat preferences of the species. In the WA wheatbelt, Parsons (2008) has created statistical models of Malleefowl occurrence in remnants within the wheatbelt, and Short and Parsons (2008) have applied these models to prioritise management initiatives.

No particular populations or general areas can be described as being of greater importance for the long-term survival of Malleefowl than any other at this stage. Malleefowl still occur over most of their range, and although populations tend to be sparser in areas with low or highly variable winter rainfall, this is compensated by these areas being extensive. Conversely, Malleefowl densities are highest in remnants of habitat within the wheatbelts, but these areas are usually small and fragmented and will require intensive management in the long term to retain the species.

Part C Known and potential threats

Biology and ecology relevant to threatening processes

General ecology

Food

Malleefowl are generalist feeders. Various anecdotal reports and studies have described the diet of Malleefowl as consisting of the seeds, flowers and fruits of shrubs (especially legumes), herbs, invertebrates, tubers and fungi (see reviews by Barker & Vestjens 1981; Booth 1986; Brickhill 1987b; and subsequent studies by Benshemesh 1992a; Kentish & Westbrooke 1994; Harlen & Priddel 1996; Reichelt & May 1997; Harold & Dennings 1998). These studies, and the differences between them, indicate that Malleefowl diet is characteristically variable and that different foods are important at different times and locations. For example, Frith (1962a) observed the diet of adults throughout the year as mostly seeds and fruits of shrubs (73%), particularly of acacias, whereas seeds from introduced herbs and crops have been predominant in the summer in other studies (Booth 1986; Brickhill 1987b; Kentish & Westbrooke 1994; van der Waag 2004), and herbs and fungi predominate through the cooler months of the year (Benshemesh 1992a; Reichelt & May 1997; Harold & Dennings 1998). In habitats bordering croplands, Malleefowl are often observed feeding on fallen grain at the edges of uncleared habitat and up to 100 m or so into cropland, and these foods may be crucial to the persistence of the birds in small reserves (Brickhill 1987b; Storr 1991; Copley & Williams 1995).

In general, the diet of chicks is thought to be similar to that of adults, although observations have been mostly restricted to summer. During this time, free-ranging chicks have been observed to eat insects and the seeds from both shrubs and herbs (Frith 1962b; Benshemesh 1992a; van der Waag 2004, D. Priddel pers. comm.).

Food resources for Malleefowl are typically varied, transient and patchily distributed (Harlen & Priddel 1996) and this reflects the highly irregular rainfall and inherent patchiness of the habitats they occur in (Stafford Smith & Morton 1990). In particular, a diversity of food shrubs, rather than abundance of any one species, is probably as critical to ensure continuity of food for the birds during lean times such as droughts (Harlen & Priddel 1996). This is supported by studies showing that Malleefowl are more abundant in areas where shrubs are more diverse (Woinarski 1989b).

While a regular supply of food throughout the year is clearly important for the birds' persistence in an area, occasional super-abundance of foods probably benefits the survival of chicks and may be important for recruitment of young into the adult population. In one observational study, over half the diet in some months comprised fallen lerp, a food that had not previously (or subsequently to any degree) been recorded in Malleefowl diets (Benshemesh 1992a). Lerp are the secreted shields of sap-sucking psyllid insects and are high in sugars and starch. While usually rare, lerp occasionally occurs in astonishing numbers (Benshemesh 1996b). The occasional availability of such super-abundant foods may greatly enhance chick survival as their mortality from stress and predation is dependent on food supply.

Life History

Mating system and nesting habits

Malleefowl show little sexual dimorphism and are generally monogamous, probably pairing for life (Frith 1959, 1962b). However, a single case of polygyny has been recorded (Weathers *et al.* 1990) in which two females laid eggs in separate mounds tended by the same male. Malleefowl breed annually except in drought years (Frith 1959; Booth & Seymour 1983; Benshemesh 1995b). The mound comprises a large mass of sand, usually 3-5 metres in diameter and one metre high, within which up to a cubic metre of moist litter is buried. The construction of this incubator-mound involves several months of intermittent work (autumn to spring) by both members of a pair, but when completed (early spring) the sexes lead mostly separate lives (Frith 1959). The male then spends several hours each day maintaining the condition of the mound and regulating the incubation temperature, while the female spends most of her time feeding for egg production and may only visit the nest to lay. Early in the breeding season the heat for incubation of the eggs is produced by microbial decomposition of the litter, but late in the season heat from the sun is also utilised (Frith 1956b). The main function of the litter incorporated into the mound appears to be to enable the birds an early start to egg laying. Successful mounds that have been built without leaf litter have been recorded (Frith 1959, P. Burton pers. comm., J. McLaughlin pers. comm., pers. obs.), but these are generally rare and are usually built in early summer rather than spring.

Eggs

Egg laying usually begins in September and an egg is laid every 5-7 days until mid to late summer (Frith 1959). The incubation period of eggs varies with temperature, but is about 60 days at typical nest temperatures (Frith 1959; Vleck *et al.* 1984; Booth 1987a). Five detailed studies have been conducted on the breeding success of Malleefowl, all of which were in south-east Australia (Frith 1959; Booth 1987b; Brickhill 1987b; Benshemesh 1992a; Benshemesh & Burton 1997a). Average clutch size varied between years and localities, but was often 15-25 eggs of which about 80% hatched unless the nest was disturbed by predators (Frith 1959; Benshemesh & Burton 1997a) or unseasonal weather conditions (Brickhill 1987b). Much of the variation in clutch size is due to the duration of the egg laying season, which is thought to depend on food supply and the onset of very hot weather (Frith 1959; Benshemesh 1992a; Benshemesh & Burton 1997a). Egg size has been shown to be related to the survivorship of chicks (Benshemesh 1992a), and also varies substantially (up to 15%) both between years (Frith 1959; Benshemesh 1992a), and the five studies generally. The availability of food (Frith 1959; Booth 1987b) and water balance (Benshemesh 1992a) are possible causes for this variation in mean egg sizes in populations, but the relationships are not clearly understood.

Chicks

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

Age of breeding and longevity of adults

In captivity, Malleefowl reach breeding age at 3-4 years (Bellchambers 1916, K. Brumby pers. comm., M. Johnson pers. comm.). Once birds reach breeding age they appear to be long-lived, although data are limited, anecdotal and of uncertain generality:

- Frith (1962a) noted that none of his banded birds disappeared during his eight-year study unless an area was cleared.
- During a radio-tracking study in Victoria, several Malleefowl were monitored for a cumulative total of over 20 years during which time most birds were subjected to a fire followed by a severe six month drought, yet only two deaths were recorded (Benshemesh 1992a).
- In captivity a male of at least 19 years old (and perhaps much older) bred at the Adelaide Zoo until at least 1998 (M. Johnson and M. Craig pers. comm.).
- An unbanded but recognisable pair of Malleefowl was known to breed for 25 years at the Little Desert in Victoria. During this time the birds became remarkably accepting of the close proximity of the local ranger, Keith Hately, before one of the pair disappeared (K. Hately pers. comm.).
- Also at the Little Desert, an unbanded but recognisable pair was claimed to have been known to breed over 17 years, although they apparently found other mates and did not breed together towards the end of this period (W. Reichelt pers. comm.).
- At Yalgogrin in NSW, of 25 breeding Malleefowl that were banded in 1988 only four were still alive 12 years later (Priddel & Wheeler 2003). Overall, the average longevity of Malleefowl in the study was 7.5 years, although the age of birds when they were first captured and marked as breeding adults was unknown. The population declined markedly during the study.

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

Recruitment

There is very little information on recruitment of young Malleefowl into adult populations. Measuring recruitment directly is difficult because Malleefowl cannot be banded until they are near adult size, and other methods of marking chicks are inconspicuous in the field. Nonetheless, there is evidence that recruitment is occurring naturally to some extent. At Yalgogrin (NSW), unbanded birds appeared in a small and isolated population several years after all breeding birds had been banded (Priddel & Wheeler 2003), although the breeding population declined nonetheless as this recruitment was less than the mortality of adults. Elsewhere, the persistence of Malleefowl populations in many areas and the return of Malleefowl to areas that have previously been burnt by large fires suggest that recruitment occurs in the wild. But it is not known whether such recruitment is adequate to maintain populations or under what conditions recruitment may occur.

Measuring the recruitment of young into the adult population is also made difficult by the very high mortality of chicks and the long period of time before survivors may appear in the breeding population. This high mortality of chicks is not surprising considering the harshness of the arid and semi-arid environment during summer and autumn, the lack of parental care, and the fecundity and longevity of adult Malleefowl (Frith 1962b). On average, a pair of Malleefowl may produce hundreds of chicks in a lifetime but require only two chicks to survive to breeding age to sustain a stable population (Frith 1962a). What proportion of chicks must survive to sustain a population is not known but is likely to be about 2% assuming an average breeding life of ten years in the wild.

For the bird's populations to remain stable, recruitment of young into the breeding population must occur within the life of the adults, but there is no reason to expect that recruitment should be evenly distributed across years. Recruitment could be an episodic event with negligible survival of young in most years offset by much higher survivorship during years when there is plentiful food or mild weather conditions prevail (Benshemesh 1992a). Such seasonal variability characterises the Australian arid and semi-arid zones to a remarkable degree by world standards (Stafford Smith & Morton 1990; Stafford Smith 1995), and food for Malleefowl is known to become super-abundant in some years (Benshemesh 1992a, 1996b), and scarce during dry years (Harlen & Priddel 1996). Seasonal differences in the survival of young may also be expected if egg size has a bearing on the survivorship of chicks immediately after hatching (Benshemesh 1992a) as egg size varies markedly between years (Frith 1959).

Dispersal, mobility and ranging

Adults

Malleefowl mostly move about their home-range by foot, and rarely fly except when they are disturbed or to roost in the canopy (Frith 1962b). Breeding birds tend to be sedentary, nesting in the same general area year after year (Frith 1959; Benshemesh 1992a). Nonetheless, a pair sometimes moves several kilometres between nesting seasons for no apparent reason (Frith 1959). Home-ranges do not appear to be defended, although in the vicinity of its nest the male is vigorously aggressive toward other Malleefowl except its mate (Frith 1959). Radio-tracking studies (Booth 1987b; Benshemesh 1992a) have shown that over the course of a year the birds may range over one to several square kilometres and that home-ranges overlap considerably. During the breeding season, males spend most of their time in the vicinity of their nests and consequently male home-ranges are usually much smaller than those of their mates at these times, and may rarely overlap with other males. The male and female of a pair spend most of their time together outside the breeding season and hence their ranging behaviour is similar at these times (Benshemesh unpublished data).

Malleefowl appear to disperse on foot, and various anecdotal reports suggest they use corridors of relatively thick vegetation when dispersing through open landscapes. These include sightings of single birds (D. Martin pers. comm.; S. Dennings and K. Vaux pers. comm.) and pairs (K. Willis pers. comm.) walking along wooded strips of vegetation along roadsides several kilometres from the nearest remnant of native scrub. Similarly, birds have been reported to use strips of dense unburnt vegetation when dispersing through an otherwise burnt landscape (Benshemesh 1992a).

Chicks

Malleefowl chicks are capable of dispersing widely almost immediately after emerging from their nests and do not seem confined to particular habitat types. Mean dispersal rates of over 600 m per day have been measured for newly hatched chicks, with some chicks averaging over two kilometres per day (Benshemesh 1992a). In this radio-tracking study, dispersing chicks readily moved out of the unburnt habitats in which they were released and into recently burnt mallee and open woodlands with little cover. Some chicks settled in small (2-8 ha) areas of burnt or unburnt mallee habitat where they found food and at least some unburnt trees for roosting.

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

In WA, Jessica van der Vaag is currently completing a PhD thesis (University of Western Australia) examining the movements and behaviour of Malleefowl chicks in isolated reserves and this study is likely to greatly increase our knowledge of chick behaviour and ecology.

Threats

Clearing

Clearing of the mallee for wheat and sheep production has been the major factor in the decline of Malleefowl in southern Australia, and this was forewarned by some of the earliest writers on Malleefowl (Campbell 1884; Campbell 1901; Mattingley 1908; Bellchambers 1916, 1918; Barrett 1919; Chandler 1934). The best habitats for Malleefowl tended to be on the more fertile soils and received relatively high rainfall (Frith 1962a), but these have been almost entirely cleared. Overall, up to 80% of the wheat belts in Western Australian and the eastern states have already been cleared (Glanznig 1995). This clearing has not only removed Malleefowl habitat, but also threatens remaining habitat due to fragmentation and dryland salinity (George *et al.* 1994; Agriculture Western Australia *et al.* 1996a; 1996b).

Habitat remnants, where they exist within the wheat belts, are often very small and isolated (Brickhill 1987b; Saunders 1989; Saunders & Curry 1990; Cutten 1997; Priddel & Wheeler 2003). The larger remnants occur typically in areas unsuitable for agriculture (Land Conservation Council 1987; Sparrow 1989) and are often of marginal quality for Malleefowl (Frith 1962a; Brickhill 1987b; Priddel 1989, 1990; Benshemesh 1992a; Copley & Williams 1995).

Clearing continues to be a threat to Malleefowl populations outside reserves even though controls on the clearing of mallee on private land have been imposed in New South Wales (*Native Vegetation Act 2003*), Victoria (*Planning and Environment Act 1987*- Clause 52.17 and *Victoria's Native Vegetation Framework 2002*), South Australia (*Native Vegetation Act 1991*), and in Western Australia (*Environmental Protection Amendment Act 2003*).

While agriculture has been the greatest reason for clearing mallee habitat in the past, new threats are emerging that are targeting remaining areas of habitat. Numerous mining operations have been proposed in mallee areas of NSW, SA, Victoria and WA covering many thousands of hectares, and there have also been proposals to clear habitat for industrial waste containment facilities. Some forms of mining involve the removal of all vegetation at a site and causes major disturbance to the substrate which may have long lasting effects despite efforts at revegetation. Such destructive mining should be prohibited in areas that support remnant vegetation and relatively high densities of Malleefowl unless clear long term gains for Malleefowl can be demonstrated.

Another form of habitat loss and modification is the harvesting of mallee eucalypts for charcoal or oil, and the harvesting of Broombush (*Melaleuca uncinata*) for building materials, and in some cases these industries may compromise Malleefowl conservation. For example, Yalgogrin in central NSW is managed for commercial eucalypt production, but is also a highly significant area for Malleefowl conservation and harbours a declining population of the species (Priddel & Wheeler 2003). The part played by eucalypt harvesting in the decline of the Malleefowl has not been studied but the gross changes to habitat structure and floristic composition are likely to be detrimental. In other areas, a lack of regulation and adherence to specified harvesting prescriptions may reduce Malleefowl habitat viability and quality from too-frequent harvesting regimes and excessive removal of stems (D. Oliver pers. comm.).

Malleefowl are protected in every state in which they occur and clearing applications are unlikely to be granted for areas where existing populations are known. However, the only current criterion for which a site's importance for Malleefowl conservation can be assessed is the obvious presence of the birds. Given that Malleefowl are elusive and rare, their presence may easily be missed. Broad GIS based habitat models (e.g. Clarke 2005; Parsons 2008) may provide an important tool for recognising suitable Malleefowl habitat, although this approach is limited by the information available on GIS systems. The ability to recognise *potentially* good Malleefowl habitat is also important, especially in regard to fire which may remove Malleefowl in the first instance but from which the habitat completely recovers provided it is not heavily grazed. There is a need to adequately describe Malleefowl habitat so that suitable sites for the species, and sites that may become suitable in time, can be recognised.

Fragmentation and isolation

Before European settlement, mallee habitats were extensive and nearly contiguous across Australia (Specht 1981; Hill 1989) and surrounded by other habitat types that also harboured Malleefowl. However, clearing for agriculture has resulted in fragmentation of the remnant population into a large number of small populations with little opportunity for dispersal between them. Small and isolated populations are especially vulnerable to local extinction by a range of processes that may deplete the number of individuals or degrade the overall fitness of each population (Nei *et al.* 1975; Denniston 1978; Shaffer 1981). Also, populations in low quality habitats may have always depended on immigration from surrounding areas (Van Horne 1983; Pulliam 1988; Lawton 1993), and once isolated from these better quality areas may be unable to sustain themselves.

The clearing and fragmentation of Malleefowl habitats is also likely to exacerbate other threats. For example, foxes are probably more abundant near cleared land (Saunders *et al.* 1995), fragments of mallee may be completely consumed by fire leading to local extinction where sources for recolonisation no longer exist, and fragmentation may increase the exposure of Malleefowl to agrochemicals. Also, the combination of fragmentation of the landscape and climate change may seriously threaten the conservation of species such as the Malleefowl (Peters & Darling 1985). This is especially the case considering the severe impact on Malleefowl predicted under enhanced greenhouse scenarios in some regions (Bennett *et al.* 1991; Parsons 2008) and on mallee habitats in general (Greenwood & Boardman 1989).

Grazing

In areas grazed by sheep, Frith (1962a) showed that Malleefowl breeding densities were reduced by 85-90% compared to similar ungrazed habitats. Other herbivores may also compete with Malleefowl for herbaceous foods and damage shrubs that are important as seed sources for the birds. Rabbits are usually rare in mallee habitats (Frith 1962a) except at the mallee edge, but feral goats are abundant in some areas (Henzell & McLeod 1984; Newsome 1989; Pople *et al.* 1996) and are probably even more damaging to shrub populations than sheep (Harrington 1979, 1986). High numbers of kangaroos may also be a problem in areas where their numbers are artificially high due to access to water sources and agriculture, and absence of predators. In central Australia, sheep and feral goats are rare but high numbers of other introduced herbivores such as domestic cattle, rabbits, and feral camels occur in some areas and provide reasons for concern.

The effects of these herbivores are twofold. Firstly, grazing and browsing denies Malleefowl of food that may otherwise be available to them. Secondly, when maintained at high densities these herbivores may cause long-term change to the structure and floristic diversity of habitats (Harrington *et al.* 1984; Chesterfield & Parsons 1985; Friedel & James 1995). This may make habitat structure less suitable for Malleefowl and, by making habitats more open, the birds may become more vulnerable to predators. Heavy grazing may also reduce the soil-stored seed of many perennial and ephemeral species, with potentially serious implications for the quality of Malleefowl habitats. Such grazing may also reduce the diversity and abundance of invertebrates (Greenslade 1992) which are another important food source of Malleefowl. These more insidious effects of grazing are especially important after fire when vegetation is regenerating and has yet to reproduce (Leigh & Holgate 1979; Hopkins 1982; Christensen & Maisey 1987, A. Willson pers. comm.), and where herbivore numbers are maintained at high levels by the provision of artificial water sources. By benefiting large grazing animals, such water sources may profoundly affect the distribution and abundance of native plants and animals for a radius of at least 10 km (Landsberg *et al.* 1997; Harrington 2002). Relatively few areas within the pastoral zone are more than 10 km from artificial water sources. Thus, most areas in the pastoral zone are probably affected by artificially high grazing pressure.

Feral goats and sheep are of particular concern for Malleefowl conservation in southern Australia as large tracts of mallee support goats or are used to graze sheep. Some of the highest goat densities occur in reserves that support Malleefowl populations, particularly in large reserves and pastoral leases in NSW and eastern SA north of the Murray River. Sheep grazing for pastoral production continues on public land over vast areas of Malleefowl habitat, especially in WA and NSW. Feral deer may also be a problem in some Malleefowl habitats in more mesic areas (D. Peacock pers. comm.)

There is little doubt that past and present grazing has damaged Malleefowl habitat and continued grazing by sheep, goats and perhaps kangaroos is keeping Malleefowl populations lower than would otherwise be the case. Much of the land most affected by grazing may be of relatively low quality for Malleefowl (Frith 1962a; Brickhill 1987b), but the size of these areas suggests they may be of considerable value to Malleefowl populations. Also, while these grazed areas may be sub-optimal for Malleefowl, their significance is all the greater now that most of the best quality habitat has already been cleared.

Predation

Predation by the introduced fox, and to a lesser extent by cats and raptors, is a major cause of mortality of Malleefowl. Foxes in particular are known to take Malleefowl at all stages of the bird's life cycle. Foxes are the only documented predators of Malleefowl eggs (apart from humans), although dingoes and dogs (and large varanids) might also be expected to raid nests. Foxes have been known to take over a third of eggs at some sites (Frith 1962a; Benshemesh & Burton 1997a; 1999, D. Priddel and R. Wheeler pers. comm.), but fox predation on eggs has usually been found to be negligible in large studies (Booth 1987b; Brickhill 1987a; Benshemesh 1992a). The two detailed cases where foxes were shown to have taken a substantial proportion of eggs followed widespread rabbit reduction by introduced viruses (myxomatosis in the 1950s, and rabbit haemorrhagic disease in 1996). The subsequent loss of rabbits as food for foxes may have caused foxes to switch prey to Malleefowl eggs (Benshemesh & Burton 1999).

Predation on Malleefowl chicks is severe but difficult to measure in wild populations. Chicks released in mid-summer within a day of hatching have been shown to experience heavy mortality due to predation by foxes/cats, predation by raptors, and metabolic stress, in approximately equal proportions (Benshemesh 1992a). Mortality was found to be greatest during the first few days and 80% of chicks were dead within ten days. Similarly, captive-reared chicks that were of various ages up to five months old and released into a small habitat remnant in autumn and winter experienced heavy (55-68%) mortality from introduced predators (predominantly foxes but also occasionally by cats) and 26-39% by raptors (Priddel & Wheeler 1994). In areas where fox abundance has been greatly reduced, juvenile Malleefowl have nonetheless suffered high mortality from raptors (Harlen & Priddel 1992). Older captive-reared Malleefowl appear less susceptible to raptors, but are still highly susceptible to fox (and possibly cat) predation. At least 50% of juveniles (3-5 months old) released in autumn were thought to be killed by foxes, and a further 13% by either foxes or cats, whereas only 4% were known to have been taken by raptors (Priddel &

Wheeler 1996). Predation probably accounted for an even greater proportion of juveniles than these percentages suggest as all juveniles were known to be dead within 104 days, although the cause of death could not be ascertained in nearly a quarter of cases. Sub-adult birds (14-28 months old) survived better than the younger juveniles released in the same areas, although fox predation still accounted for about 70% of birds that were released. Studies have also demonstrated that intensive fox baiting increases the survival of captive-reared birds released in the wild (Copley & Williams 1995; Priddel & Wheeler 1997), and a population of Malleefowl has been successfully re-introduced to Peron Peninsula following intensive predator and exotic herbivore control (C. Simms pers. comm.).

A common element in all these studies is that chick cohorts of any age encounter massive mortality rates during the first few days after they are released. Thereafter, mortality rates decline as birds spend more time in a habitat, and this possibly reflects the development of experience by the birds in finding reliable food sources and in evading predators. This pattern is most pronounced for chicks and captive-reared juveniles, but also applies to captive-reared sub-adults. It is also worth noting that all releases of radio-tagged Malleefowl less than a month old have occurred late in the breeding season, whereas it is characteristic for avian breeding success and offspring survival to be highest early in the breeding season and decline thereafter (Perrins 1970, Daan *et al*. 1989, Rohwer 1992).

Fox control improves the survival of captive-reared birds, but the degree to which fox predation is responsible for the decline of existing Malleefowl populations is less clear. Foxes are most common in mallee near agricultural land (Saunders *et al.* 1995), where high densities may be maintained by the ready availability of their principal foods such as rabbits, mice and sheep carrion (Saunders *et al.* 1995). However, many of the highest Malleefowl breeding densities occur in such areas and have appeared stable in the absence of habitat disturbance or drought (Frith 1962a; Benshemesh 1992a; Copley & Williams 1995). In some cases in Victoria there has been little change in Malleefowl breeding densities over periods of several decades (Benshemesh 1997b), even though fox numbers have been high in that state since the 1970s (B. Coman pers. comm.), suggesting that in some cases, at least, foxes and Malleefowl may coexist. Nonetheless, Malleefowl populations are clearly in decline in many areas and it is likely that fox predation plays a part in this trend.

There is little clear evidence that Malleefowl populations have increased following fox control operations, even though fox control is widely practised in areas where Malleefowl conservation is a concern. For example, fox control has failed to increase breeding densities after more than a decade of baiting at Bakara in SA (Gates 2004), Dryandra in WA (A. Friend pers. comm.) and Yathong in NSW (D. Oliver pers. comm.). The Dryandra example is interesting in this regard as several species of medium-sized native mammals increased greatly after fox baiting, but Malleefowl numbers appear to have stayed the same or declined. Increased Malleefowl densities have been observed at Mallee Cliffs NP in NSW and this might be a result of a consistent and relatively intense program of fox control since 1998, although other factors may also be involved (R. Dayman pers. comm.).

The lack of evidence for a positive effect of fox control on Malleefowl breeding densities may be due to a number of factors. Firstly, the effectiveness of control programs at reducing fox numbers is not always clear and in some cases the lack of a response by Malleefowl might simply have been due to the failure to adequately reduce foxes (Short 2004). Secondly, Malleefowl populations fluctuate for a range of environmental reasons, especially drought, and these may mask the benefits of fox control (drought may be particularly relevant to Bakara and Yathong). Thirdly, the effect of predation may vary with habitat type and be less important in some areas than others (Benshemesh 1992a; Short 2004). Finally, and most importantly, the lack of evidence about the effects of fox control on Malleefowl is simply due to the lack of adequately controlled and replicated studies on the subject. This is not due to lack of opportunity as much as a lack of coordination and appropriate experimental design. A recent review of pest control in Australia found that Malleefowl occurred in more areas baited for foxes than virtually any other threatened species (Reddiex *et al.* 2004), and monitoring of Malleefowl breeding densities also occurs at numerous sites across the continent. Yet there has been no concerted attempt to adequately combine these two elements into an experimental test that would clarify the effectiveness of fox control in benefiting Malleefowl. Evaluation of the effectiveness of fox control in Malleefowl recovery is a high priority, to ensure that resources for Malleefowl recovery are targeted in an effective and efficient manner.

While the relationship between fox predation and Malleefowl declines remains unclear, there is little doubt that the threat posed by foxes (and cats) is *potentially* severe and efforts should be made to reduce their numbers wherever Malleefowl populations show signs of decline. This is especially important when rabbit numbers are suddenly reduced, such as following the spread of rabbit haemorrhagic disease, as this may lead to 'prey-switching' by foxes (Pech & Hood 1998).

Foxes are not the only ground predator of Malleefowl, and the nature of the relationship between foxes, cats and dingoes/dogs is also relevant in arid areas where all three usually occur. There is some evidence that interactions occur between these predators in many arid areas and that dingoes might suppress both foxes and cats (Robley *et al.* 2004). Foxes are probably the most efficient predators of Malleefowl and baiting can efficiently reduce their numbers. However, this also reduces dingo numbers and may result in significant local increases in cat numbers and/or activity for which there are as yet no efficient control measures. It is unclear how the relationship between these predators, and the available methods of their control, can best be manipulated to benefit Malleefowl.

Fire (wildfire and intentional burns)

Large fires are a major threat to the conservation of Malleefowl and many other threatened mallee birds (Woinarski 1999; Baker-Gabb 2004; Clarke 2005). Populations of Malleefowl may suddenly be eliminated from vast areas that are burnt, and even if there are nearby sources of recolonisation, recovery in the burnt area to densities that occurred before the fire appears to be very slow, requiring 30 to 60 years (Woinarski 1989b; Benshemesh 1990, 1992a; Clarke 2005). Habitats much older than 30 years post-fire are rare in eastern Australia. Conservation reserves should ideally be large enough to allow for large-scale disturbance such as fire without the entire area being affected (Wright 1974; Pickett & Thompson 1978). However, the potential scale and frequency of fire in mallee habitats suggests that even the largest reserves may be entirely consumed by a single fire (Land Conservation Council 1987; Blakers & McMillen 1988).

In some states that support Malleefowl, intentional broad-scale burning has been advocated as a pastoral management technique. Frequent burning may more than double the productivity of pastoral mallee habitats for sheep (MacLeod 1990), and for this reason has been promoted by pastoral extension services in New South Wales (Choate 1989; Muir 1992). Intentional broad-scale burning has also been advocated as a means of producing permanent habitat change in NSW mallee to reduce tree and shrub density and benefit sheep grazing (Noble 1989). Hodgkinson *et al.* (1984) and Noble (1984) suggest that much of the mallee under leasehold in NSW has been burnt on a 10-20 year cycle to increase forage production, eliminate shrubs unpalatable for sheep, and for fuel reduction, although these authors may have overstated the extent of this practice (A. Willson, pers. comm.). Where such fire frequencies are employed, Malleefowl populations are likely to be greatly reduced or even eradicated (Benshemesh 1990, 1992a).

Disease, inbreeding and chemical exposure

There is no information on disease in wild Malleefowl populations although the species is susceptible to a range of common diseases in captive situations and may also be susceptible to exotic diseases, especially those found in other Galliformes (R. Woods pers. comm.). This is an issue in programs where Malleefowl are released following a period in captivity, especially in a zoo situation, and also where domestic fowl and pheasant farms are located near areas occupied by Malleefowl.

There is no information on genetic deterioration of Malleefowl, although a range of problems are expected on theoretical grounds where populations are small and isolated. Likewise, there is no evidence that agrochemicals are currently a threat, although the increased exposure of Malleefowl to such chemicals in fragmented landscapes warrants some concern.

Climate change

Current predictions of climate change for Australia (Pittock & Wratt 2001) provide considerable cause for concern and the projected changes in rainfall and temperatures, and concomitant changes in biota, are likely to threaten Malleefowl over their entire range (Parsons 2008). If these predictions are correct, and if the changes are not arrested, substantial declines in Malleefowl populations are likely and the future of the species may be bleak.

Populations and areas under threat

There is no information to suggest that any particular population of Malleefowl is under more threat than another. Rather, threats vary from place to place and there are no locations where the species can be confidently regarded as secure. While issues such as fire, predation and climate change threaten the species wherever it occurs, threats resulting from clearing, fragmentation and grazing tend to be more concentrated in the southern agricultural regions where Malleefowl typically occur at higher densities.

Existing conservation research and management practices

Habitat protection

Conservation reserves containing Malleefowl have been established in New South Wales, South Australia, Victoria, and Western Australia.

In south-eastern Australia, most of the best quality Malleefowl habitat that remained after clearing has been included in conservation reserves, although these are typically small. However, in the WA wheatbelt nearly half (45%) of the remaining Malleefowl habitat is on private land (Short and Parsons 2008) with the remainder occurring on public estate such as reserves and unallocated crown land.

A number of private conservation reserves have been established in recent years that are important for Malleefowl. The Australian Wildlife Conservancy (AWC) operates a number of private conservation reserves across Australia that support Malleefowl, including Dakalanta (SA), Mt Gibson (WA), Scotia (NSW), and Yookamurra (SA). Bush Heritage Australia also owns and manages a number of large reserves that are important for Malleefowl such as Eurardy and Charles Darwin reserves north of Perth (WA), as well as a number of smaller reserves (Chereninup Creek, Monjibup, Yarrabee and Peniup Creek reserves) that form part of the Gondwana Link stage 1 project that aims to restore and reconnect fragmented habitats between the Stirling Range and the Fitzgerald River National Parks (WA). In South Australia, two former grazing leases that include large areas of Malleefowl habitat have also been purchased and managed for conservation as part of the Riverland Biosphere Reserve: Calperum, managed by Community Land Management Inc., and Gluepot, managed by Birds Australia.

On private land in South Australia, some areas of high quality Malleefowl habitat are reserved in perpetuity as Heritage Agreement areas, although most of these are isolated fragments. In Victoria, the Trust for Nature has been active in purchasing or covenanting remnant private blocks that are important for Malleefowl conservation.

Controls on the clearing of mallee have been imposed on private land throughout the Malleefowl's range. Nonetheless, in some cases habitat is being degraded through grazing, vegetation harvesting (e.g. broombush and eucalyptus), and too frequent (or infrequent) fire. Edge effects may also profoundly alter the integrity of small patches of habitat (Saunders 2004).

In south west NSW there are still continuous areas of high rainfall mallee on leasehold land that are not part of the formal reserve system and these are crucial for the long-term conservation of Malleefowl in the region (D. Oliver pers. comm.). Assisting landholders to maintain and enhance these habitats is a priority and extensive areas of vegetation have been incorporated into 'southern mallee landuse agreements' in recent years (D. Oliver pers. comm.). These agreements between government and landholders require landholders to put aside parcels of remnant vegetation as conservation areas in exchange for permission to clear other parcels of land. These new conservation areas may provide further areas of suitable habitat for Malleefowl conservation, however the management of these areas may be lacking in regard to some of the key threatening processes such as fire management and feral animal control. Also the clearing of land may further fragment Malleefowl habitat and dispersal corridors.

On Aboriginal Land in the arid regions of SA and WA, Indigenous Protected Areas (IPAs) have been declared and provide recognition of conservation values to large areas that harbour Malleefowl, albeit in low numbers. These are important covenants and provide salaries for Indigenous landowners to manage the landscapes for their conservation values. In two such IPAs in the Anangu-Pitjantjatjara Lands of SA (Walalkara and Watarru), Indigenous rangers and other members of local communities have undertaken surveys and monitoring of Malleefowl, fire protection works and limited predator control.

Fire

Across Australia, fire management plans have been developed for numerous reserves that are important for Malleefowl conservation. Unfortunately, few have addressed or focussed on Malleefowl requirements and there is generally a poor knowledge of which areas *within* large reserves are most important for Malleefowl conservation, and thus where efforts should be directed for the species' protection. Insofar that fire management plans aim to limit the extent of large fires and promote patchiness, Malleefowl are likely to benefit. However, fire management would be improved by a detailed knowledge of the whereabouts of important populations within reserves, enabling protection from both wild and planned fires. In central Australia, patch burning has specifically targeted the protection of Malleefowl breeding habitat in some parts of the Anangu-Pitjantjatjara Lands and fire history maps have been produced to guide this effort (B. Cooke pers. comm.; P. Yates pers. comm.).

Fencing

Remnants of native vegetation have been fenced as part of regional conservation programs by government agencies, Landcare and some other groups to protect local flora from stock grazing. This also assists Malleefowl conservation. For example, in WA the North Central Malleefowl Preservation Group and Malleefowl Preservation Group have both been active in fencing, and DEC WA (formerly CALM) has fenced off Peron Peninsula at Shark Bay onto which Malleefowl were translocated as part of "Project Eden". In south-western NSW, landuse agreements (see p.31) require landholders to fence parcels of remnant vegetation as conservation areas in exchange for permission to clear other parcels of land. At Scotia Sanctuary in NSW, about 8,000 ha of mallee has been fenced by a private organisation (Earth Sanctuaries and now Australian Wildlife Conservancy) to remove and exclude herbivores and predators.

Habitat revegetation and connectivity

Areas are being revegetated specifically for Malleefowl conservation by the Malleefowl Preservation Group in WA (Harold & Dennings 1998), and Friends of the Malleefowl and the Little Desert Lodge in Victoria (W. Reichelt pers. comm). In the former case, the revegetated habitat links one patch of habitat with another, and over 20 km of fencing and revegetation have been completed. Habitat corridors to support wildlife in general are being established in a few areas by government agencies, Landcare and other groups, and may also assist Malleefowl conservation. In SA, the NatureLinks Program is developing several projects for improving connectivity, some of which will be relevant to Malleefowl. Large scale habitat linkage programs based on the WildCountry philosophy (Recher 2003; Wilderness Society 2003) are also underway in SA, south-west WA

('Gondwana Link') and Victoria ('Hindmarsh Bio-link') and are likely to benefit Malleefowl in the long term. The need for corridors has not been established, but will become clear from the genetic studies underway. Accordingly widespread connectivity restoration for malleefowl alone should await the genetic results. Increasingly genetic studies are turning up surprises about how animals can move through cleared landscapes: sometimes those thought to be affected by fragmentation turn out to be genetically continuous throughout fragmented areas, and sometimes vice versa.

Goats

Goats have been reduced in some reserves where their numbers were especially high. At Yathong Nature Reserve (NSW) an integrated campaign of closing off watering points and commercial harvesting has reduced goat numbers enormously since 1994. Similar goat reduction campaigns have been conducted north of the Murray River in SA and in south-west NSW (J. Gates pers. comm.; R. Dayman pers. comm.). During the last five years in particular, water closures and culling at Gluepot Reserve and Riverland Biosphere Reserve (SA) have significantly reduced the capacity of these areas to harbour goats, although goat numbers are increasing in other areas important for Malleefowl conservation (Gates 2004). In the Victorian Murray-Sunset National Park, closure of catchment dams, fencing and culling reduced goat densities by over 70% between 2000 and 2004 (P. Sandell pers. comm.). Goats have been virtually eliminated from the Peron Peninsula in WA which is fenced to prevent reinvasion.

Predator control

Fox control programs have been implemented in all states where Malleefowl occur and use a variety of baiting techniques of varying intensity and frequency. 1080 poison (sodium fluoracetate) is used in baits.

In NSW, predation by foxes is listed as a key threatening process under Schedule 3 of the *Threatened Species Conservation Act 1995*. Regular fox-baiting is occurring at Yathong, Mallee Cliffs, Nombinnie, Round Hill and Tarawi nature reserves and at Scotia Sanctuary (D. Oliver pers. comm.; R. Dayman pers. comm.) About 8,000 ha of Scotia Sanctuary is also fenced to exclude predators. Assessment of the benefits of fox control is occurring through a monitoring program established through the NSW Fox Threat Abatement Plan (NSW National Parks and Wildlife Service 2001), and has shown improved survival of translocated Malleefowl (DEC NSW 2005).

In WA, Western Shield is continuing and involves broad scale aerial baiting of most conservation reserves in south-west WA (Bailey 1996), including many areas in which Malleefowl occur. Western Shield has been operating since 1996 and is believed to have greatly reduced fox abundance in these areas. Project Eden, which involves the control of both foxes and cats (as well as goats and sheep) from the Peron Peninsula (Thompson & Shepherd 1995) is also continuing. These aerial programs are run by the Department of Environment and Conservation WA, and that agency also conducts regular and intensive ground-based baiting at Dryandra State Forest where Malleefowl occur. Coordinated ground-based fox baiting programs are also conducted by community groups and are continuing over large areas in the northern wheatbelt of WA to protect Malleefowl in that area (Cail & Cail 2004), and at Mt Gibson Sanctuary (Australian Wildlife Conservancy) and Charles Darwin Reserve (Bush Heritage Australia), but have declined in the southern wheatbelt due to changes in government and agency support (Dennings 2004). In the pastoral zone, baiting of dingoes is thought to also reduce fox abundance over large areas, some of which harbour Malleefowl (Benshemesh & Malleefowl Preservation Group 2001; Sanders *et al.* 2003).

In South Australia, there are a number of fox control programs operating at various scales. A large scale and long term coordinated baiting program involving landholders and government agencies in the Mantung-Maggea area and in the vicinity of Bakara has been operating since 1990 and is continuing (Williams 1994; Pfeiffer 2002; Gates 2004). Large-scale coordinated baiting programs have recently also been initiated over much of Eyre Peninsula (Freeman *et al.* 2004). Fox control programs are also occurring on Calperum and Taylorville Stations which are managed by Community Land Management, and are part of the Riverland Biosphere Reserve; on the adjacent Gluepot Reserve; across Innes National Park on southern Yorke Peninsula; and at Mt Scott Conservation Park and along the Coorong National Park in the South-East.

In Victoria, a large-scale fox baiting program commenced in Hattah-Kulkyne NP in 2001 as part of a wider 'adaptive experimental management' program to assess the effectiveness of fox baiting and measure prey responses (Robley & Wright 2003). Malleefowl are not specifically included in the suite of prey considered likely to respond within the five year life of the experiment. However, any changes in Malleefowl nesting activity within existing monitoring sites in the area will be assessed in light of changes in fox activity (P. Sandell, pers. comm.). Fox baiting of parts of Wychitella Fauna Reserve has recently been initiated by local community groups specifically to protect Malleefowl (P. Morison pers. comm.). Elsewhere within the range of Malleefowl in Victoria fox baiting is occurring at low intensity or in small areas and is of questionable effectiveness (P. Sandell, pers. comm.). Aerial baiting is not permitted in Victoria.

In addition to fox reduction programs instigated to protect Malleefowl and other fauna, numerous Landcare groups and individuals bait for foxes in agricultural areas across the Malleefowl's range, and these programs may provide incidental benefit to Malleefowl.

In general, while fox control operations are extensive in areas supporting Malleefowl, there is little coordination or documentation of these programs across Australia, their effectiveness at reducing fox densities is often questionable and rarely adequately monitored, and their benefit to wildlife is often not measured at all (e.g. see Reddiex *et al.* 2004). Monitoring, evaluation and documentation of the effectiveness of fox control efforts should be regarded as a critical component of Malleefowl recovery.

Predator control techniques

The effectiveness of using 1080 poison baiting methods to reduce fox populations has been demonstrated in a range of habitat types by DEC WA in Western Australia (D. Algar pers. comm.). DEC WA is also developing methods of controlling feral cats across large areas by baiting and it is anticipated that these will soon be available (D. Algar pers. comm.). The development of viral-vectored fertility control of animals such as foxes and rabbits (Creagh 1992; Tyndale-Biscoe 1994) is not likely to be available in the foreseeable future.

Effects of predation

Two approaches are being employed to assess the effects of predation by the fox on Malleefowl. Firstly, the response of Malleefowl breeding density to a reduction in fox abundance is being examined in conjunction with some Malleefowl monitoring programs. Monitoring of Malleefowl densities at sites in which fox numbers are not reduced is also undertaken in South Australia and Victoria.

Secondly, in New South Wales, Malleefowl chicks were reared in captivity and released into areas where fox abundance was reduced by baiting. This work demonstrated that foxes account for a large proportion of captive-reared Malleefowl mortalities, that baiting increases survivorship of chicks, and that the most successful time to release captive-reared birds is in spring when they are sub-adults (Priddel & Wheeler 1994, 1996; 1997, D. Priddel pers. comm.). In SA, captive reared Malleefowl were released into habitat remnants and suffered similarly high predation from foxes regardless of whether the understorey was disturbed or intact (Priddel *et al*. 2007). The authors concluded that Malleefowl populations across Australia are threatened by foxes, placing the species at risk of extinction.

As part of the NHT-funded "National Malleefowl Monitoring, Population Assessment and Conservation Action Project", data on Malleefowl monitoring and fox control efforts from various states were recently collated, to assess the relationship between fox control and Malleefowl breeding success (Benshemesh *et al.* 2007). This study used data from several sites in NSW, SA, Vic and WA to examine the degree to which fox abundance and fox control influence Malleefowl numbers at the population level. The study found that while fox baiting did appear to result in a decline in fox numbers, there was no evidence of a benefit to Malleefowl breeding numbers or amelioration of Malleefowl declines. While this study involved nearly 600 site-years of data, it was nonetheless subject to some limitations. The authors conclude that there should be more rigorous evaluation of the need for fox control in conserving Malleefowl populations. Further investigations involving well-designed and coordinated management experiments are required to provide a reliable assessment of the efficacy of fox control for Malleefowl populations in different regions, and under different baiting intensities.

Recording Malleefowl distribution

Every state in which Malleefowl occur has some type of wildlife atlas for the recording of wildlife observations. For the most part these atlases store incidental observations and in this regard differ from the more systematic Birds Australia atlas project in which observers visit sites specifically to map the distribution of birds (Blakers *et al.* 1984; Barrett *et al.* 2003). Nonetheless, the state wildlife atlases provide an important view of the past and present distribution of Malleefowl. Representation is, however, patchy especially in remote areas where observations are infrequent.

An extensive postal survey of landholders has been conducted in south-east South Australia (Cutten 1997), and more recently on the Eyre and Yorke Peninsulas (S Pillman, pers. comm.). The purpose of the surveys was to locate areas in which Malleefowl persist in remnants of native vegetation and to describe the current distribution of the species. Both postal surveys successfully identified numerous areas where Malleefowl had not previously been recorded, particularly on small remnants outside the reserve system. This information is invaluable for conserving Malleefowl in agricultural landscapes and provides planners with clues as to where habitat linkages would be most effective.

In WA, the Malleefowl Preservation Group encourages rural community members to report Malleefowl sightings (Harold & Dennings 1998) through the distribution of sighting forms, talks and displays to raise public awareness. Although this project has only been running for about a decade, the resulting data have already greatly increased knowledge of the species' current distribution in the wheat belt of WA. Funding was obtained from the Natural Heritage Trust for CSIRO to examine the spatial and temporal trends in these data, and Blair Parsons has recently completed a PhD thesis which analysed these sightings data for the WA Wheatbelt (Parsons 2008, Parsons *et al*. 2008). The Malleefowl Preservation Group is continuing to collect these data.

Outside of the agricultural area in WA, there have been few recent records of Malleefowl and little is known of its current distribution. This includes a huge arc of uncleared land north and west of the agricultural area and the arid regions of the state in which Malleefowl previously occurred. The Malleefowl Preservation Group, with support from Nickel West (formerly WMC Resources) and dedicated volunteers, has actively sought sightings in the arid pastoral zone and, at Yeelirrie Station, has conducted surveys over hundreds of square kilometres (Benshemesh & Malleefowl Preservation Group 2001; Sanders *et al.* 2003). These surveys rely on detection of the distinctive footprints of Malleefowl rather than sightings of birds or mounds, and have been highly successful at identifying key sites of Malleefowl activity in this vast landscape.

In central Australia, surveys have been initiated by SA Department for Environment and Heritage (DEH) and Anangu Pitjantjatjara Yankunytjatjara Land Management (APLYM) to ascertain the distribution and abundance of Malleefowl in the Great Victoria Desert in the north-west corner of SA (Benshemesh 1995a, 1996a, 1997a; Hill 2002; Copley *et al*. 2003). These surveys have focussed on the Walalkara and Watarru Indigenous Protected Areas (IPA) and relied on both Aboriginal knowledge of their land and searches for the birds' footprints, and have been successful both in locating Malleefowl and in raising community awareness. Within the last five years, the interest in Malleefowl at Watarru IPA in particular has flourished with the involvement of the local school and the recent 'Kuka Kanyini' initiative, an Anangu Pitjantjatjara regional wildlife management program (L. Liddle pers. com.), in addition to the ongoing work of APYLM. Over twenty sites have now been identified in the Anangu-Pitjantjatjara Lands (APL) where there has been some Malleefowl activity over the previous few years. This result is remarkable given that most authorities considered Malleefowl to be extinct in central Australia until the early 1990s. Apart from greatly increasing our knowledge of Malleefowl in central Australia, a protective attitude to the species has ensued that has probably eliminated human hunting and egg-raiding pressures on the species.

Monitoring population trends

Programs to monitor the breeding density of Malleefowl have been established in the four states in which the species occurs, although methods vary (Table 1).

Ground based monitoring of breeding densities

Ground based monitoring techniques are used in NSW, SA, Vic and WA and provide the principal form of monitoring Malleefowl trends on a national scale. Sites are blocks of habitat, typically 2-4 km^2 in size, which is a size that is both manageable and adequate to provide an estimate of breeding density. Teams of people are used to thoroughly search each site and the locations of all Malleefowl mounds are recorded. Thereafter, mounds are ideally re-visited every year and inspected in regard to signs of Malleefowl activity, and the sites are re-searched intermittently to detect new mounds. The monitoring program is wholly or largely conducted by volunteers in each state with the support of state wildlife authorities and/or land management agencies. Sites are usually located in nature reserves or private property. While the focus of the monitoring is to determine the breeding density at each site each year, other data are also collected including the abundance of Malleefowl, fox and other animals' prints and scats, and descriptions of the condition of each mound which are used to check data. Dropped Malleefowl feathers are also routinely collected during monitoring and are stored for subsequent genetic analysis (Piggott and Taylor 2003; NHT National Malleefowl Monitoring Project 2007), and in Victoria, predator scats are collected off mounds for content analysis (P. Sandell pers. comm.).

Currently, more than 2100 nests at 94 sites are monitored by ground based techniques nationally (Table 1). In Victoria, a database is used by the Victorian Malleefowl Recovery Group (VMRG) to store data and generate automatic annual reports, and this has in the past been made available to groups in both SA and WA. The VMRG is in the process of redesigning the database and is also revising the monitoring manual (NHT National Malleefowl Monitoring Project 2007) which serves as a national standard for monitoring Malleefowl.

Table 1. Summary of Malleefowl monitoring sites across Australia. Number of sites and nests refers to the number at the time of writing (2005). Years of data refers to the maximum (oldest) site monitored although the majority of sites in some areas have been only recently installed.

State	Type	No. Sites	No. Nests	Years of Data (max)	Frequency	Responsibility
NSW	Aerial	5	na	c. 15	Annual	DEC
	Ground	4	27+	c. 10	Some annual	DEC
SA	Std. Ground	14	403	15	Some annual	DEH Murraylands
	Std. Ground	5	229	9	Some annual	DEH West
	Std. Ground	2	69	8	Some annual	DEH South East
	Std. Ground	1	26	5	Some annual	DEH Yorke
	Std. Ground	10	84	6	Some annual	CLM Calperum
	Std. Ground	7	92	5	Some annual	BA Gluepot
	Tracking	2*	na	10	Casual	APYLM/DEH
Vic	Std. Ground	29	962	17	Annual	VMRG/PV
WA	Std. Ground	12	149+	13	Some annual	MPG
	Std. Ground	5	96	9	Annual	NCMPG
	Std. Ground	2	7	2	Annual	FONEM
	Std. Ground	2	21	1	Annual	Bush Heritage
	Std. Ground	2	9	2	Casual	AWC
	Ground	1		c.10	Casual	BA Eyre Bird Obs
	Tracking	1	na	5	2-3 yrs	MPG/WMC
	Other	1	na	>10		DEC Dryandra
total	Aerial	5				
	Ground	94	2174+			
	Tracking	3				
	Other	1				

*: multiple sites in 2 Indigenous Protected Areas

na: not applicable (methods do not rely on revisiting nests)

There have been major developments in on-ground monitoring of breeding densities in the past five years. Firstly, the improved accuracy of standard GPSs since May 2000 has simplified navigation to mounds and made marking monitoring sites with grids unnecessary. Secondly, new monitoring sites have been installed, as recommended in the previous Recovery Plan, and there are now about one hundred sites across Australia at which breeding densities are monitored by volunteers. Green Corps were used to install a number of new monitoring sites for community groups in the wheatbelt of WA, and on Eyre Peninsula in SA, although subsequent monitoring has not been consistent

(S. Dennings pers. comm.; P. Peeters pers. comm.). Thirdly, electronic recording of data on Palm handheld computers connected to GPS units using Cybertracker software (Liebenberg 2003) has simplified field work, greatly reduced the need to transcribe data, and improved both accuracy and efficiency in Victoria (Benshemesh 2004; Patford *et al.* 2004). Community groups in SA and WA have recently adopted the technology and may similarly benefit from this improvement. Also, digital cameras, which are now inexpensive, are used to record an image of each mound cheaply and in a database-friendly form. Fourthly, there has been a resurgence of interest in standardising techniques and sharing data across Australia. Since the national forum on Malleefowl conservation held in Mildura in 2004 (Victorian Malleefowl Recovery Group 2004) monitoring processes in SA, Vic and WA have been standardised and there is a general eagerness to pool data for analysis and planning. This is an important development because the pooled set of monitoring data provides a much firmer basis for analysis than several individual sets separated by political boundaries. The monitoring sites represent a diversity of ecological contexts and management practices (predator control, fire history, landscape context etc.) from which the relative contribution of each of the threatening processes can be identified, and effective practices tested. Finally, several aspects of the monitoring effort have recently been addressed: the data previously collected has been collated from across Australia (Benshemesh 2006b, Benshemesh 2006a) and statistically analysed in regard to predator baiting, rainfall and isolation (Benshemesh et al. 2007); the effectiveness and efficiencies of the system have been reviewed (Benshemesh 2007); and many sites have been re-visited to search for new mounds.

While there is currently considerable vitality in monitoring by volunteers, the system needs further development for its full potential to be realised. In particular, a national database needs to be developed; gaps in the representativeness of monitoring sites need to be identified and filled from a national perspective; and plans need to be developed for adaptive management of Malleefowl at monitoring sites.

Aerial monitoring of breeding densities

Aerial monitoring is currently funded under the NSW Fox Threat Abatement Plan (FoxTAP) and involves flying 100 random transects across each of five 100 km^2 grids at Mallee Cliffs (and adjacent leasehold), Nombinnie/Round Hill, Tarawi and Yathong conservation reserves using a helicopter to detect mounds
(D. Oliver pers. comm.; R. Dayman pers. comm.; J. Gorman pers. com.). Where time and funding is available, aerial surveys of previously marked mounds are conducted to determine if they are used for breeding. In the Lower Darling Area alone a total of 442 nests (active and inactive) are currently monitored most years (Mallee Cliffs NP, Tarawi NR, Wild Dog conservation area and Sunnyside Station). These mounds are marked to facilitate recognition from the air (Brickhill 1985, D. Priddel and R. Wheeler pers. comm.).

Tracking

In arid regions where detection of Malleefowl signs is difficult due to very low densities, tracking is used to monitor the continued presence of the species in selected areas. This technique relies on detection of the distinctive footprints of Malleefowl rather than sightings of birds or mounds, although known mounds are also visited. At Yeelirrie Station in central WA, the Malleefowl Preservation Group (MPG) organises systematic tracking every two to three years, whereas monitoring in the Anangu-Pitjantjatjara Lands is conducted in a less structured manner.

Other monitoring

At Dryandra State Forest in WA, Malleefowl sightings have been routinely recorded on standard transects used to monitor other species.

Assessment of longevity and population turnover

At Yalgogrin, a small and isolated remnant of mallee vegetation in New South Wales, an entire population of Malleefowl has been banded and DEC NSW staff monitored the rate of population turnover between 1986 and 1999 by identifying birds at mounds (Priddel & Wheeler 2003). Yalgogrin is managed commercially for eucalyptus oil production, which involves major disturbance to the habitats. It was also occasionally grazed by sheep and was not subject to fox control. This research has provided crucial data on the longevity of breeding birds and measures of recruitment into the breeding population as the population declined over a ten-year period, particularly during droughts.

Determining habitat requirements

Clarke (2005) examined the broad habitat requirements of Malleefowl and other threatened mallee birds of the Murray Mallee using GIS models and recent sightings of the species. In particular, this study examined the fire age class preferences of these species and reaffirmed that Malleefowl prefer older age classes (as did most other threatened mallee birds). Clarke also used the models to map the current suitability for Malleefowl of habitats within several large blocks of mallee, including the Big Desert/Wyperfeld reserve complex, Murray-Sunset reserve complex, Riverland Biosphere Reserve, Ngarkat Conservation Park, and lower Murray-Darling Basin.

Currently, Jessica van der Waag is engaged in a PhD study at the University of Western Australia examining the survivorship of Malleefowl chicks in relation to food availability and habitat in a variable environment (J. van der Waag pers. com.). Jessica previously completed an Honours project on Malleefowl ecology, and examined the feeding habits of chicks shortly after they emerge from mounds (van der Waag 2003).

Blair Parsons, also a PhD student at the University of Western Australia, has recently completed his studies on the habitat requirements of Malleefowl as part of the CSIRO/WWF project that utilised data collected by the Malleefowl Preservation Group (Parsons 2008). Blair explored:

- the effectiveness of bioclimatic modelling for determining the range, and defining climatic variation within the range, of Malleefowl;
- methods for quantifying changes in the range of Malleefowl and determining drivers of change;
- methods for using presence-only and presence-absence location data and remotely-sensed environmental data to model the distribution of Malleefowl, both at regional and local scales;
- the occurrence of Malleefowl at the scale of individual remnants, a scale that cannot be adequately addressed using remotely-sensed data; and
- the influence of fire on Malleefowl in south-west Western Australia, using an approach that combined the use of remote sensing analysis and field-based survey.

Captive-breeding

A captive-breeding program for Malleefowl has been established at Western Plains Zoo at the instigation of New South Wales National Parks and Wildlife. Facilities have been built to house 16 breeding pairs. The 450 or so chicks produced between 1990 and 2002 were released on Yathong Nature Reserve and since 2003, 48 chicks have been released at Nombinnie.

Malleefowl breed successfully at the Adelaide Zoo and have produced numerous chicks in the past. These chicks are a by-product of the Malleefowl exhibit and are not bred for a specific purpose. However, they are available for conservation purposes (M. Craig pers. comm.). Local provenance Malleefowl from Ferries-MacDonald Conservation Park are also held and bred at Monarto Zoological Park.

Malleefowl have also bred in an enclosure at the Little Desert Lodge, Victoria, since 1995, although few young have been produced (W. Reichelt pers. comm.).

Re-introductions and supplementation

Releasing captive-reared Malleefowl into the wild has been attempted both where local extinctions have occurred (termed 're-introduction'), and where existing population levels are lower than expected and may require additional birds to make them viable (termed 'supplementation'). Introduction (i.e. releasing a species where it was not previously known) has also been attempted with Malleefowl at various times in eastern Australia, but has invariably been unsuccessful (Cooper 1975; Copley & Williams 1995; Copley 1995).

At Yathong Nature Reserve and Yalgogrin in NSW, captive-reared Malleefowl were experimentally released into areas as part of studies to determine the survival of Malleefowl in the wild (Priddel & Wheeler 1994, 1996, 1997). Fox predation of the captive-reared birds was the major cause of death, and few birds survived more than a month or so. An extensive fox control program was initiated at Yathong in the early 1990s to lessen predation, and goat and rabbit numbers have also been greatly reduced (G. Devine, pers. comm.). Supplementation of existing populations subsequently occurred at Yathong with much greater success; about 80% of released birds survived the first six months (D. Priddel pers. comm.). In total, about 450 captive reared Malleefowl were released at Yathong between 1990 and 2002. Since 2003, 48 chicks have been released at Nombinnie NR, which adjoins Yathong NR to the south, with preliminary radiotracking studies revealing high survival rates (Roberts 2006). This program may be extended to other reserves where Malleefowl have declined when the breeding population at Yathong shows clear signs of recovery, although this has not yet occurred (D. Oliver pers. comm.).

At Yookamurra Sanctuary in SA, a Malleefowl re-introduction has been attempted in a relatively small (1100 ha) area in which foxes and cats were eradicated and excluded by predator-proof fencing. Malleefowl were known to have occurred at the site at low densities in the past, but were locally extinct. Captive-reared birds were released at the site in 1993, but all either flew over the fence to unprotected areas or were taken by birds of prey (Copley & Williams 1995). Some of the birds that escaped from their release sites survived in surrounding areas for at least a year (S. Williams pers. comm.).

On the Peron Peninsula in WA, captive-reared Malleefowl have been re-introduced as part of Project Eden. Captive reared chicks were hatched from eggs that were sourced from Malleefowl mounds within 200km of the Peron Peninsula, and precise provenance information has been recorded (C. Sims pers. comm.). This initiative aimed to rehabilitate an area that was previously heavily grazed by sheep and to reintroduce native mammals and Malleefowl that had become locally extinct. Sheep and goats were removed from the peninsula several years before the re-introductions, and the virtual eradication of foxes and reduction in cat numbers has been achieved by continuing control measures (C. Sims pers. comm., D. Algar pers. comm.). The Peron Peninsula was chosen for the project because of the relative ease with which introduced predators and herbivores could be excluded by fencing across its narrow isthmus. Survivorship of Malleefowl has been high, and several breeding attempts have been recorded (C. Sims pers. comm.).

Further insights into re-introduction techniques are likely from Jessica van der Waag's PhD study (as discussed under 'Habitat requirements').

Rapid survey techniques

A technique for broad-scale survey of Malleefowl breeding densities using air-borne infra-red scanners has been developed in Victoria (Benshemesh 1994, Benshemesh and Emison 1996). A series of test scans were conducted in 1992, but access to necessary equipment was not available to thoroughly analyse these while funds lasted. Nonetheless, some of these data have been transferred to exabyte cartridges (a less restrictive medium) and distributed to the RMIT UniversityDepartment of Land and Information. While there have been some attempts to further develop this technique (L. Bruggerman pers. comm.; Thompson and Thompson 2008), its usefulness for survey and monitoring has yet to be demonstrated.

Education

Malleefowl are held in captivity at the Adelaide Zoological Gardens, at the Western Plains Zoo, and at the Little Desert Lodge in Victoria. Some information on the biology and conservation of the species is displayed at each of these places, and the birds themselves are exhibited. Western Plains Zoo, in conjunction with the NSW Department of Education, has produced an information package focused on Malleefowl and the broader issue of mallee conservation. At Little Desert Lodge, an education kit has also been produced and visiting school groups are encouraged to learn about Malleefowl in the field and conduct conservation projects. Several thousand students have been through the program in the past decade (W Reichelt pers. comm.).

In both SA and WA, Malleefowl is used as a flagship species for education and to raise awareness of conservation in rural communities (Williams 1994). This approach has been very successful, owing both to the widespread appeal of the species in rural communities, and the dedication of a small number of people.

In WA, the Malleefowl Preservation Group (MPG) has been especially active in talking to rural community groups, schools and at conferences, and displays are shown at every opportunity at local shows and fairs (Harold & Dennings 1998). The MPG has also developed a "Malleefowl Magic" schools kit aimed at junior, middle and upper primary school classes and Susanne Dennings of the MPG has presented this program to over 50 schools within the current or former range of the Malleefowl. As a curriculum and outcome based program, the education package includes story books (Reilley 1990), a teacher's work book, activity sheets and teacher's feed back form, and a CD with an "Old Man Malleefowl" song and Malleefowl calls. Similarly, the North Central Malleefowl Preservation Group (Dalwallinu Shire WA) has been active in involving schools.

In Victoria, members of the Malleefowl Preservation Society talk to school groups (A. Vann pers. comm.), and Malleefowl are also a feature of some National Park interpretation activities. Parks Victoria has prepared an educational video on Malleefowl conservation titled “Icon of the Mallee”. This has been distributed to schools across the Victorian Mallee and also distributed in WA (P. Sandell pers. comm.). More recently, the Victorian Malleefowl Recovery Group has produced an education kit for primary schools (Byrne 2007) that is linked to curriculum standards and is currently being trialed in 20 schools in SA and Vic. The intention is to produce a product that will be suitable for use in all primary schools, particularly in the Victorian Mallee and Wimmera, and in South Australia.

Community Groups

Numerous community groups have become involved in Malleefowl conservation. The major groups are listed in Appendix IV, and their contributions are discussed under various headings in this section.

The Victorian Malleefowl Recovery Group, a community group formed with the primary goal of monitoring Malleefowl, hosted a successful national forum in February 2004 in Mildura. Similarly, the Western Australia Malleefowl Network which comprises a number of community groups active in Malleefowl conservation, hosted another national forum in 2007 in Katanning (WA). The proceedings of these forums provide a detailed overview of current issues, activities and community involvement in the recovery process and are available for download on the internet (http://www.malleefowlvictoria.org.au/seminar.html).

Three regular newsletters specifically regarding Malleefowl conservation are produced to inform people of issues and activities:

- “Around the Mounds” is a national newsletter produced by the Threatened Species Network (Adelaide) and provides a summary of both the progress in Malleefowl conservation in each State, and activities that volunteers may join;
- “Malleefowl Matter” is produced by the Malleefowl Preservation Group (WA) three times a year and has a primary focus on the southern wheatbelt of WA. (http://www.malleefowl.com.au/Newsletters.htm); and
- VMRG Newsletter is produced twice a year and is available for download at their website (http://www.malleefowlvictoria.org.au/members.html).

Birds Australia also produces “Volunteer”, a national newsletter for the Threatened Bird Network, which publicises Malleefowl activities that require volunteers.

Previous National Recovery Plans for Malleefowl

A Research Phase Recovery Plan was produced in 1992 (Benshemesh 1992b), and a National Recovery Plan in 2000. Funding was not provided for the implementation of either of these plans, although some NHT funds were recently provided to tackle parts of the 2000 National Recovery Plan that dealt with the collation and analysis of monitoring data collected by community volunteers and state agencies (Benshemesh et al. 2008). Nontheless, considerable progress has been made since 2000 in the following areas:

- developing a representative and effective community based monitoring system;
- standardising monitoring processes and collaborating across regional and state boundaries, (NHT National Malleefowl Monitoring Project 2007, Benshemesh *et al*. 2008);
- reviewing monitoring procedure and analyzing past monitoring data (Gates 2004, Gillam 2005, Benshemesh 2007, Benshemesh *et al*. 2007);
- detailing the distribution of Malleefowl in remote areas of Central Australia such as in the Anangu-Pitjantjatjara Lands (SA) and at Yeelirrie in central WA, and on Eyre Peninsula (Bellchambers 2007, Benshemesh *et al*. 2007, Ward and Clarke 2007);
- re-introducing Malleefowl on Peron Peninsula following intensive predator and exotic herbivore control;
- understanding the species' population dynamics in an isolated and declining population (Priddel & Wheeler 2003);
- hosting national forums in Mildura in 2004 and Katanning in 2007 to discuss the conservation and recovery of Malleefowl. The forums attracted about 170 participants from across the nation. Proceedings of each of these forums are available on the internet (http://www.malleefowlvictoria.org.au/seminar.html);
- re-forming of the national recovery team (at the 2004 forum);
- providing general information and advice about Malleefowl management and for Natural Resource Management authorities across Australia (Benshemesh 2008);
- producing a regional plan for the conservation of Malleefowl in the WA Wheatbelt (Short and Parsons 2008);
- collection of feather and other samples for genetic analysis; and
- ARC linkage funding was provided to the University of Melbourne for work on the conservation genetics of Malleefowl and a PhD student started work on this project in late 2008.

Despite this progress, Malleefowl populations continue to decline in many areas. Statistical analysis of past monitoring data suggests that at least part of this decline is linked to the prolonged dry winter conditions that have affected southern Australia over the past decade (Benshemesh et al. 2007). This analysis also suggested that conventional management techniques such as fox control were not effective at benefiting Malleefowl populations. Reducing the uncertainty surrounding the effectiveness of management actions is a major part of the current plan through the development of a rigorous adaptive management process based on the extensive network of community monitoring sites.

Part D Objectives, criteria and actions

Recovery objectives and criteria

Overall objective

De-list Malleefowl as a threatened species under the EPBC Act.

Recovery Criteria

To support achievement of the overall objective, criteria for success are:

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

Specific objectives

<u>MANAGING POPULATIONS</u>

1: Reduce permanent habitat loss

2: Reduce the threat of grazing pressure on Malleefowl populations

3: Reduce fire threats

4: Reduce predation

5: Reduce isolation of fragmented populations

6: Promote Malleefowl-friendly agricultural practices

7: Reduce mortality on roads

<u>PLANNING, RESEARCH, AND MONITORING</u>

8: Provide information for regional planning

9: Monitor Malleefowl and develop an adaptive management framework

10: Determine the current distribution of Malleefowl

11: Examine population dynamics: longevity, recruitment and parentage

12: Describe habitat requirements that determine Malleefowl abundance

13: Define appropriate genetic units for management of Malleefowl

14: Assess captive breeding and re-introduction of Malleefowl

15: Investigate infertility and agrochemicals

<u>COMMUNITY INVOLVEMENT AND PROJECT COORDINATION:</u>

16: Facilitate communication between groups

17: Raise public awareness through education and publicity

18: Manage the recovery process

Performance criteria

The following performance criteria relate to the objectives above:

1.1 The total area of Malleefowl habitat protected in reserves, conservation covenants and similar management agreements, increases over the life of the plan.

1.2 No decline in the known area of occupied or mapped potential Malleefowl habitat over the life of the plan.

2.1 Goats and sheep are removed from conservation reserves, or at least kept at low numbers.

2.2 Artificial sources of water in conservation reserves are closed or fenced.

2.3 The area of known Malleefowl habitat protected from stock grazing (e.g. through fencing) increases over the life of the plan.

2.4 Rabbit numbers are reduced where they are abundant in or near Malleefowl habitat.

3.1 Fire management plans which consider the habitat requirements of Malleefowl are developed and implemented for all reserves in which Malleefowl occur.

3.2 Broad-scale agricultural burning is avoided in areas that harbour Malleefowl.

3.3 Fires in Malleefowl habitat are mapped and their effects monitored to inform future planning.

4.1 Fox control efforts are adequately documented near monitoring sites.

4.2 Fox numbers are reduced where Malleefowl densities have declined and fox predation is a likely explanation for such declines.

5.1 Habitat links between remnants are increased in priority areas as identified in regional Malleefowl conservation plans.

6.1 Increased adoption of asynchronous fallowing by crop farmers in areas adjacent to Malleefowl habitat.

7.1 Occurrence of road kills is recorded each year, patterns analysed and frequency reduced.

7.2 Signs are erected where needed to warn drivers that Malleefowl may be on the road ahead.

8.1 Regional conservation plans for Malleefowl are prepared.

9.1 Monitoring data are analysed and reviewed and a national adaptive management design is developed through collaboration by 2008.

9.2 Monitoring continues at existing sites across Australia according to national standards, with:

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

9.3 Effectiveness of fox baiting at increasing Malleefowl breeding density is adequately tested, with a consistent and substantial reduction in fox abundance achieved at the baited grids.

9.4 The Malleefowl monitoring effort is facilitated, standardised and coordinated at a national level.

10.1 The distribution and status of Malleefowl in remote areas is clarified and local involvement is encouraged.

10.2 The distribution and status of Malleefowl in settled rural areas is clarified.

11.1 The feasibility of automatic recorders for identifying Malleefowl is examined and efficient capture techniques are developed, with a report available by 30 June 2009.

11.2 The longevity of breeding Malleefowl and the turnover of the breeding population is measured for areas with and without fox control.

11.3 Recruitment of young into breeding populations is measured for areas with and without fox control.

12.1 The habitat requirements and preferences of Malleefowl are described, important habitat components are identified, and a habitat suitability model is produced.

13.1 Genetic structure of Malleefowl populations is determined at a national level, as well as at a local scale to establish current population connectivity.

14.1 Past and current translocation, captive-rearing and breeding programs are reviewed, studbook and husbandry manual produced, and the future directions are clarified.

15.1 The extent of infertility of Malleefowl in small reserves is investigated.

16.1 A national Malleefowl community forum is held every three years and the national newsletter continues to provide a national perspective.

17.1 Increased public awareness of the Malleefowl recovery effort, beneficial management practices, and the contributions made by community groups.

18.1 Recovery process is coordinated and managed effectively by the recovery team, which:

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

The relationship between objectives, performance criteria and actions is shown in Table 2.

Table 2. Summary of relationship between objectives, performance criteria and actions. (Note that some actions are relevant to more than one objective)

Specific objectives		Performance criteria		Actions
1. Reduce habitat loss	→	P1.1 The total area of Malleefowl habitat protected in reserves, conservation covenants and similar management agreements, increases over the life of the plan	→	A1.1 Retain areas that support Malleefowl and protect them from incremental clearing, and report annually on clearing
			→	A1.2 Encourage landholders to enter into conservation covenants and similar agreements
		P1.2 No decline in the known area of occupied or mapped potential Malleefowl habitat over the life of the plan	→	A1.3 Support initiatives that reduce further salinisation
2. Reduce grazing pressure	→	P2.1 Goat and sheep are removed or in low numbers in conservation reserves	→	A2.1 Remove goats and sheep from reserves
	→	P2.2 Artificial sources of water in conservation reserves are closed or fenced	→	A2.2 Close or fence artificial sources of water in conservation reserves
	→	P2.3 The area of known Malleefowl habitat protected from stock grazing (e.g. through fencing) increases over the life of the plan	→	A2.3 Erect adequate fencing to protect Malleefowl habitat
			→	A2.5 Inform graziers of the damaging effects of grazing on Malleefowl habitat
	→	P2.4 Rabbit numbers are reduced where they are abundant in or near Malleefowl habitat	→	A2.4 Reduce rabbit numbers where they are abundant in or near Malleefowl habitat

Specific objectives		Performance criteria		Actions
3. Reduce fire threats	→	P3.1 Fire management plans which consider the habitat requirements of Malleefowl are developed and implemented for all reserves in which Malleefowl occur	→	A3.1 Reduce the occurrence of large fires, and promote patchiness of fires, where Malleefowl conservation is a priority in large reserves
			→	A3.2 Provide for access to and protection of small habitat remnants to prevent fire spreading to or from surrounding land
			→	A3.3 Encourage traditional patch-burning practices by Aboriginal people in Central Australia
		P3.2 Broad-scale agricultural burning is reduced in areas that harbour Malleefowl	→	A3.4 Discourage broad-scale burning for agricultural purposes in areas that harbour Malleefowl
		P3.3 Fires in Malleefowl habitat are mapped and their effects monitored to inform future planning	→	A3.5 Map fires in Malleefowl habitat and monitor the effects of fire at Malleefowl monitoring sites
4. Reduce predation	→	P4.1 Fox control efforts are adequately documented near monitoring sites	→	A4.1 Record and centralise details of fox control in or near areas where there are estimates of Malleefowl abundance
	→	P4.2 Fox numbers are reduced where Malleefowl show decline and fox predation is a likely explanation for this decline	→	A4.2 Reduce fox numbers in small and isolated habitat remnants where Malleefowl densities have declined and fox predation is a likely explanation for such declines
			→	A4.3 Reduce fox numbers in large areas of native habitat where Malleefowl densities have declined and fox predation is a likely explanation for such declines
5. Reduce isolation	→	P5.1 Habitat links between remnants are increased in priority areas as identified in regional Malleefowl conservation plans	→	A5.1 Maintain and/or revegetate strategic corridors to link patches

Specific objectives		Performance criteria		Actions
6. Malleefowl-friendly farming	→	P6.1 Increased adoption of asynchronous fallowing by farmers in areas adjacent to Malleefowl habitat	→ →	A6.1 Encourage farmers with cropland surrounding small remnants of Malleefowl habitat to cooperatively ensure that some grain is grown every year A2.5 Inform graziers of the damaging effects of grazing on Malleefowl habitat
7. Reduce mortality on roads	→ →	P7.1 Occurrence of road kills is recorded each year, patterns analysed and frequency reduced P7.2 Signs are erected where needed to warn drivers that Malleefowl may be on the road	→ →	A7.1 Minimise the amount of grain spilt during transport through areas that harbour Malleefowl A7.2 Erect signs to warn drivers where Malleefowl may be on the road ahead
8. Provide information for regional planning	→	P8.1 Regional conservation plans for Malleefowl are prepared	→	A8.1 Prepare regional conservation plans for Malleefowl
9. Monitor Malleefowl and manage adaptively	→ →	P9.1 Monitoring data is analysed and reviewed and national adaptive management design is developed through collaboration by 2008 P9.2 Monitoring continues at existing sites across Australia according to national standards, with: • monitoring completed in each state by 1 Feburary each year (data for each monitoring site recorded as described in manual, entered in database, and provided to Birds Australia in electronic format) • monitoring data analysed by state and nationally by 31 May each year • summary report distributed to participants by 30 June each year	→ →	A9.1 Analyse and review monitoring data. Recommend improvements and develop site-specific management plans consistent with a national adaptive management design A9.2 Monitor and manage existing monitoring sites across Australia

Specific objectives	Performance criteria	Actions
	→ 9.3 Effectiveness of fox baiting at increasing Malleefowl breeding density is adequately tested	→ A9.3 Undertake effective fox control at two monitoring sites in each state over a period of five years and evaluate the benefits of this on Malleefowl breeding numbers using appropriate experimental design
	→ P9.4 The Malleefowl monitoring effort is facilitated, standardised and coordinated at a national level	→ A9.4 Facilitate and standardise monitoring and co-ordinate national monitoring effort
10 Determine the current distribution of Malleefowl	→ P10.1 The distribution and status of Malleefowl in remote areas is clarified and local involvement is encouraged	→ A10.1 Detail the distribution of Malleefowl in remote areas of SA and WA by field surveys, and describe the habitats in which Malleefowl are found
	→ P10.2 The distribution and status of Malleefowl in settled rural areas is clarified	→ A10.2 Detail the distribution of Malleefowl in settled rural areas by site inspections and postal surveys, and ascertain the degree of decline and fragmentation of remaining Malleefowl populations
11. Examine population dynamics	→ P11.1 The feasibility of automatic recorders for identifying Malleefowl is examined and efficient capture techniques are developed, with a report available by 30 June 2008.	→ A11.1 Examine the feasibility of automatic recorders for identifying Malleefowl and develop capture techniques
	→ P11.2 The longevity of breeding Malleefowl and the turnover of the breeding population is measured for areas with and without fox control	→ A11.2 Measure the longevity of breeding Malleefowl and the turnover of the breeding population, both in areas where fox numbers are reduced and where they are not reduced
	→ P11.3 Recruitment of young into breeding populations is measured for areas with and without fox control	→ A11.3 Measure recruitment of young into breeding populations by marking and releasing chicks, and subsequently monitoring breeding adults

Specific objectives	Performance criteria	Actions
12 Describe habitat requirements	→ P12.1 The habitat requirements and preferences of Malleefowl are described, important habitat components are identified, and a habitat suitability model is produced	→ A12.1 Describe the habitat requirements and preferences of Malleefowl, with a view to identifying important habitat components that may underlie variations in breeding densities
13 Define appropriate genetic units for management and landscape genetics	→ P13.1 Genetic structure of Malleefowl populations is determined at a national level	→ A13.1 Perform mitochondrial and nuclear DNA analyses of Malleefowl across the species' range, and determine where major disjunctions in genetic variation occur
14 Assess captive breeding and re-introduction	→ P14.1 Past and current translocation, captive-rearing and breeding programs are reviewed, studbook and husbandry manual produced, and the future directions are clarified	→ A14.1 Review past and current translocation, captive-rearing and breeding programs
15 Investigate infertility and agrochemicals	→ P15.1 The extent of infertility of Malleefowl in small reserves is investigated	→ A15.1 Assess the extent of infertility of Malleefowl in small reserves and investigate the possibility that this is caused by agricultural chemicals used on crops and pastures in which the birds feed
16 Facilitate communication between groups	→ P16.1 A national Malleefowl community forum is held every three years and the national newsletter continues to provide a national perspective	→ A16.1 Hold a national Malleefowl community forum every three years and support the national newsletter

Specific objectives		Performance criteria		Actions
17 Raise public awareness	→	P17.1 Increased public awareness of the Malleefowl recovery effort, beneficial management practices, the contributions made by community groups, and the legislative protections afforded to the species at national and state level	→	A17.1 Publicise the recovery effort, beneficial management practices, the contributions made by community groups, and the legislative protections afforded to the species at national and state level
18 Manage the recovery process	→	P18.1 Recovery process is coordinated and managed effectively by the recovery team, which: • meets at least annually • ensures that all key stakeholders are aware of, and support, planned actions, and are kept informed of progress • ensures that the results of actions in this plan are assessed, reported and reviewed.	→	A18.1 Regularly review progress in the recovery plan and manage the recovery process on a national and state level through teams with appropriate expertise and community standing, and appropriate reporting

Recovery Actions

The following actions are presented in three sections regarding A) general management of populations; B) planning, research and monitoring; and C) involving interested people and groups. Actions are grouped under common objectives and are briefly discussed. Within each section the highest priority objectives and actions are presented first, with due regard to the severity of the threats addressed and the likely national benefits to Malleefowl conservation. Details are provided on the costs of each action where practicable.

A) MANAGING POPULATIONS

Improving the management of Crown and leasehold public land is a crucial factor in improving the conservation status of Malleefowl. Sympathetic management on private land will also increasingly benefit Malleefowl conservation.

Specific costings are not provided for actions in this section, as they form part of broader conservation programs and aspirations and/or will be dependent on the priorities identified through the process of regional planning (see Action 8.1).

Objective 1: Reduce permanent habitat loss

Action 1.1 Retain areas that support Malleefowl, and those that support Malleefowl habitat, and protect them from incremental clearing. Report annually on known clearing in Malleefowl habitat.

Justification

Clearing causes permanent loss of Malleefowl habitat and has been the major factor in the decline of Malleefowl in agricultural areas. Clearing often continues in a piecemeal fashion and is a concern in all states.

Method

Native vegetation clearance controls exist in most states (see Appendix III) and often specifically protect habitats that harbour threatened species such as Malleefowl. However, sites that are important for Malleefowl will often need to be identified before they are protected under these initiatives (see Actions 8.1 and 10.1). Important sites for the conservation of Malleefowl include areas in which the species is resident and also those areas that form dispersal corridors between populations.

Where possible, records should be collated annually on the known legal and illegal clearance of known and potential Malleefowl habitat in each NRM region.

Action 1.2 Encourage landholders to enter into conservation covenants and similar agreements.

Justification

Management agreements between landholders and contracting organisations provide an opportunity for partnership and cooperation in conserving remnant Malleefowl habitat. In particular, statutory covenants can prescribe positive management as well as providing protection in perpetuity against deleterious activities such as clearing and grazing.

Method

Landholders should be encouraged by governments and local conservation groups to enter into management agreements for land that is important for Malleefowl. Programs in most states provide for statutory covenants that are binding in perpetuity (see Appendix III), and these are often associated with incentives for landholders.

Some programs involving leaseholds allow for the clearing of some habitats in exchange for improved conservation management of other areas (e.g. Department of Land and Water Conservation 1997). Such programs will be most beneficial to Malleefowl and other species where a regional approach to conservation is adopted, rather than a property-by-property approach which may result in accelerated fragmentation of Malleefowl populations and habitat. In general, the importance of a property for Malleefowl conservation should be assessed with regard to not only the occurrence of the species, but also in regard to the value of the property as a habitat link for dispersing Malleefowl and the conservation status of surrounding areas (see Action 8.1). Similarly, the effect of clearing areas for development should be assessed with due regard to how this may indirectly affect nearby Malleefowl populations in terms of favouring some predators and competitors of Malleefowl.

Landholders who undertake management agreements on their property should be recognised for their contribution to Malleefowl conservation. Suitable forms of recognition might include publicising the value of such protected remnants in Malleefowl newsletters and local media (see Actions , 16.1, 17.1), connecting the landholder to the network of Malleefowl conservation groups, and sending Malleefowl newsletters to those who undertake agreements that protect Malleefowl. Incentive funding for landholders to maintain and enhance Malleefowl habitat may also be available through existing Natural Resource Management frameworks in each state.

Action 1.3 Support initiatives that reduce further salinisation.

Justification

Salinisation of the land threatens some Malleefowl habitats where they are close to cleared land, especially in WA and south-east SA. This is one of the most insidious environmental problems facing dryland agriculture in southern Australia and reducing salinity will benefit Malleefowl as well as the economic and social viability of rural landscapes.

Method

Increased salinity is mostly caused by a rising watertable due to excessive clearing. In high-risk areas, the watertable can be stabilised by preserving and planting native-vegetation that is perennial and deep-rooted. In general, commercial crops of trees, shrubs and other perennial species should be encouraged in preference to annual crops and pasture. Establishing corridors of native vegetation will also help reduce salinity (see Action 5.1).

Objective 2: Reduce the threat of grazing pressure on Malleefowl populations.

General Comments

Valuable work could be conducted to further examine the effect of sheep, goat, and cattle densities on Malleefowl and might lead to better management techniques that allow stock and Malleefowl to coexist. However, a severe effect of grazing has been demonstrated and suggests that grazing by stock is inimical to Malleefowl conservation. Accordingly, conservation funds should be directed at reducing or eliminating grazing by introduced herbivores in areas important for Malleefowl.

Although sheep grazing in Malleefowl habitat has been shown to severely deplete local Malleefowl populations, such habitat is nonetheless more useful for Malleefowl conservation than cleared habitat. Grazed habitat may still support some Malleefowl and may be important in providing connectivity to other sites occupied by the species. Reduced grazing pressures in such situations would improve a habitat's value for both resident and dispersing Malleefowl.

Action 2.1 Remove goats and sheep from conservation reserves, or keep them at low numbers.

Justification

The severe effect of sheep grazing on Malleefowl abundance has been documented, and the effect of goats is likely to be similar if not worse. These introduced herbivores should thus be removed from Malleefowl habitats where the conservation of the species is a priority.

Methods

Useful techniques to reduce feral goat numbers include closing off or limiting access to artificial watering points, harvesting, and culling.

Action 2.2 Close or fence artificial sources of water in conservation reserves.

Justification

High grazing pressure has a deleterious effect on Malleefowl abundance. In many large conservation reserves, artificial sources of water provide access to water during the summer and this has resulted in much higher numbers of goats, sheep and kangaroos than would otherwise be the case. Consequently, the total grazing pressure in areas with artificial water is likely to be high, and may remain high even after culling programs.

Methods

Artificial water sources, such as old dams, should be levelled so that they do not hold water, or fenced to deny access by goats and other herbivores where these animals may be harming Malleefowl habitat.

Action 2.3 Erect adequate fencing to protect Malleefowl habitat.

Justification

Adequate fencing is required to prevent incursions by domestic stock and goats, and to prevent these animals from dispersing into, and becoming resident in, Malleefowl habitats. Edges of habitat remnants and habitat corridors are especially prone to damage from stock as high densities of sheltering animals graze and trample native vegetation.

Methods

Various government programs across Australia provide financial assistance for fencing remnant native vegetation (see Appendix III). Fence types vary and are designed to exclude different animals. Basic stock fencing is effective against sheep and cattle, whereas fences designed to exclude goats or rabbits are considerably more expensive.

Action 2.4 Reduce rabbit numbers where they are abundant in or near Malleefowl habitat.

Justification

Rabbits are common in some Malleefowl habitats, and are often very common near the boundary of remnant habitat and cleared land. Rabbits are likely to compete with Malleefowl for food, provide a relatively stable food source that supports high fox numbers, and cause long-term habitat degradation. Cyclic declines in rabbit abundance associated with drought or disease are thought to lead to prey-switching by foxes.

Methods

Useful techniques to locally reduce rabbit numbers include 1080 baiting; myxomatosis and rabbit haemorrhagic disease; shooting; and gassing and ripping rabbit warrens. Rabbit control should be integrated with fox control (Action 4.2) to prevent foxes from switching prey to Malleefowl when rabbit numbers are suddenly reduced. Monitoring should be conducted as part of site-specific management plans (Action 9.1), to assess the impacts of rabbit control efforts on rabbit numbers and Malleefowl populations.

Action 2.5 Inform graziers of the damaging effects of grazing on Malleefowl habitat.

Justification

Grazing by stock has been shown to have a severe effect on Malleefowl abundance. Although some graziers are aware of this effect, many are not.

Methods

Information on the effects of grazing and on managing Malleefowl habitat should be distributed widely (see Action 17.1) and displayed at field days, fairs, rural community centres and zoos. In particular, graziers should be informed of the negative effects of allowing sheep, goats or cattle to feed in or trample Malleefowl habitat, especially during drought and after fire when the vegetation is most vulnerable.

Objective 3: Reduce fire threats

Further information is desirable to develop more effective fire management practices that both protect economic and social interests and conserve biodiversity (this applies to all species, not just Malleefowl).

Action 3.1 Reduce the occurrence of large fires, and promote patchiness of fires, where Malleefowl conservation is a priority in large reserves.

Justification

Large fires are highly destructive to Malleefowl populations and diminish the suitability of habitat for Malleefowl thereafter for at least 30 years. Over the last few decades, large fires have devastated Malleefowl populations and there is an urgent need to prevent their recurrence.

Methods

Fire management plans should be drafted and implemented for all large reserves. These plans should focus on strategic ways of limiting the spread of large fires, and promoting more patchy burns when wildfire occurs. Fire exclusion from large reserves is neither desirable nor feasible. Areas that are most important for Malleefowl should be identified (Action 8.1) and strategies should be developed in fire management plans for protecting these in particular. Fire management requires considerable planning and may require habitat modifications (e.g. installing effective firebreaks, patch burns etc.). Control burns may be useful in some habitats to interrupt fuel continuity and to establish linear firebreaks, but the risk of fire escape should also be acknowledged and considered when choosing a method of protecting areas of special significance.

Action 3.2 Provide for access to and adequate protection of small habitat remnants to prevent fire spreading to or from surrounding land.

Justification

Small (<5,000 ha) habitat remnants are subject to different risks from fire than are large reserves. Small remnants typically contain older habitat than large reserves and burn less frequently, but they are at a high risk of being completely consumed should a fire occur. Fire in small and isolated remnants may thus be more likely to cause local extinction of Malleefowl.

Methods

Fire management plans should be drafted and implemented for small reserves that harbour Malleefowl. Extensive fire protection works such as wide firebreaks may significantly compromise the integrity of small reserves, and in some cases the relative ease of access to fires in small reserves may obviate the need for extensive preventative measures. This should be taken into account in planning fire protection for small reserves, and weighed against the regional significance of potentially losing a local population in a small reserve in the event of fire.

Action 3.3 Encourage traditional burning practices by Aboriginal people in Central Australia.

Justification

Traditional patch burning disrupts the continuity of fuels, thereby reducing the risk of large fires, and may also benefit Malleefowl by stimulating regeneration episodes in spinifex habitats in which the birds feed.

Methods

Aboriginal people should be encouraged to conduct traditional burning where this does not threaten dense mulga habitats or Malleefowl nests. Australian Government programs provide funds to employ Aboriginal owners to undertake traditional fire management, particularly in Indigenous Protected Areas.

Action 3.4 Discourage broad-scale burning for agricultural purposes in areas that harbour Malleefowl.

Justification

In some areas, such as western NSW, broad-scale fire has been promoted in the past to promote forage production for stock. This is likely to be highly destructive of Malleefowl populations and to diminish the suitability of habitat for Malleefowl for at least 30 years thereafter.

Methods

Information on the damaging effects of broad-scale burning on Malleefowl should be distributed widely (see Action 17.1) and displayed at field days, fairs, and rural community centres in regions where such burning is practised.

Action 3.5 Map fires in Malleefowl habitat and monitor the effects of fire at Malleefowl monitoring sites.

Justification

Information on fire history and the effects of fire on Malleefowl habitat is required to inform planning and management of Malleefowl habitat sites (i.e. Actions 3.1, 8.1 and 9.1).

Methods

Fires in any known Malleefowl habitat should be mapped, and the effects of fire on habitats and on Malleefowl persistence in an area should be monitored where practicable, particularly when fire occurs at established Malleefowl monitoring sites.

Objective 4: Reduce predation

Foxes are efficient predators of Malleefowl and reducing fox numbers is likely to benefit the birds, especially in areas where Malleefowl are under stress from other factors, or where Malleefowl are re-introduced. This is especially the case in small reserves and near the edges of large reserves, but applies in all habitats and landscape configurations. However, two general points should be kept in mind:

1) Baiting for foxes in and around Malleefowl habitat is only recommended where it can be conducted at scale (ideally hundreds of km^2), intensity (2-5 baits per km^2) and frequency (2-4 times per year) that ensures its efficiency.
2) In areas in which Malleefowl numbers are monitored, it will be necessary to leave some areas unbaited in order to assess the benefits of fox control.

Action 4.1 Record and centralise details of fox control in or near areas where there are estimates of Malleefowl abundance.

Justification

It is still unclear how important fox predation is in determining Malleefowl abundance, or how effective various levels of fox control are at increasing Malleefowl populations or reversing declines. Fox control is conducted across Australia by various public and private land managers and for a variety of purposes, and even where details are recorded these are often difficult to locate. Ensuring that adequate details of fox control are recorded, and centralising these records, will provide valuable information for assessing the effectiveness of fox control in benefiting Malleefowl. This is especially important in or near areas where there are measures of Malleefowl abundance. Similar recommendations have been made in a recent review of pest control operations in Australia (Reddiex *et al.* 2004).

Method

The need to record and centralise fox control details in areas where Malleefowl occur should be widely publicised through government agencies and the community network (see Action 17.1) and displayed at field days, fairs, and rural community centres. Relevant details include the method, intensity and frequency of fox control, and the results in terms of fox abundance. In conjunction with fox control, Malleefowl breeding density and/or the frequency of Malleefowl sightings should also be recorded so that benefit to the birds can be assessed. A summary of these fox control and Malleefowl data should be centralised on the Malleefowl monitoring database (see Action 9.4).

Action 4.2 Reduce fox numbers in small and isolated habitat remnants.

Justification

Malleefowl are especially vulnerable in small and isolated habitat remnants and the effects of predation by foxes are likely to be amplified by proximity to agricultural land and the restricted opportunities for immigration and emigration by the birds. Reducing fox numbers may benefit the birds, but control measures should only be conducted at a scale, intensity and frequency that ensures their efficiency.

Method

Control of foxes and rabbits should be integrated in Malleefowl areas to reduce predation on Malleefowl and prevent a build-up of rabbits. In general, rabbits should be poisoned before foxes, as poisoned rabbits may cause significant secondary poisoning of foxes and make further fox control more effective. Fox control is most effective when the target area and surrounding areas are baited simultaneously to inhibit reinvasion. 1080 baits are commonly used for fox baiting and usually cost less than one dollar each, although preferred baits and methods of delivery vary with location.

Action 4.3 Reduce fox numbers in large areas of native habitat where Malleefowl densities have declined and fox predation is a likely explanation for such declines.

Justification

Excessive predation by foxes is a serious threat to Malleefowl in some areas and may lead to declines in Malleefowl abundance, especially following severe reductions in rabbit populations or other staple foods of foxes. While there is uncertainty regarding the effectiveness of fox control at increasing Malleefowl populations or reversing declines, widespread fox control is recommended as a precautionary measure where Malleefowl densities have declined and fox predation is a likely explanation for such declines.

Method

Fox control in large areas of native habitat is often difficult to achieve on the ground due to limited vehicular access. In WA and NSW, widespread fox control is achieved by 1080 aerial baiting and techniques have been developed that provide an effective and efficient kill of foxes with a reduced risk of off-target mortalities. In WA, such aerial baiting is conducted four times a year over large areas as part of Western Shield and Project Eden. The abundance of Malleefowl should be monitored where widespread baiting is conducted and at similar unbaited areas so that benefits to Malleefowl can be assessed.

In Central Australia, baiting for foxes in and around Malleefowl habitat is only recommended where it can be conducted at scale (hundreds of km^2), intensity (2-5 baits per km^2) and frequency (2-4 times per year) that ensures its efficiency, and where foxes are more common than dingoes. The relative abundance of foxes and dingoes can be deduced by the frequency of these animals' tracks. Foxes may be suppressed by dingoes and are likely to pose a much greater threat to Malleefowl. However, conventional fox baiting is also effective at killing dingoes and may be counterproductive to Malleefowl conservation if an absence of dingoes allows foxes to reinvade the area. Also, conventional 1080 baiting is ineffective against cats and in arid areas these predators often increase substantially in numbers after the abundance of larger carnivores is reduced.

As the effectiveness of fox baiting in benefiting Malleefowl is still uncertain, fox control should always be well documented (Action 4.1) and associated with measures of the response of both foxes and Malleefowl over a number of years (Action 9.2, 9.3).

Objective 5: Reduce isolation of fragmented populations

Action 5.1 Develop strategic corridors of native vegetation to connect patches of habitat that are suitable for Malleefowl.

Justification

The future for Malleefowl in small and isolated reserves is grim. Population sizes are typically very small, often numbering just a few birds, and remnant patches of habitat are often surrounded by cleared land that is a hostile environment for

Malleefowl to traverse or survive in. In such isolated situations, populations are vulnerable to a range of deleterious effects due to genetic deteriotion and demographic stochasticity. Corridors of native vegetation that link remnants may greatly benefit Malleefowl and enable populations to persist much longer by facilitating movement of animals between habitat patches. While there are few data from which to deduce the effectiveness of such corridors for Malleefowl, or what their attributes should be, there is evidence that Malleefowl use even narrow roadside strips of native vegetation in preference to crossing open ground.

Method

Planning will operate at a regional level and aim at establishing networks of interconnected patches (see Action 8.1) by maintaining existing habitat links, and by identifying priorities for new links, to be established through planting or natural regeneration. This action will be informed by studies on the landscape genetics of Malleefowl (Action 13.1) which will clarify the degree of genetic isolation of Malleefowl populations and identify the landscape features that provide effective connectivity or barriers to the movement of Malleefowl. Until this information becomes available, corridors should be planned to comprise both trees and shrubs to provide Malleefowl with overhead and horizontal cover and be fenced to exclude grazing by stock. The vulnerability of Malleefowl to predators and traffic is likely to increase with decreasing corridor width and with the amount of time needed to travel along its length. Accordingly, corridors should be as wide and as short as possible and always connect remnants, never leading from a remnant to nowhere in particular. Such dead-end corridors may lead Malleefowl into areas in which they become increasingly vulnerable. Also, favoured food plants (such as acacias) should be no more common along narrow corridors than in the habitats they connect. This will reduce the risk of birds regularly feeding in corridors where they may be especially vulnerable.

Objective 6: Promote Malleefowl-friendly agricultural practices

Action 6.1 Encourage farmers with cropland surrounding small remnants of Malleefowl habitat to cooperatively ensure that some grain is grown every year.

Justification

While fragmentation of habitat due to past clearing poses problems for Malleefowl, it is also true that Malleefowl may benefit from the proximity to croplands. Malleefowl often feed out from the edges of their habitat on fallen grain and green-pick, and in some areas may depend on these food sources. However, in many areas the ground is fallowed and crops are not grown every year. Malleefowl in habitat remnants adjacent to crops would probably benefit if some accessible crops were grown each year and provided a more regular supply of grain. This might be achieved by ensuring that not all cropland surrounding a habitat remnant was fallow at the same time, and would not necessarily require extra work for farmers.

Method

Information on the likely benefit to Malleefowl of asynchronous fallowing should be displayed at field days, fairs, and rural community centres, along with other information on how to benefit the species (see Action 17.1).

Objective 7: Reduce Malleefowl mortality on roads

In some cases, road mortality may be substantial and damaging to a small population. For example, during one year, 13 Malleefowl were killed along a two-kilometre stretch of road in Western Australia (G. McNeil pers. comm.)

Freshly dead Malleefowl should always be collected and passed on to wildlife authorities either fresh or frozen as such specimens are valuable to science. Most local wildlife authority offices have a freezer for such purposes.

Action 7.1 Minimise the amount of grain spilt during transport through areas that harbour Malleefowl.

Justification

Malleefowl are often killed on roads where they frequently feed on spilt grain.

Method

Grain transporters should be encouraged to minimise the amount of grain spilt as they travel through areas that support Malleefowl. Educational signs at grain silos and weighbridges in areas where Malleefowl are likely to occur may be an effective means of informing transporters of the issue. Motorists in general should also be made aware of the problem (see Action 7.2). Information on the negative effects on Malleefowl of grain spilt on roads should be distributed widely and displayed at field days, fairs, and rural community centres (see Action 17.1). Spilt grain is also a hazard for other threatened species, such as Superb and Regent Parrots, and in areas where Malleefowl occur with these species an effort should be made to combine signs and displays. A grain-spill awareness campaign for the Superb Parrot was undertaken by NSW National Parks and Wildlife Service in the late 1990s using educational signs at weighbridges.

Action 7.2 Erect signs to warn drivers where Malleefowl may be on the road ahead.

Justification

Malleefowl are often hit by traffic on roads. This risk could be reduced through effective signage to educate motorists.

Method

In areas where Malleefowl are often seen on roads, signs should be erected alerting motorists of the possibility that Malleefowl may be on the road ahead, that they are a threatened species, and that they usually do not flee when approached by traffic. Educational signs at grain silos and weighbridges in areas where Malleefowl occur may also be effective in alerting transporters of the issue.

Motorists should be encouraged to report any sightings of road-killed Malleefowl to local authorities, to assist in evaluating trends in road mortalities and the effectiveness of recovery actions to mitigate this threat.

B) PLANNING, RESEARCH, AND MONITORING

The following actions involve the collection of information and are presented in detail to promote a collaborative and standardised national approach. This information is needed both to assist in planning management actions, and to evaluate the success or otherwise of management actions used to various degrees across Australia.

Objective 8: Provide information for regional planning

Action 8.1 Prepare regional conservation plans for Malleefowl.

Specific Aim

Prepare regional conservation plans for Malleefowl that collate existing information needed for conservation planning, identify key areas for conservation, summarise likely threats relevant to each site where Malleefowl occur, and propose site-specific measures to improve the conservation of the species in the long-term.

Justification

A site-specific approach to Malleefowl conservation and population management is required but is beyond the scope of this National Recovery Plan. To be most effective, site-specific management actions should be developed from a regional perspective of Malleefowl conservation and land management. Preparation of regional Malleefowl conservation plans will provide this perspective by examining the past and current distribution and abundance of the species, detailing the availability and general condition of remaining habitat, identifying key habitat areas, and evaluating opportunities to mitigate local threats with appropriate management. This information will be used to plan site-specific management strategies in each state.

The regional conservation plans will also:

- inform the Integrated Natural Resource Management process within the regions, especially in regard to regional vegetation, landscape and threatened species planning,
- facilitate a regional approach to land use assessments that are currently made on a property-by-property basis (e.g. the Property Development Agreements in NSW),
- provide baselines from which future changes and trends in Malleefowl habitat condition, threats and management can be measured and assessed at a regional level and incorporated into regular CMA/NRM reporting.

Methods

Four broad geographic regions are suggested based on the major discontinuities in the range of Malleefowl across Australia (see Appendix II).

- Western Australia (west of Kalgoorlie);
- Central Australia (WA Goldfields and south-eastern coast, NT, and western SA from northern Eyre Peninsula to the NT and WA borders);
- South-eastern Australia – southern Eyre Peninsula, Yorke Peninsula and Murray Mallee (south-east SA, south-west NSW, Vic); and

- Central NSW (east of the 144th Longitude).

Within each of these regions the threats to Malleefowl populations may be expected to be similar, and although populations have been fragmented there is some potential for ameliorating this with appropriate management. This regionalisation provides a framework for planning, but other regionalisations based on boundaries of States, NRM catchments or bioregions might be more politically workable. In such cases, local plans will nonetheless consider information from neighbouring areas within the regions outlined above.

Existing GIS data, satellite imagery, and aerial photography will be used to compile maps of the vicinity of known and suspected Malleefowl sites showing:

- Malleefowl sightings and monitoring sites;
- broad habitat type;
- remaining native vegetation;
- vegetated roadsides and other landscape features that may act as corridors;
- fire history and current fire management plans;
- land tenure and land use (including proposed uses, such as sand-mining);
- predator control efforts, and herbivore control efforts.

These maps, together with information on past distribution (Appendix II) and the results from Actions 9.1, 9.2, 10.1 and 10.2 (Monitoring, Adaptive Management Plan, and Current Distribution), will form the basis of each conservation plan. Malleefowl population size in each discrete patch will be estimated, and major knowledge gaps for the species' distribution and sites of greatest significance will be identified. The regional plans will consider on a site-by-site basis where and how resources should best be directed to secure self-sustaining populations, with appropriate habitat management and control of introduced herbivores and predators.

Finally, this work will briefly detail, prioritise and cost measures urgently required to secure the species within each region in the long-term. In particular, the plans will examine the need and feasibility of producing networks of interconnected patches in specific areas and consider the need to restock areas with Malleefowl.

The information collated in the course of this project will be presented in a way that facilitates regular reporting of environmental changes that may affect Malleefowl conservation to, and by, regional CMA/NRM boards (e.g. net vegetation losses to clearance and/or fire; net area of habitat restoration or re-vegetation works; etc.).

Costs

Compiling each conservation plan is likely to involve ten to twenty weeks work. This work should follow the establishment of monitoring sites and surveys of the distribution of the species.

State and National cost summary ($000s)

Year	1	2	3	Thereafter	Total
Western Australia[1,3]	0	0	17.0	0	17.0
Central Australia[1]	0	0	17.0	0	17.0
South-east[2]	0	0	11.3	0	11.3
Central NSW[2]	0	0	11.3	0	11.3
National Total	0	0	56.6	0	56.6

Notes: 1) Based on 15 weeks; 2) Based on 10 weeks @ $50 k/yr plus 18% oncosts; and 3) A regional plan for the WA Wheatbelt has already been completed ((Short and Parsons 2008).

Objective 9: Monitor Malleefowl and develop an adaptive management framework at monitoring sites

Justification

There are now over 60 sites across Australia at which Malleefowl breeding densities are monitored by community volunteers. This network of sites provides an invaluable resource for Malleefowl conservation providing 1) a means of assessing trends in populations, and 2) an opportunity to examine the success of different management practices, and the effects of environmental factors, at replicated sites across the continent.

Adaptive management is a pragmatic and collaborative process of learning by doing that involves an experimental approach to management and a high degree of collaboration between stakeholders (Walters 1986; Possingham 2001). The approach would provide an organising framework at a national level with which to integrate research and management, improve conservation outcomes and efficiency, and involve all stakeholders. The approach is appropriate for Malleefowl conservation because:

- The species displays a fair degree of resilience and still occurs over much of its uncleared range, providing opportunities for replicating management treatments and controls (non-treatment sites). The current network of monitoring sites represents a tiny proportion of this range and is spread out across the continent, and consequently, varying management treatments at these sites is unlikely to compromise the conservation of the species. However, carefully designed management experiments would provide information on beneficial practices.
- There is currently some uncertainty about the effectiveness of management actions in reversing declines, and in the role of environmental factors. Climate change, and the long-term effects of fragmentation, will most likely amplify these uncertainties in the future and exacerbate local threats. The adaptive management approach embraces and provides a means of resolving such uncertainties.
- There is already a strong community involvement in Malleefowl conservation and a general enthusiasm for collaboration with agencies and land managers. Community volunteers organise and conduct most of the Malleefowl monitoring that occurs in southern Australia, while agencies manage these sites in varying ways. These are key ingredients in adaptive

management, and provide a firm basis upon which to design an effective national program.

Strategy

Several steps are required to develop a national adaptive management approach:

1) Analyse and review the current monitoring system both operationally and in terms of trends in Malleefowl breeding numbers (Action 9.1)
2) Develop site specific management plans and provide annual reports on progress toward agreed targets (Action 9.1).
3) Conduct monitoring (Action 9.2)
4) Implement experimental management (Action 9.3)
5) Facilitate monitoring and national standardisation (Action 9.4)

Action 9.1 Analyse and review monitoring data. Recommend improvements and develop site-specific management plans for monitoring sites, consistent with a national adaptive management design.

Justification

Substantial amounts of Malleefowl monitoring data have been collected on the ground by hundreds of volunteers at over 60 sites in SA, Vic and WA. These data describe breeding densities in fixed areas and, for the most part, comparable methods have been used. In some cases the data sets span over 20 years. This is a highly valuable resource, but there has been only limited analysis of population trends or the relationships of these trends to environmental factors such as rainfall, fire, and management practices (such as fox control). There has been no assessment of the adequacy of the monitoring system itself to deliver the information that is required, either in regard to the data that is collected, or in regard to the representation of areas within the monitoring system.

Benshemesh *et al.* (2007) have recently collated Malleefowl monitoring data from Victoria, NSW, SA and WA, and have analysed trends in Malleefowl breeding density in relation to fox control efforts, rainfall, landscape fragmentation and fire history. This study has produced a number of valuable findings and recommendations in relation to Malleefowl conservation.

With the burgeoning interest and community involvement in monitoring Malleefowl, the analysis of data already collected and the review and improvement of the current system are high priorities, both to learn about Malleefowl trends, and to maintain volunteer interest in the program. This also provides an opportunity to develop a national adaptive management framework that would transform the largely passive or observational character of monitoring into a dynamic system for examining the effectiveness of various management options.

It is likely that many of the inadequacies of the current system and opportunities for improvement would come to light in an analysis of the data. Consequently both the analysis and review are combined here in a single action. Note that this action specifically addresses the ground-based monitoring; analysis of aerial monitoring data from NSW is planned as part of the NSW Fox Threat Abatement Plan review.

Method

The review of monitoring processes will focus on assessing the information that is currently collected at monitoring sites, examining the representativeness of the current sites, and recommending improvements. A process developed in Victoria has been adopted as a national standard, but involves collecting large quantities of data at mounds, and could probably be made more efficient (some of the information collected is intentionally redundant to enable error checking, but technological developments make these obsolete). On the other hand, improved methods of collecting data on predator and herbivore abundance may be required if the data collected on these are inadequate.

Finally, the opportunities for adopting a national-scale adaptive management approach for the monitoring sites will be examined. Each step in this process will require collaboration with community groups (who conduct the monitoring) and local or regional management authorities. Specifically, this will require:

- Documenting the on-going and past management actions at each site, and the feasible management options for the future in collaboration with local management authorities,
- Formulating a set of key management questions that may be efficiently answered through the monitoring system. For example, an assessment of the benefits of fox control on Malleefowl populations could be answered and formalised within this framework. Other examples include improving habitat by reducing herbivores/competitors such as sheep, goats, deer and kangaroos, or promoting likely food plants for chicks and adults through limited burning or plantings.
- Recommending cost-effective modifications to the existing arrangement of monitoring sites to increase the power of the system to answer questions and with due regard to experimental design. Modifications may involve establishing new monitoring sites in specific areas to improve representation, or changing management of existing sites.
- Developing concise five-year management plans for each monitoring site in collaboration with local authorities and community groups, and the advice of statisticians. These site plans will prescribe agreed management actions, and provide simple annual reporting criteria for these actions which will be collated each year by state or national coordinators nominated by the recovery team.

The draft recommendations and plans will be presented and discussed at the National Malleefowl Forum in 2009 where endorsement will be sought.

Costs

Note: Funding for the analysis and review part of this project was provided from the Natural Heritage Trust through the Mallee Catchment Management Authority (Vic), and this part of the project was completed in late 2007 (Benshemesh 2007, Benshemesh *et al*. 2007).

State and National cost summary ($000s)

Year	1	2	thereafter	Total
Analyse and review monitoring systems[1]	49	0	0	49
Develop collaborative adaptive management framework[1]	0	49	0	49
Travel and telephone	0	10	0	10
Statistical advice	5	5	0	10
National Total	54	64	0	118.0

Notes: 1) Parts of this action have already been achieved; 2) Based on 36 weeks @ 60 k/yr plus 18% oncosts.

Action 9.2 Monitor and manage existing monitoring sites across Australia.

Justification

Knowledge of the stability of Malleefowl populations is fundamental to their conservation across Australia. Ground-based monitoring sites are the most cost-effective way of collecting these data and the techniques are suited to community involvement. The monitoring project will show where declines are occurring, and how rapidly they are proceeding, and as such will facilitate evaluation of performance against the recovery criteria in this plan. Monitoring also underpins the adaptive management approach (Action 9.1) which will experimentally determine the most beneficial management practices.

This action will rely largely on the efforts of volunteers, monitoring breeding densities on foot. In NSW, the aerial monitoring of Malleefowl nests under the NSW FoxTAP program is supported by this plan (the approximate annual budget for aerial monitoring in NSW is $75,000 excluding DECC in-kind costs; D. Oliver pers. comm.) but is not specifically budgeted or considered further here.

Methods

Monitoring sites will include a sample of habitats and landscape configurations that are deemed representative for the Malleefowl populations in each State (Action 9.1). Every known Malleefowl mound within each monitoring site will be visited annually to determine whether it is being used for breeding. Sites will be at least 200 ha in size. Experience in Victoria and South Australia suggests that one to three person-days per site is usually adequate to visit all mounds in a site. Data collection and reporting will be standardised across the states and modelled on existing studies: this currently involves the use of handheld computers linked to GPS and the use of customised Cybertracker software to collect the data in the field. This equipment has already been purchased by monitoring groups in SA, Vic and WA and further costs are not anticipated. An existing database and field manual will be used to facilitate all aspects of the monitoring, and if necessary these will be improved.

New nests built by the birds after the sites are searched will usually not be known unless the site is searched again. New nests are not common, but it is nonetheless important that monitored sites be re-searched regularly so that any new nests can be added to the monitoring. Monitoring of previously-known nests provides a minimum estimate of the breeding numbers at a site, and this may be adequate for distinguishing sites at which a decline may have occurred from those where numbers have been stable or increasing. More accurate data than this requires regular re-searching of monitoring sites.

This action is suited to community participation and this will be encouraged. The recovery team will also facilitate and direct community groups to ensure a coherent national approach. In fact, it is unlikely that this action will succeed without community involvement, as regular monitoring and re-searches of sites may otherwise be prohibitively expensive. It is envisaged that community-based volunteers may eventually run the project under the guidance of the recovery team.

Rain gauges that are capable of collecting yearly rainfall will be stationed at every grid unless accurate rainfall data are already collected and available from adjacent landholders or nearby towns. Solar powered, automatic rain gauges cost about $1500 and should be installed at all grids for which adequate rainfall information is otherwise unobtainable. Rainfall has a major bearing on food availability and Malleefowl breeding density but is extremely variable in time and space in semi-arid and arid areas. These rainfall data will thus be important in interpreting changes in Malleefowl breeding densities in the future.

All data will be centralised at Birds Australia so that the national database can be administered from a single source and made available for the recovery team. This will also facilitate a national perspective on the species' conservation. This central point for all records will act as a national archive, but access to these data will only be allowed with permission from those who provided the data (usually community groups) and the recovery team.

Costs

A total of 60 sites are budgeted.

National cost summary per year for 5 years ($000s)

Year	1	2	3	4	5	Total
Potential in kind by community groups						
Monitoring labour[1]	58	58	58	58	58	290
Re-search[2] (each site every 3 years)	96	96	96	96	96	480
Support funds required						
Monitoring transport and support[3]	9	9	9	9	9	45
Re-search transport and support[4]	9	9	9	9	9	45
Automatic rain gauges[5]	30	0	0	0	0	30
Annual database management[6]	6	6	6	6	6	30
National Total (60 grids)	208	178	178	178	178	920
In kind total	154	154	154	154	154	770
Support total	54	24	24	24	24	150

Notes on costing: 1) For 60 sites @$960/site average (pairs of people working 8 hrs/day @$20/hr for 3 days/site). Community groups are currently operating at this level; 2) 20 sites per year @$4800/site (10 people over 3 days@20/hr each); 3) Travel estimated as $150 per site for 60 sites.; 4) Travel estimated as $450 for 20 sites (3 vehicles); 5) 20 units @$1500 per unit; 6) 12 days per year @$500/day for database consultant.

Action 9.3 Undertake effective fox control at two monitoring sites in each state over a period of five years and evaluate the benefits of this on Malleefowl breeding numbers using appropriate experimental design.

Justification

It is still unclear how effective fox control is at increasing Malleefowl populations or reversing declines. This action will assess the benefit to Malleefowl of reducing fox abundance by thorough 1080 baiting in a controlled experiment. The action is a core component of the adaptive management approach to the monitoring sites (Actions 9.1 and 9.2) and research into the population turnover of Malleefowl (Actions 11.2 and 11.3).

Methods

A selection of sites that are regularly monitored (Action 9.2) will be baited for foxes, and each of these will be paired with another similar site that is not baited (experimental control) so the effects of baiting are evident amongst seasonal fluctuations. These unbaited sites will provide an experimental control to assess the long-term benefits of such baiting regimes. Foxes will be reduced within a five-kilometre radius of the baited monitoring grid to provide an adequate buffer, and surrounding landholders will be encouraged to participate in this program. The relative abundance of foxes within the study sites will be assessed by bait-take as well as by systematically recording the frequency of fox signs on Malleefowl mounds (Action 9.2). Local wildlife authorities, the recovery team, and local community groups will determine the exact method of baiting. Baiting effort will have to be increased if fox abundance does not decline substantially within 12 months.

Costs

The cost of baiting varies with scale, frequency, and intensity. Here, baiting costs are estimated for an area of 110 km^2 centred on each monitoring grid (includes five-kilometre buffer) that is baited four times a year at a density of six baits per square kilometre. Data on the trends in Malleefowl abundance at both baited and unbaited grids will be provided by Action 9.2 and no further cost is anticipated. Incorporating existing predator control programs (such as NSW FoxTAP sites) into the experimental design where this is possible, and the involvement of community volunteers, may reduce some of these costs.

Costs

State and National cost summary for baiting 2 ground-based monitoring sites in each state for 5 years

Annual cost summary ($000s)

Year	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
NSW[1]	15.6	15.6	15.6	15.6	15.6	78.0
SA[1]	15.6	15.6	15.6	15.6	15.6	78.0
VIC[1]	15.6	15.6	15.6	15.6	15.6	78.0
WA[2]	10.6	10.6	10.6	10.6	10.6	53.0
National Total	57.4	57.4	57.4	57.4	57.4	287.0

Notes on costing for 6 sites, 2 in each of SA, VIC, WA: 1) 2640 baits per site per year @$1.00/bait and $1.20/bait for distribution where tethering or burying is required, plus $4k for vehicle and other costs; and 2) 2640 baits per site per year @$0.75/bait and $0.50/bait for distribution, plus $4k for vehicle and other costs.

Comment

Costs may be reduced by selecting grids that are already baited for other reasons, and by involving landholders in maintaining the buffer zone around each grid. Clear benefits to Malleefowl at baited sites might be measured within the five years budgeted for this project. However, the project should be continued for another five years if no measurable increase in Malleefowl numbers is achieved within this timeframe.

Action 9.4 Facilitate and standardise monitoring and co-ordinate national monitoring effort.

Justification

A part-time national coordinator is required to facilitate community monitoring by ensuring standardisation of data collection and techniques, assisting with training, and helping to establish efficient and self-sufficient procedures at a national level. An overarching level of coordination will also prevent the fragmentation and duplication of volunteer effort across Australia, ensure compatibility of data, and help maintain the interest and commitment of volunteers.

Methods

The part-time coordinator will work closely with state and regional facilitators and community groups to provide simple systems of data collection, collation, storage and preliminary analysis and reporting. These systems will be modelled on those currently used in Victoria where volunteer groups essentially run the operational side of the monitoring program (collecting and downloading data). The coordinator will provide the means to achieve this, including training guidelines, manuals for field operations and data management. The coordinator will oversee this process on a national scale and the role of the coordinator is expected to diminish as efficient national systems are put in place.

A new national database will be developed to store and safeguard the data, provide access and reports to authorised people, and perform many of the routine data management tasks that are currently done manually. The new database will be web-based to provide easy access from anywhere in

Australia, and will be designed to maintain the standards and operational procedures of national Malleefowl monitoring program.

Costs

Note: Funding has been provided for years 1 and 2 of this project (2005/06 and 2006/07) from the National Heritage Trust through the Mallee Catchment Management Authority (VIC).

Annual cost summary ($000s)

Year	1	2	3	4	5	Total
Coordinate national[1]	22.7	11.3	11.3	6.8	6.8	58.9
Database development[2]	25.0	0	0	0	0	25.0
Database maintenance and ISP costs		5.0	5.0	5.0	5.0	20.0
Modify and distribute manual	2.0	0	0	0	0	2.0
National Total	49.7	16.3	16.3	11.8	11.8	105.9

Notes on costing: 1) 20 weeks in year 1, 10 weeks in yrs 2 &3, and 6 weeks in yrs 4 & 5 @$50k/yr plus on costs (18%); and 2) Consultant for 50 days @$500/day.

Objective 10: Determine the current distribution of Malleefowl

Justification

An understanding of the distribution and continuity of Malleefowl populations is crucial for effective management at a local, regional and national scale. However, the current distribution of Malleefowl is poorly known and relies for the most part on incidental sightings of the birds that are recorded in wildlife atlases in each state. As Malleefowl are often cryptic and elusive they are frequently missed in conventional bird surveys and therefore a more systematic approach to recording the distribution of Malleefowl is required.

Action 10.1 Detail the distribution of Malleefowl in remote areas of SA and WA by field surveys, and describe the habitats in which Malleefowl are found.

Justification

The current distribution of Malleefowl is poorly known in remote areas such as north and east of the WA wheat belt, and the central deserts of NT, SA and WA. Although the density of Malleefowl in these areas is low, the enormous areas involved suggest they may be of great importance for Malleefowl conservation. Data on the distribution, abundance and habitat preferences of Malleefowl in these remote areas will form the basis of future monitoring.

Methods

Searches will concentrate on localities at which Malleefowl have previously been recorded and an effort will be made to actively seek information from people with close links to the land, particularly Aboriginal elders, and also mineral exploration and mining companies. At each locality identified from these sources a range of sites will be selected for searches for Malleefowl footprints. Previous studies in central Australia have found Malleefowl in both open mallee and thick mulga, and these habitats had in common some tree cover to three metres in height and (relatively) thick vegetation. These features will be used to select potential sites from satellite images in the absence of advice from people who have experience with Malleefowl in these areas. Methods of conducting searches for footprints involve searching a series of transects through selected areas. Because rain and strong winds eliminate footprints, these surveys will only be conducted after at least one week of dry and calm weather.

Learning from local informants is critical to the success of such searches, especially Aboriginal people who may have access to both first hand experience and traditional knowledge of Malleefowl habitats and localities. Moreover, traditional owners are in an ideal position to search for Malleefowl and conduct routine monitoring, although older traditional owners will often require younger assistants to walk long distances in search of tracks.

The success of the Indigenous Malleefowl program in the Anangu Pitjantjatjara Yangkunytjatjara Lands should be publicised in Aboriginal communities across the species' range in order to encourage these and other efforts. Accordingly, a poster will be produced for communities and schools with the objective of informing traditional landowners of the plight of Malleefowl and the successes in the APL, and inviting information and participation. These posters will be distributed to schools several months before sites are visited on the ground.

Electronic data recording will be encouraged (e.g. palm-type computers and GPS using the Cybertracker system) and a data management system will be developed that services the efforts of traditional owners while centralising data storage. Reporting systems will be developed in consultation with traditional owners and land management coordinators to both service the needs of participants and provide a national perspective.

Costs

Costs will involve vehicle and field expenses for a project officer for six months and a technical assistant for four months (mostly in the field) in both Western Australia (west of the Great Victoria Desert), and in Central Australia (including the WA side of the Great Victoria Desert).

Annual cost summary ($000s)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Salary: Project officer[1]	29.5	29.5	0	0	0	59.0
Salary: Traditional Owner salaries [2]	23.6	23.6	23.6	23.6	23.6	118.0
Vehicle	15.0	15.0	10.0	10.0	10.0	60.0
Cybertracker hardware and system development	8.0	0	0	0	0	8.0
Miscellaneous (digital cameras, etc.)	3.0	2.0	2.0	2.0	2.0	11.0
National Total	79.1	70.1	35.6	35.6	35.6	256.0

Notes on costing: 1) 26 weeks @50k/yr plus on costs (18%); 2) 26 weeks @40k/yr plus on costs (18%).

Action 10.2 Detail the distribution of Malleefowl in settled rural areas by site inspections and postal surveys, and ascertain the degree of decline and fragmentation of remaining Malleefowl populations.

Justification

This action will provide distribution data for agricultural and mining areas as a result of postal surveys and active searches where Malleefowl have previously been recorded and where it is conceivable that they may still exist. The primary outcome of this action will be a distribution map showing both positive and negative results from the postal and field surveys, and these will be related to maps of existing woody cover. These distribution maps will provide:

- much needed information on the degree to which Malleefowl have declined in range and where conservation works should be directed,
- a basis for regional management plans, especially for planning habitat corridors to reduce isolation of populations, and
- a benchmark from which to assess the conservation of Malleefowl in the future.

Methods

These surveys will be conducted where the current distribution of Malleefowl is still not well known and where declines are suspected. Two methods are recommended for this action. Firstly, a brief questionnaire and sighting-form will be arranged and sent to landholders living in areas where Malleefowl may once have occurred (deduced from previous records, see Appendix II). Postal surveys have successfully been used to obtain such information for Malleefowl in NSW (Brickhill 1987b), SA (Cutten 1997, S. Pillman pers. comm.), and WA (Parsons 2008), and for other rare fauna (Mawson & Long 1995; Lunney *et al.* 1997), but require careful checking and validation. Post-outs will also include a form for future sightings, and these will form the basis for a Malleefowl-watch program run by the Threatened Species Network and modelled on existing programs. These postal surveys will be conducted in pastoral and rural areas of NSW, south-western Victoria, and parts of WA where the current distribution of Malleefowl is not well known and where declines are suspected. Elsewhere in rural areas, postal surveys are not a priority as the distribution of Malleefowl is well established; recent postal surveys in the WA Wheatbelt in particular have provided valuable information and provide a model of how future surveys may be undertaken and analysed (Parson 2008, Parsons *et al*. 2008). In central Australia postal surveys are unlikely to be successful due to the remoteness of potential sites.

Secondly, active searches for Malleefowl footprints will be conducted at selected sites in order to verify unusual postal records or where the current distribution of the species is still not well known and where declines are suspected. In sandy areas, searching for Malleefowl footprints is a reliable and efficient method of detecting the presence of the species. Prints of Malleefowl are readily identified as they are distinctive and easily photographed, and they generally persist on the ground for days or weeks. Sites will be selected from areas where Malleefowl may have occurred in the past (as suggested by historical records, see Appendix II), where continuing declines are suspected, and where the substrate is sandy and loose (as is mostly the case in Malleefowl habitat). A standard method will be followed at each site and observers will record the frequency at which footprints are encountered, whether these were from single or paired birds, the location and distance searched, and the number of days since rain or strong winds. The data collection phase of this project would be suitable for volunteers.

Mapping of available habitat will be achieved using existing GIS maps and satellite imagery. Malleefowl distribution will be mapped and related to clearing history, fire history, major types of land tenure (freehold, leasehold, reserves and uncommitted), patch size and landscape connectivity.

Results will be stored by the recovery team on a database and made freely available for research.

Costs

The cost of this project involves material and postage costs (approx. $1 per send-out) and the cost of a part-time project officer in each region. It may be feasible for one project officer to conduct the work in more than one region. Cost of salaries might be reduced by utilising volunteer networks.

Annual cost summary ($000s)

	Yr1	Yr2	Yr3	TOTAL
Postal survey salaries and report[1]	36.2	0	0	36.2
Field verification salaries and report[2]	18.1	18.1	0	36.2
Vehicle	6.5	6.5	0	13.0
Miscellaneous	6.8	0.9	0	7.7
National Total	67.6	25.5	0.0	93.1

Notes on costing: 1) 32 weeks @50k/yr plus on costs (18%); 2) 16 weeks @50k/yr plus on costs (18%).

Objective 11: Examine population dynamics: longevity, recruitment and parentage

An understanding of the population dynamics of Malleefowl is essential in order to plan effective recovery actions.

Action 11.1. Examine the feasibility of automatic recorders for identifying Malleefowl and develop capture techniques.

Specific Aims

Assess the effectiveness of transponder readers and various antenna designs for automatically recording the identity of adults at nests, assess the effect of implanting transponders into neonate chicks, and refine methods of capturing adult Malleefowl.

Justification

Measuring the longevity of breeding Malleefowl and the recruitment of young into the breeding population are dependent on developing efficient methods of capturing the birds and subsequently identifying them in the field. Identification can be achieved by conspicuous methods of marking birds (e.g. colour bands, wing-tags), or electronically by use of passive integrated transponders (PITs). With PIT technology, automatic recorders are often used to identify animals. In regard to Malleefowl, this would provide a large saving in the on-going cost of labour as the PIT reader would only need to be moved between active mounds at each site rather than requiring teams of observers to visually identify birds from hides. PIT technology is proven and widely used in industry, zoos, husbandry and wildlife research. Most studies suggest the effects of PITs on birds are comparable with bands (which are unsuitable for young Malleefowl) and PITs probably have less detrimental effects than radio-transmitters. How PIT technology can be best employed for examining Malleefowl population structure and recruitment requires some captive and field study.

Methods

Correct placement of the reader antenna within a Malleefowl's mound is critical to reading the implanted PITs. The effectiveness of various antenna configurations at different positions within the mound will be examined by observation of both the transponder reader and the birds' behaviour in the mound. Breeding Malleefowl at Adelaide and Western Plains Zoos have already been implanted with miniature Trovan transponders in their breast muscles and this study could commence without further handling of the birds. These transponders have a read range of about 10 cm and may be implanted in either adults or chicks. Other systems are available that use larger transponders with a reliable read-range of 60 cm (e.g. TIRIS by Texas Instruments) and would be suitable for adults but not neonate chicks.

Efficient and rapid capture of breeding pairs may be possible using new trapping techniques based on behavioural lures (J. Benshemesh, unpublished data). These techniques will be trialed in the field on 15 breeding pairs. The birds need not be caught during this trial, as the success of a technique may be measured by the time taken to lure both the male and female of a pair into a confined area.

Costs

Annual cost summary ($000s)

	Yr1	Thereafter	Total
Salaries and report[1]	13.6	0	13.6
Transponder reader	3.0	0	3.0
Travel & expenses	3.0	0	3.0
National Total	19.6	0	19.6

Notes on costing: 1) 12 weeks @50k/yr plus on costs (18%).

Action 11.2. Measure the longevity of breeding Malleefowl and the turnover of the breeding population, both in areas where fox numbers are reduced and where they are not reduced.

Justification

The adequacy of recruitment in Malleefowl populations is of central concern to the conservation of the species and requires firm measures of the average breeding life span of wild Malleefowl and estimates of the turnover of birds in the breeding population. These are essential for modelling the viability of Malleefowl populations, and cannot be reliably obtained by other means. The effect of reducing fox abundance on these parameters is also important information and will provide insights into the effects of these predators on the population dynamics of Malleefowl.

Methods

Six sites will be selected from those established for monitoring (Action 9.1, 9.2), three of which will be baited for foxes and these will be paired with similar sites at which fox numbers are not reduced. These three pairs of sites will be located across the southern range of the species in WA, SA, and VIC/NSW.

It is important that all these sites be isolated and contain no more than about 15 breeding pairs [potential monitoring sites include Wandown and Menzies (Vic), Ferries-MacDonald (SA), Foster's Rd (WA)]. During the first year, all breeding birds will be caught and permanently marked with both transponders and conventional bands or tags for identification in later years. Blood and feather samples will also be obtained from all handled birds and deposited in museum collections for future genetic reference.

In subsequent years, the presence of every bird at the site will be monitored annually using automatic equipment that is moved from nest to nest during the breeding season (or by direct observation if necessary). This equipment (transponder 'fixed-reader') will be solar powered and, while at a mound, will log the identity of every bird implanted with a transponder that visits that mound. Useful estimates of longevity and population turnover are likely to involve at least five to ten years of data collection assuming an average longevity of 10-20 years for breeding birds.

The work will include the development of standards and protocols for monitoring and the use of the equipment, and production of reporting forms for the information collected in subsequent years. These will be provided in the form of a methods manual and database.

This project could proceed using visual markers alone on birds (see Priddel & Wheeler 2003). However, annual costs of identifying the birds would be much greater, and the effort involved may be more difficult to sustain over several years. The proposed method that involves moving PIT readers from mound to mound requires much less time and effort and makes direct measurement of recruitment possible (Action 11.3).

Costs

State and National costs summary for 6 sites ($000s)

Year	Yr1 [1]	Yr2 [2]	Yr3	Yr4	Yr5	Total
WA (2 sites)	25.0	5.6	5.6	5.6	5.6	47.4
SA (2 sites)	25.0	5.6	5.6	5.6	5.6	47.4
VIC/NSW (2 sites)	25.0	5.6	5.6	5.6	5.6	47.4
National Total	75.0	16.8	16.8	16.8	16.8	142.2

Notes on costing: 1) Each site costing 4 weeks @50k/yr plus on costs (18%)=4.5k, plus 2k vehicle, plus 6k equipment;and 2) Each site costing a total of 10 days@40k/yr plus on costs (18%) plus 1k vehicle. Note that costs after the first year could be reduced by over 60% if volunteers were involved.

Comments

- This is a long-term project and monitoring of the populations at the six sites will continue at least until the half-life of the population is determined. This will almost certainly be more than the five years costed here.
- Community involvement in this project is encouraged as most costs are those for labour and the tasks involved in monitoring are interesting and informative.
- As Malleefowl will become individually known, monitoring the survival and movements of Malleefowl will be likely to boost community interest by enabling people to learn of the birds' habits over several years. This is also likely to increase interest in the grid based monitoring program, the Malleefowl recovery process, and conservation generally.
- While monitoring has been budgeted every year and this is recommended, less frequent monitoring would not jeopardise the value of this action.

Action 11.3. Measure recruitment of young into breeding populations by marking and releasing chicks, and subsequently monitoring breeding adults.

Justification

The adequacy of recruitment in Malleefowl populations is of central concern to the conservation of the species. This long-term project will provide firm measures of the rate and pattern of recruitment of young into the breeding populations, the seasonal conditions under which successful recruitment of young occurs, and the age at which young birds begin breeding. These measures are essential for modelling the viability of Malleefowl populations, and cannot be reliably obtained by other means. The effect of reducing fox abundance on these parameters will also be measured and provide insights into the effect of these predators on the population dynamics of Malleefowl.

Methods

This action is contingent on the success of Action 11.1 and the implementation of Action 11.2.

Chicks will be marked with transponders at four of the six sites at which adult identity is monitored (above). Two of these will be baited for foxes, and these will be paired with similar sites at which fox numbers are not controlled. Chicks will be obtained either by artificially incubating eggs removed from mounds, or by trapping chicks as they emerge from mounds in the field. These chicks will be implanted with a transponder, measured, weighed, and released at the mound from which they originated within as short a period of time as is feasible in order to minimise behavioural changes due to captivity. Up to 100 chicks (6-8 clutches) will be treated in this way at each site and this program will continue for five years to sample different seasons. Within any one season, representation will be similar for the chicks that emerge early (November-December) from mounds, and those that emerge late in the season (February-March).

It is important for neonate chicks to be the focus of this study rather than older captive-reared birds. Although losses are expected to be high (very few are expected to survive to breeding age) the results from using neonate chicks will best reflect the natural situation and will also minimise housing costs.

Genetic samples will be obtained from every chick and deposited in museum collections for future genetic reference. Samples obtained during the first two years will be used to determine the chicks' parentage. Although Malleefowl are assumed to be monogamous, extra-pair matings are likely for this species, and a clearer understanding of the species' mating systems will provide important information on their conservation genetics.

Costs

State and National costs summary for four sites ($000s)

Year	Yr1	Yr 2	Yr 3	Yr 4	Yr 5	Total
Set-up[1]	8.0	0	0	0	0	8.0
Genetic analysis of parentage	2.5	2.5	0	0	0	5.0
Analysis and report	0	10.0	0	0	0	10.0
Annual costs[2]	18.4	18.4	18.4	18.4	18.4	92.0
National Total	28.9	30.9	18.4	18.4	18.4	115.0

Notes on costing: 1) Setup costs involve an incubator and training at each of the four sites; and 2) Salaries at each of four sites costing 10 days @50k/yr plus on costs (18%)=2.3k for collecting, implanting and release of chicks, plus 1.2k vehicle, plus 1.1k transponders and injectors.

Objective 12: Describe habitat requirements that determine Malleefowl abundance

Action 12.1. Describe the habitat requirements and preferences of Malleefowl, with a view to identifying important habitat components that may underlie variations in breeding densities.

Justification

Little is known about the habitat features that are important for the persistence and success of Malleefowl. A detailed analysis of these requirements will provide a basis for understanding the response of the species to a range of factors and the birds' habitat preferences in general. This will elucidate the factors that are limiting the abundance of the species. Other benefits for management will include the ability to:

- specify management practices that may enhance the suitability of habitat for Malleefowl;
- identify areas that may or may not be suitable for translocation of Malleefowl;
- identify habitats that may become more important for Malleefowl in the future, such as those that are currently regenerating after fire or past grazing.

An understanding of the habitat requirements of the species is particularly pertinent now, considering predicted climate changes and the effects this may have on habitats that Malleefowl occupy.

Methods

This work will be conducted across all states and use the monitoring grids where the abundance of Malleefowl has previously been determined. There are currently over 60 such sites across Australia where densities have been measured, and in many cases there is trend data spanning over a decade. These will provide a firm basis for multivariate analyses and modelling.

Sampling strategies will be developed to measure habitat variables and involve statistically adequate replicates at each site. Variables will be selected to provide indices of habitat structure, substrate, abundance and diversity of food types, climate/rainfall, predator abundance, disturbance history (e.g. fire, grazing, etc.) and landscape characteristics such as reserve size, connectivity, and distance from open habitats such as woodlands or agricultural land. In particular, indices of food abundance will focus on general classifications (i.e. herbs, seeds, insects) of those foods known to be consumed by Malleefowl. Sampling will occur in spring when annual plants are present, and in autumn when food is most likely to be in short supply.

Analysis will focus on the identification of critical factors that explain the large variations in breeding density across Australia. In this regard, specific hypotheses will be extracted from the literature and tested against the data set. The monitoring data will be made available to the project and an effort will also be made to explain temporal trends in Malleefowl abundance. All data collected in this study will be available to the recovery team and archived in its raw form for future reference.

Costs

The major costs associated with this action will be salaries for one full-time research officer for 12 months and one full-time field assistant for four months during data collection. The work will be conducted in the second or third year of this plan after the Malleefowl breeding densities have been determined at a range of sites in Western Australia and New South Wales. The work would suit post-graduate research (MSc or PhD) or professional ecologists.

National costs summary ($000s)

	Yr1	Thereafter	Total
Salary: Project officer (12 mo)	59.0	0	59.0
Salary: Assistant (4 mo)	15.4	0	15.4
Vehicle and travel	8.0	0	8.0
Miscellaneous	2.5	0	2.5
National Total	84.9	0	84.9

Notes on costing: 1) Project officer for 12 months @50k plus on costs (18%); and 2) Assistant 4 months @40k/yr plus on costs (18%).

Objective 13: Define appropriate genetic units for management of Malleefowl

Action 13.1. Perform mitochondrial and nuclear DNA analyses of Malleefowl populations across the species' range, and determine where major disjunctions in genetic variation occur.

Justification

The geographic distribution of genetic variability in Malleefowl throughout its range is not known. However, this is essential information if this genetic diversity and the species in general are to be conserved. In particular, an understanding of the genetic structure of the species is essential for the management of its fragmented populations and for rational implementation of translocation programs such as re-introductions and supplementation of existing populations. Reasons to suspect that genetic differentiation of populations may have occurred include the enormous range and presumed low vagility of the species, fragmentation of its range, and because morphological differences between western and eastern birds have been suggested by some authorities.

This action, involving both mitochondrial and nuclear DNA analyses, will provide a definitive description of the genetic variation in Malleefowl across Australia. This will provide an objective measure of the appropriate units of management for the species and how these relate to political and administrative boundaries.

Methods

Malleefowl genetic material, in the form of tissues from embryos and feathers, has been collected across the species' range. Blood or tissue samples from adults, and skin and feather samples from museum specimens, have also been collected from zoos and museums around Australia. To date, the South Australian Museum has examined genetic variation in a portion of the mitochondrial *cytochrome oxidase 1* gene from six individual Malleefowl from across the species' range. While each had a unique mitochondrial haplotype, the level of sequence divergence was very low, ranging from 0.3% to 0.8%. (Steve Donnellan pers. comm.). Sequence divergence among *cytochrome oxidase 1* genes of other megapode species ranges from 5% to 21.5% indicating that megapodes do not have an intrinsically slow rate of *cytochrome oxidase 1* molecular evolution,and thus these preliminary results on the Malleefowl specimens suggest there may be low diversity within the species (Steve Donnellan pers. comm.). .

The South Australian Museum now plans to examine genetic variation in mitochondrial genes and nuclear microsatellite loci. Classification of management units for Malleefowl requires information from both of these types of genetic markers. Sufficient samples are available to complete an analysis of the distribution of genetic variation in the Malleefowl. However funds are required to complete the mitochondrial DNA analysis and to isolate microsatellite markers and type the samples. An application has been made to the Australian Research Council to fund this work and also to develop a landscape genetic approach ((Manel et al. 2003, Storfer et al. 2007) and conduct population viability analyses of Malleefowl populations, through the ARC Linkage Grants scheme.

Technical officers will conduct these analyses on the available genetic material at the South Australian Museum and the University of Melbourne over two years. Scientific staff at that institution will supervise all aspects of the work including reporting of the results and detailing the management implications.

The study is designed to test for population sub-structuring at the local, regional and national levels. The following milestones are listed in temporal order:

- find variable mitochondrial marker(s) and assess the level of molecular diversity;
- determine the best sampling design and method of analysis,
- isolate, characterise and determine the variability of at least 8 microsatellite loci;
- assess the population structuring at the national level, and for selected regions; and
- assess local genetic structuring to identify landscape features that promote or impede population connectivity.

Costs

Itemised costs ($000s)

MtDNA typing	
Preparation of tissue samples	1.0
128 samples at $28/sample	3.6
Salary: technical officer 8 months	17.6
Microsatellite Isolation and Typing	
Isolation and PCR primer design for 8 loci	5.0
Typing of 200 samples for 8 loci	4.5
Salary: part-time technical officer 12 months	26.4
TOTAL	58.1

National costs summary ($000s)

Year	1	2	Thereafter	Total
Salaries [1]	15.9	28.1	0	44.0
Materials [2]	4.6	9.5	0	14.1
National Total	20.5	37.6	0	58.1

Notes on costing: 1) Part time technical officer over 20 months; and 2) MtDNA typing of 128 samples incl. prep.= 4.6k, plus microsatellite isolation and typing for 8 loci and 200 samples= 9.5k.

Objective 14: Assess captive breeding and re-introduction of Malleefowl.

General Comments

Re-introduction is a management option which aims at re-establishing a species (such as Malleefowl) where it has become locally extinct, whereas supplementation involves adding individuals to an existing population where it is shown that the population cannot survive without additional individuals.

Re-introduction and supplementation of Malleefowl populations should only be undertaken after first restoring the integrity of habitats (e.g. reducing grazing and predators, fire protection, fencing, restoring connectivity; see Objectives 1 to 7); verifying that the intended release sites are suitable habitat for the long-term success of Malleefowl (Objective 12); and ensuring that risks of disease transmission have been assessed and mitigated through appropriate captive husbandry and translocation protocols. Ideally, these programs should be conducted after the current distribution and abundance of the species has been detailed (Objective 10), and the appropriate genetic units for management have been determined (Objective 13). For supplementation as an ongoing management program it is also important to understand the population dynamics of the species (Objective 11) so that a suitable number of birds can be introduced into existing populations. Pending the collection of some of these data and a review of translocation programs, efforts to conserve Malleefowl should be concentrated on the wild populations in the short to medium term.

Before further re-introduction/supplementation programs are initiated, it is important to assess the success of current and past programs. Ideally, success should be measured in terms of the establishment of self-sustaining breeding populations although such results may not be obtained for at least five years following the releases. The regional management plans (Objective 8) will provide a basis for translocation programs should they be shown to be required.

Action 14.1. Review past and current translocation, captive-rearing and breeding programs

Specific Aims

Assess the success of the current programs in terms of the fates of eggs and birds while in captivity and determine the causes of bird losses and injuries with a view of minimising these in the future. Provide a husbandry manual for captive-raising and captive-breeding Malleefowl for the purpose of re-introduction and supplementation of populations. Clarify the future direction of the Western Plains Zoo and its role in providing a continuing captive breeding program for re-introduction or supplementation of Malleefowl populations.

Justification

There have been three captive-rearing programs in recent years in NSW (involving DECC NSW and the Western Plains Zoo), WA DEC (“Project Eden” involving CALM), and in SA (involving DEH and Adelaide Zoo at Monarto). The success of these programs has differed markedly in terms of survival of eggs and birds while in captivity and after release. There are clearly lessons to learn to improve husbandry techniques. Accordingly, the techniques that have been used should be assessed, and the most successful methods should be documented to improve the success of current and future programs. The role of the captive-breeding programs should also be reviewed and clarified.

Methods

Data on the sources, reasons for losses, and ultimate fate of all birds held in captive-rearing programs will be collated. A husbandry manual for Malleefowl in captivity will be produced by Western Plains Zoo with input from NSW DECC, WA DEC, the Adelaide Zoo, and Mr Whimpey Reichelt (Little Desert Lodge, Vic). This husbandry manual will include guidelines for collecting, transporting and incubating eggs, and the subsequent diet, care and handling of Malleefowl while they are in captivity. A studbook will be developed by Western Plains Zoo for the birds across Australia that are held and bred in captivity. The role of the Western Plains Zoo in providing a continuing captive-breeding program for ecological research and re-introduction/supplementation of Malleefowl populations will also be reviewed.

Opportunities and protocols for collecting baseline data on the disease status of Malleefowl populations (both wild and captive) should be investigated through liaison with the Wildlife Health Network and any future research projects.

Cost

National costs summary ($000s)

	Yr 1	Thereafter	Total
Husbandry Manual and Studbook[1]	9.0	0	9.0
Review[1]	9.0	0	9.0
National Total	18.0	0	18.0

Notes on costing: 1) 8 weeks@50k/yr plus on costs (18%).

Objective 15: Investigate infertility and agrochemicals

Action 15.1. Assess the extent of infertility of Malleefowl in small reserves and investigate the possibility that this is caused by senescence, inbreeding depression and/or agricultural chemicals used on crops and pastures in which the birds feed.

Justification

Several anecdotal accounts suggest that Malleefowl fertility is declining in small habitat remnants near croplands (S. Donellan and R. Foster pers. comm 1996; see also Brickhill 1987a). As Malleefowl frequently feed on the edges of crops and pastures, it is possible that this effect is due to agricultural chemicals although there is little evidence as yet to support this hypothesis. Other possible causes include senescing individuals and inbreeding depression. This action would document the extent of the problem and determine whether a larger study is warranted.

Method

A sample of six small reserves bordered by cropland will form the basis of this action, and these sites will be selected in south-east SA where there are considerable data on the distribution of Malleefowl, and where chemically induced infertility has been speculated. Up to three mounds per site will be sampled, and mounds would be excavated at least four times during the breeding season using established techniques to determine the number of eggs laid and hatching success, and to non-destructively obtain genetic samples (such as egg membranes remnant after hatching). These data will be compared to previous detailed studies that have described the reproductive output and hatching success of Malleefowl at a range of reserves. A list of chemicals used in the recent past on adjacent crops where Malleefowl feed will be sought from relevant farmers. If this study does reveal low fertility it may be necessary to collect further samples by destructive sampling of eggs, or by artificially incubating eggs and releasing chicks after blood and other samples have been obtained (this stage of the study is subject to the demonstration of low fertility and is not costed at this stage).

All birds found dead on roadsides or elsewhere will be collected and sent to wildlife authorities either fresh or frozen. Analyses of these birds will include genetic analysis, examination of the cause of death, the likely age of the specimen, and the condition of its reproductive organs. Genetic samples will be obtained from all specimens and lodged in museums and made available to genetic studies (Action 13.1).

Costs

Costs are estimated for a consultant, but tertiary students or community members with appropriate training could conduct this project.

National costs summary ($000s)

	Yr1	Thereafter	Total
Salaries (consultant)	5.6	0	5.6
Vehicle	1.6	0	1.6
National Total	7.2	0	7.2

C) COMMUNITY INVOLVEMENT AND PROJECT COORDINATION

Objective 16: Facilitate communication between groups

Action 16.1 Hold a national Malleefowl community forum every three years and support the national newsletter

Justification

The involvement and support of the public has been and will increasingly be crucial to the Malleefowl recovery effort across Australia. Community groups have been instrumental in establishing monitoring sites, monitoring breeding numbers, collecting feathers for genetic analyses, survey and soliciting records, education, and improving habitat by establishing corridors, fencing out stock and reserving land. The geographic range of Malleefowl means these groups often work in isolation although they face similar challenges across the continent. Moreover, groups often perceive they have few avenues available for advice and are often reluctant to directly approach wildlife authorities or other community groups. Triennial national forums will encourage the formation of a network of volunteers and other people interested in Malleefowl conservation across Australia and provide the means for them to communicate effectively between themselves and with the recovery team.

Methods

The national Malleefowl conservation newsletter “Around the Mounds” will continue to provide biannual updates of progress toward Malleefowl conservation across Australia, particularly in terms of the Recovery Plan. National Malleefowl Forums foster a nationwide community attitude, facilitate links with a variety of people and to the recovery team, and provide a means of focussing the considerable community involvement onto the most effective recovery actions. Forums have been held in 1995 (Adelaide), 2004 (Mildura) and 2007 (Katanning) and will be held triennially thereafter in alternating states. Important issues to be addressed at the next forum include the implementation of this recovery plan and, in particular, the adoption of a national adaptive management approach to the monitoring program (Objective 9). Adaptive management requires a high degree of consultation and collaboration, and these are best achieved through public meetings that include all stakeholders.

Costs

Costs for the Malleefowl Forum involve transport for delegates, conference organisation and venue, and publication of proceedings.

National costs summary ($000s)

	Yr1	Yr2	Yr3	Yr4	Yr5	Total
National Total	32.0	2.0	2.0	32.0	2.0	70.0

Notes on costing: National newsletter support @2k/year, forum @30k every 3rd year.

Objective 17: Raise public awareness through education and publicity

Action 17.1 Publicise the recovery effort, beneficial management practices, and the contributions made by community groups.

Justification

The involvement and support of the public is vital for the recovery effort in both on-ground management and research actions. Community groups provide an important avenue of disseminating information about Malleefowl conservation and beneficial management. The Malleefowl is popular in rural areas and is also a useful flagship species as it and many of the management actions required to secure existing populations are of a general benefit to conservation. Public recognition of the contributions of community groups is important to maintain the enthusiasm and interest of these groups. This publicity will also assist groups in recruiting members, and raise public awareness of conservation in general, and Malleefowl in particular.

Methods

A number of community groups and individuals regularly present information on Malleefowl and the recovery effort to the wider public. This information is presented in talks to local organisations, clubs, and schools, and by displays at field days, fairs, and rural community centres. This service has great potential for publicising, to a diverse array of landholders and land-managers, the threats to Malleefowl, and beneficial management practices. The continuation of these services will be encouraged and supported by the recovery team. While remuneration for this service is usually not required, assistance in developing displays and presentations would greatly enhance the educative value of this publicity.

Public zoos that display Malleefowl will display information about the Malleefowl recovery effort with emphasis on community involvement. Community groups should develop a close working relationship with media units in such zoos and with the Threatened Species Network, as collaboration would provide mutual advantages for public relations and the conservation of Malleefowl.

Costs

Zoos that exhibit Malleefowl exist in NSW, SA, VIC, and WA. Community members in these states also provide presentations to schools and other groups.

National costs summary ($000s)

Year	Yr1	Yr2	Yr3	Yr4	Yr5	Total
Assistance for presentations and displays by community groups (4 states)	8.0	4.0	4.0	4.0	4.0	24.0
Display boards at Zoos (4 zoos)	8.0	0	0	0	0	8.0
National Total	16.0	4.0	4.0	4.0	4.0	32.0

Objective 18: Manage the recovery process

Action 18.1 Regularly review progress in the recovery plan and manage the recovery process on a national and state level through teams with appropriate expertise and community standing, and appropriate reporting.

Justification

The existing Recovery Plan must be reviewed and modified as necessary in the light of new information, and progress on actions must be coordinated and monitored throughout the species' range. The recovery team is the appropriate body to undertake this management, and should continue to include representation of community groups. On a state level, government and non-government agencies, zoos, and various independent community groups have been and are likely to be involved in recovery actions, and representatives of these interested parties should meet regularly to review progress and coordinate activities.

Methods

Meetings of the national recovery team will be convened once a year or more often if appropriate. In the past, meetings of the Malleefowl Recovery Team have been by phone-conference or arranged to coincide with other species' recovery team meetings. The team will comprise representatives from wildlife authorities in each state in which Malleefowl occur; the Australian Government Department of the Environment, Water, Heritage and the Arts; Birds Australia; Threatened Species Network; academics and researchers; and community representatives from each state with an active recovery group. Invitations to attend the meetings as observers will also be extended to the TSN coordinator and wildlife authorities in the Northern Territory.

State based recovery groups will be convened once a year in early spring or more often if needed. State groups will focus on facilitating and implementing the recovery actions, particularly at the community level, and coordinating the activities of individual parties.
Regional reports against the actions and performance criteria in this plan should be completed annually, and compiled as state and national reports. The most appropriate group or agency to complete the regional reports will vary between regions, and will be identified by the state recovery group.

Costs

National costs summary ($000s)

Year	Yr1	Yr2	Yr3	Yr4	Yr5	Total
State group meetings (4 states)	5.0	5.0	5.0	5.0	5.0	25.0
National meetings	5.0	5.0	5.0	5.0	5.0	25.0
National Total	10.0	10.0	10.0	10.0	10.0	50.0

Notes on costing: Costs are for phone conferences, travel expenses and reporting of minutes. In kind salary costs are not included.

E Management practices

Part D, Section A details management practices that are necessary to avoid a significant adverse impact on the species. Management practices are likely to be beneficial to Malleefowl where they:

- Secure habitat in which Malleefowl occur;
- Maintain and create linkages between suitable Malleefowl habitat patches;
- Reduce the chance of large fires (planned or unplanned) that may burn most or all suitable habitat within a few years, and increase the chance of unburnt patches of habitat remaining after fire;
- Manage total grazing pressure (stock, feral and native) to low levels where Malleefowl occur;
- Control introduced foxes and cats that prey upon Malleefowl;
- Encourage the reliable availability of Malleefowl foods (e.g. asynchronous cropping);
- Reduce mortality on roads;
- Integrate with large scale programs that attempt to clarify the most efficient management practices (e.g. the adaptive management approach, Objective 9). This will require a degree of commitment, and in some areas may require restraint of some management actions in order to assess their effectiveness.

F Duration and costs

Duration

This recovery plan outlines actions for improving the conservation status of Malleefowl for a five-year period, starting in 2008. Costings are indicative only and intended to guide government agencies, CMA/NRM boards, and university researchers in their budgeting processes.

Note: Over one third of the projected costs below are expected to be covered by voluntary contributions from community groups involved in a range of activities. Asterisks denote actions for which volunteer contributions (VC) are likely to lead to greatest savings.

Five year Budget ($000s)

Action		Yr1	Yr2	Yr3	Yr4	Yr5	*Total*	*VC*	*Priority*
8.1	Prepare regional conservation plans	0	0	56.6	0	0	*56.6*	*	1
9.1	Analyse and review monitoring, and develop adaptive management	54	64	0	0	0	*118.0*	*	1
9.2	Monitor breeding densities	208	178	178	178	178	*920.0*	***	1
9.3	Fox control (8 sites)	57.4	57.4	57.4	57.4	57.4	*287.0*	*	2
9.4	Facilitate and coordinate monitoring efforts	49.7	16.3	16.3	11.8	11.8	*105.9*	*	1
10.1	Distribution of Malleefowl in remote areas	79.1	70.1	35.6	35.6	35.6	*256.0*		1
10.2	Distribution of Malleefowl in settled areas	67.6	25.5	0	0	0	*93.1*	*	3
11.1	Feasibility of PIT readers	19.6	0	0	0	0	*19.6*	*	1
11.2	Monitor population turnover	75.0	16.8	16.8	16.8	16.8	*142.2*	***	2
11.3	Monitor recruitment	28.9	30.9	18.4	18.4	18.4	*115.0*	**	2
12.1	Habitat requirements	84.9	0	0	0	0	*84.9*	*	3
13.1	Genetic units for management	20.5	37.6	0	0	0	*58.1*		1
14.1	Review role of captive breeding	18.0	0	0	0	0	*18.0*		3
15.1	Assess infertility	7.2	0	0	0	0	*7.2*		3
16.1	National forum and newsletter	32.0	2.0	2.0	32.0	2.0	*70.0*	**	1
17.1	Raise awareness	16.0	4.0	4.0	4.0	4.0	*32.0*	**	2
18.1	Manage recovery process	10.0	10.0	10.0	10.0	10.0	*50.0*	*	1
	TOTAL	827.9	512.6	395.1	364	334	*2433.6*		

References

Agriculture Western Australia, Department of Conservation and Land Management, Department of Environmental Protection, and the Waters and Rivers Commission. 1996a. Salinity: a situation statement for Western Australia. A report to the Minister for Primary Industry and the Minister for the Environment. Pages 1-37.Government of Western Australia, Perth.

Agriculture Western Australia, Department of Conservation and Land Management, Department of Environmental Protection, and the Waters and Rivers Commission. 1996b. Western Australia Salinity Action Plan. Government of Western Australia, Perth.

Bailey, C. 1996. Western Shield: bringing wildlife back from the brink of extinction. Landscope **11**:41-48.

Baker-Gabb, D. 2001. Recovery Plan for the Black-eared Miner *Manorina melanotis* 2002-2006. Department of Environment and Heritage (SA), Adelaide.

Baker-Gabb, D. 2004. Recovery Plan for the Mallee Emu-wren, Red-lored whistler, Western Whipbird and other threatened mallee birds. (DRAFT). Department of Environment and Heritage, Canberra.

Barker, R. D., and W. J. Vestjens 1981. The Food of Australian Birds, Vol.I; Non-passerines. CSIRO, Melbourne.

Barrett, C. 1919. In Australian Wilds, The Gleanings of a Naturalist. Melbourne Publishing Company, Melbourne.

Barrett, G., A. Silcocks, R. Poulter, S. Barry, and R. Cunningham 2003. Australian Bird Atlas 1998-2001: Main Report to Environment Australia. Birds Australia, Melbourne.

Bellchambers, T. P. 1916. Notes on the Mallee Fowl. South Aust. Ornith. **2**:134-140.

Bellchambers, T. P. 1918. Notes on the mallee fowl (*Leipoa ocellata rosinae*) No. 2. South Aust. Ornith. **3**:78-81.

Bennett, S., R. Brereton, I. Mansergh, S. Berwick, K. Sandiford, and C. Wellington. 1991. The potential effect of the enhanced greenhouse climate change on selected Victorian fauna. Pages 1-224. Dept. Conservation and Environment, Victoria, Melbourne.

Benshemesh, J. 1990. Management of Malleefowl with regard to fire. Pages 206-211 in J. C. Noble, P. J. Joss, and G. K. Jones, editors. The Mallee Lands, a Conservation Perspective. CSIRO, Melbourne.

Benshemesh, J. 1992a. The conservation ecology of Malleefowl, with particular regard to fire. Pages 1-224.Monash University, Clayton.

Benshemesh, J. 1992b. Recovery plan research phase for Malleefowl. Pages 1-38.Australian National Parks and Wildlife Service, Canberra.

Benshemesh, J. 1995a. Malleefowl in the Anangu-Pitjantjatjara Lands: report on the spring 1995 expedition.Department of Environment and Natural Resources, Adelaide.

Benshemesh, J. 1995b. Monitoring Malleefowl in NW Victoria: 1994/5. Pages 1-56. Department of Natural Resources and Environment, Mildura.

Benshemesh, J. 1996a. Malleefowl in the Anangu-Pitjantjatjara Lands: report on the autumn 1995 expedition. Department of Environment and Natural Resources, Adelaide.

Benshemesh, J. 1996b. Monitoring Malleefowl in NW Victoria: 1995/6. Department of Natural Resources and Environment, Mildura.

Benshemesh, J. 1997a. Caring for Nganamara. Wingspan **7**:16-21.

Benshemesh, J. 1997b. Review of Malleefowl monitoring in Victoria. Pages 1-56. Flora and Fauna Technical Report No. 148. Department of Natural Resources and Environment, Melbourne.

Benshemesh, J. 2004. Monitoring malleefowl: Options, problems and solutions. Pages 128-134. Proceedings of the National Malleefowl Forum 2004, Mildura. Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Benshemesh, J. 2005. Malleefowl monitoring in Victoria 2004/5. Unpublished report to Victorian Malleefowl Recovery Group, Melbourne.

Benshemesh, J. 2006a. Data collation report. Unpublished report to the Victorian Malleefowl Recovery Group and the Mallee Catchment Management Authority, Mildura. http://www.malleefowlvictoria.org.au/milestone1-1.pdf.

Benshemesh, J. 2006b. Gap analysis of monitoring and associated data and an update on data collection. Unpublished report to the Victorian Malleefowl Recovery Group and the Mallee Catchment Management Authority, Mildura. http://www.malleefowlvictoria.org.au/milestone1-2.pdf.

Benshemesh, J. 2007. Review of data routinely collected in the national malleefowl monitoring program. Unpublished report to the Victorian Malleefowl Recovery Group and the Mallee Catchment Management Authority, Mildura

Benshemesh, J. 2008. Advice to Natural Resource Management regions regarding management and monitoring of Malleefowl. Victorian Malleefowl Recovery Group and the Mallee Catchment Management Authority, Mildura.

Benshemesh, J., R. Barker and M. MacFarlane. 2007. Trend analysis of Malleefowl monitoring data (revised version). Unpublished report to the Victorian Malleefowl Recovery Group and the Mallee Catchment Management Authority, Mildura. http://www.malleefowlvictoria.org.au/milestone1-3.pdf.

Benshemesh, J., and P. Burton. 1997a. Fox predation on Malleefowl after the spread of RCD in Victoria: The first Malleefowl breeding season. Pages 1-29. Parks Victoria and Department of Natural Resources and Environment, Mildura.

Benshemesh, J., and P. Burton. 1997b. Monitoring Malleefowl in NW Victoria: 1996/7. Pages 1-38. Parks Victoria and Department of Natural Resources and Environment, Mildura

Benshemesh, J., and P. Burton. 1999. Fox predation on Malleefowl three years after the spread of RCD in Victoria. Parks Victoria and Department of Natural Resources and Environment, Mildura.

Benshemesh, J. and W.B Emison, W.B. (1996). Surveying Malleefowl breeding densities using an airborne thermal scanner. Wildlife Research 23: 121-142.

Benshemesh, J., and Malleefowl Preservation Group. 2001. Community searches for Malleefowl at Yeelirrie, August 2000. Malleefowl Preservation Group, Ongerup, WA.

Benshemesh, J., A. Stokie and P. Stokie. 2008. Final report of the National Malleefowl Monitoring, Population Assessment and Conservation Action Project. Unpublished report to the Victorian Malleefowl Recovery Group and the Mallee Catchment Management Authority, Mildura

Binning, C., and M. Young. 1997. Motivating people: Using management agreements to conserve remnant vegetation. Pages 1-78.CSIRO Wildlife and Ecology, Lyneham, ACT.

Blakers, M., S. J. J. F. Davies, and P. N. Reilly 1984. The Atlas of Australian Birds. RAOU and Melb. Univ. Press, Melbourne.

Blakers, M., and L. McMillen. 1988. Mallee conservation in Victoria. Pages 1-52.RMIT Faculty of Enviromental Design and Construction, Melbourne.

Booth, D. T. 1984. Thermoregulation in neonate malleefowl *Leipoa ocellata*. Physiol. Zool. **57**:251-260.

Booth, D. T. 1986. Crop and gizzard contents of two Mallee Fowl. Emu **86**:51-53.

Booth, D. T. 1987a. Effect of temperature on development of Malleefowl *Leipoa ocellata* egg. Physiol. Zool. **60**:437-445.

Booth, D. T. 1987b. Home range and hatching success of Malleefowl, *Leipoa ocellata* Gould (Megapodiidae), in Murray mallee near Renmark, S.A. Aust. Wildl. Res. **14**:95-104.

Booth, D. T. 1987c. Metabolic response of Malleefowl *Leipoa ocellata* embryos to cooling and heating. Physiol. Zool. **60**:446-453.

Booth, D. T., and R. S. Seymour. 1983. Effect of adding water to Malleefowl mounds during a drought. Emu **84**:116-118.

Brickhill, J. 1985. An aerial survey of nests of Malleefowl *Leipoa ocellata* Gould (Megapodiidae) in central New South Wales. Aust. Wildl. Res. **12**:257-261.

Brickhill, J. 1987a. Breeding success of Malleefowl *Leipoa ocellata* in central New South Wales. Emu **87**:42-45.

Brickhill, J. 1987b. The conservation status of Malleefowl in New South Wales. Pages 1-187.University of New England, Armidale.

Byrne, T. 2007. Education package. Unpublished report to the Victorian Malleefowl Recovery Group and the Mallee Catchment Management Authority, Mildura.

Cail, S., and W. Cail. 2004. Landholder and community efforts to protect malleefowl populations in the northern wheatbellt of WA. Page 169. Proceedings of the National Malleefowl Forum 2004, Mildura. Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Campbell, A. J. 1884. Malleehens and their egg mounds. Vict. Nat. **1**:124-129.

Campbell, A. J. 1901. Nests and Eggs of Australian Birds. The Author, Melbourne.

Chandler, L. G. 1934. Notes on the Mallee-fowl. Vict. Nat. **50**:199-201.

Cheal, P. D., J. C. Day, and C. W. Meredith. 1979. Fire in the National Parks of North West Victoria. Pages 1-231.National Parks Service, Melbourne.

Chesterfield, C. J., and R. F. Parsons. 1985. Regeneration of three tree species in arid south-eastern Australia. Aust. J. Bot. **33**:715-732.

Choate, J. H. 1989. Pastoral use and management. Pages 307-317 in J. C. Noble, P. J. Joss, and G. K. Jones, editors. The Mallee Lands, a Conservation Perspective. CSIRO, Melbourne.

Christensen, P., and K. Maisey. 1987. The use of fire as a management tool in fauna conservation reserves. Pages 323-329 in D. A. Saunders, G. W. Arnold, A. A. Burbidge, and A. J. M. Hopkins, editors. Nature Conservation: The Role of Remnants of Native Vegetation. Surrey Beatty and Sons, Sydney.

Christidis, L. & Boles, W. E. 2008. Systematics and taxonomy of Australian birds. CSIRO Publishing, Melbourne.

Clark, G. A. J. 1964. Life histories and the evolution of the megapodes. Living Bird **3**:149-167.

Clarke, R. 2005. Ecological requirements of birds specialising in mallee habitats: modelling the habitat suitability for threatened mallee birds. Department of Zoology, La Trobe University, Melbourne.

Cooper, R. P. 1975. Wilson's Promontory National Park and its Avifauna. Bird Observers Club, Melbourne.

Copley, P., and S. Williams. 1995. Distribution, relative abundance and conservation of Malleefowl in South Australia. Pages 9-35. Working Papers of the National Malleefowl Forum, Adelaide.

Copley, P. B. 1995. Translocations of native vertebrates in South Australia: a review. Pages 35-42 in M. Serena, editor. Reintroduction Biology of Australian and New Zealand Fauna. Surrey Beatty and Sons, Chipping Norton.

Copley, P. B., L. M. Baker, B. J. Nesbitt, L. P. Pedler, D. Hopton, and J. N. Foulkes. 2003. Birds. Pages 243-294 in A. C. Robinson, P. B. Copley, P. D. Canty, L. M. Baker, and B. J. Nesbitt, editors. A biological survey of the Anangu-Pitjantjatjara Lands, South Australia, 1991-2001. Department for Environment and Heritage, South Australia, Adelaide.

Cowley, R. D., A. Heislers, and E. H. M. Ealey. 1969. Effects of fire on wildlife. Victoria's Resources **11**:18-22.

Creagh, C. 1992. New approaches to rabbit and fox control. Ecos **71**:18-24.

Cutten, J. L. 1997. Distribution and abundance of Malleefowl (*Leipoa ocellata*) in the Murray Mallee and South East Regions of South Australia. Pages 1-124. Nature Conservation Society of South Australia, Adelaide.

Daan, S., C. Dijkstra, R. H. Drent, and T. Meijer. 1989. Food supply and the annual timing of avian reproduction. Pages 392-407 in H. Oullet, editor. Acta XIX International Congress of Ornithology. University of Ottawa Press, Ottawa.

Day, J. 1982. Fire history and fire records. Pages 1-6 in A. Heislers, P. Lynch, and B. Walters, editors. Fire Ecology in Semi-arid Lands. CSIRO, Deniliquin.

del Hoyo, J., A. Elliot, and J. Sargatal 1994. New World Vultures to Guineafowl. Lynx Edicions, Barcelona.

Dennings, S. 2004. Gnowing is believing. Pages 110-118. Proceedings of the National Malleefowl Forum 2004, Mildura. Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Denniston, C. D. 1978. Small population size and genetic diversity: implications for endangered species. Pages 281-289 in S. A. Temple, editor. Endangered Birds: Management Techniques for Preserving Threatened Species. Univ. Wisconsin Press, Madison.

Department of Environment and Conservation NSW. 2005. Pest Management in NSW National Parks: foxes fact sheet. Department of Environment and Conservation NSW, Sydney South.

Department of Land and Water Conservation. 1997. Regional planning for clearing and cultivation in the southern mallee, NSW. Department of Land and Water Conservation and the Southern Mallee Regional Planning Committee, Buronga, NSW.

Department of Sustainability and Environment. 2003. Advisory list of threatened vertebrate fauna in Victoria - 2003. Department of Sustainability and Environment, Victoria, East Melbourne, Victoria.

Environment Australia. 2000. Revision of the Interim Biogeographical Regionalisation of Australia (IBRA) and the Development of Version 5.1 - Summary Report.Department of Environment and Heritage, Canberra.

Freeman, A., P. Peeters, and G. Tonkin. 2004. Malleefowl (*Leipoa ocellata*) conservation on Eyre Peninsula, South Australia. Pages 136-144. Proceedings of the National Malleefowl Forum 2004, Mildura. Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Friedel, M. H., and C. D. James. 1995. How does grazing of native pastures affect their biodiversity? Pages 249-259 in R. A. Bradstock, T. D. Auld, D. A. Keith, R. T. Kingsford, D. Lunney, and D. P. Siversten, editors. Conserving biodiversity: threats and solutions. Surrey Beatty and Sons.

Frith, H. J. 1955. Incubation in the Mallee Fowl (*Leipoa ocellata*, Megapodiidae). Acta XI Congressus Internationalis Ornithologici:570-574.

Frith, H. J. 1956a. Breeding habits of the family Megapodiidae. Ibis **98**:620-640.

Frith, H. J. 1956b. Temperature regulation in the nesting mounds of the Mallee-fowl, *Leipoa ocellata* Gould. CSIRO Wildl. Res. **1**:79-95.

Frith, H. J. 1959. Breeding of the Mallee Fowl, *Leipoa ocellata* Gould (Megapodiidae). CSIRO Wildl. Res. **4**:31-60.

Frith, H. J. 1962a. Conservation of the Mallee Fowl, *Leipoa ocellata* Gould (Megapodiidae). CSIRO Wildl. Res. **7**:33-49.

Frith, H. J. 1962b. The Mallee Fowl. Angus and Robertson, Sydney.

Gara, T. 1989. The Aborigine in the Great Victoria Desert. The ethnographic observations of the explorer Richard Maurice. J. Anthrop. Soc. S. Aust. **27**:15-47.

Gardner, C. A. 1957. The fire factor in relation to the vegetation of Western Australia. W. Aust. Nat. **5**:166-173.

Garnett, S. T., and G. M. Crowley. 2000. The Action Plan for Australian Birds. Environment Australia, Canberra.

Gates, J. 2004. A review of Malleefowl conservation in the Murrylands Region, South Australia:1990-2002. Department of Environment and Heritage, Adelaide, SA.

George, R. J., D. J. McFarlane, and R. J. Speed. 1994. The consequences of a changing hydrologic environment for native vegetation in southwestern Australia. Pages 9-22 in D. A. Saunders, J. L. Craig, and E. M. Mattiske, editors. Nature Conservation 4: The Role of Networks. Surrey Beatty and Sons, Chipping Norton.

Gillam, S. 2005. An update of Malleefowl monitoring in South Australia. South Australian Department for Environment and Heritage, Adelaide.

Glanznig, A. 1995. Native vegetation clearance, habitat loss and biodiversity decline: An overview of recent native vegetation clearance in

Australia and its implications for biodiversity. Pages 1-46.Biodiversity Unit, Department of Environment, Sport and Territories, Canberra.

Greenslade, P. 1992. Conserving invertebrate biodiversity in agricultural, forestry and natural ecosystems in Australia. Agric. Ecosystems Environ. **40**:297-312.

Greenwood, G., and R. Boardman. 1989. Climate change and some possible effects upon the terrestrial ecology of South Australia. Pages 135-139 in J. C. Noble, P. J. Joss, and G. K. Jones, editors. The Mallee Lands, a Conservation Perspective. CSIRO, Melbourne.

Griffin, G. F., and M. H. Friedel. 1985. Discontinuous change in central Australia: some implications of major ecological events for land management. Journal of Arid Environments **9**:63-80.

Harlen, R., and D. Priddel. 1992. Assessment of potential food resources available to Malleefowl *Leipoa ocellata*. Report 2. Monthly abundance of food resources.NSW National Parks and Wildlife Service, Sydney.

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

Harold, G., and S. Dennings. 1998. The First Five Years. Pages 1-97.Malleefowl Preservation Group, Ongerup W.A.

Harrington, G. N. 1979. The effects of feral goats and sheep on the shrub populations in semi-arid woodland. Aust. Rangel. J. **1**:334-345.

Harrington, G. N. 1986. Herbivore diet in a semi-arid !Eucalyptus populnea woodland. 2. Feral goats. Aust. J. Exp. Agic. **26**:423-429.

Harrington, G. N., A. D. Wilson, and M. D. Young, editors. 1984. Management of Australia's Rangelands.

Harrington, R. 2002. The effects of artificial watering points on the distribution and abundance of avifauna in an arid and semi-arid mallee environment. Ph.D. Thesis, University of Melbourne, Melbourne.

Henzell, R. P., and P. I. McLeod. 1984. Estimation of the density of feral goats in part of arid South Australia by means of the Petersen Estimate. Aust. Wildl. Res. **11**:93-102.

Hill, K. D. 1989. Mallee eucalypt communities: their classification and biogeography. Pages 93-108 in J. C. Noble, and Bradstock, editors. Mediterranean Landscapes in Australia: Mallee Ecosystems and Their Management. CSIRO, Melbourne.

Hill, R. 2002. Surveys for nganamara in the Anangu-Pitjanatjatjara Lands. Pages 1-7.Anangu-Pitjanatjatjara Land Management, Umuwa, SA.

Hodgkinson, K.C., G. M. Harrington, G. F. Griffin, J. C. Noble, and M. D. Young. 1984. Management of vegetation with fire. Pages 141-156 in G. N. Harrington, A. D. Wilson, and M. D. Young, editors. Management of Australia's Rangelands. CSIRO, Canberra.

Hodgkinson, K. C., and G. F. Griffin. 1982. Adaptation of shrub species to fire in the arid zone. Pages 145-152 in W. R. Barker, and P. J. M. Greenslade, editors. Evolution of the Flora and Fauna of Arid Australia. Peacock Publications, Frewville, SA.

Hopkins, A. J. M. 1982. Use of fire for ecological purposes: animal habitat management. Pages 1-6 (Part IV) in A. Heislers, P. Lynch, and B. Walters, editors. Fire Ecology in Semi Arid Lands. CSIRO, Deniliquin.

Horton, D (ed) 1994. The Encyclopaedia of Aboriginal Australia. Australian Institute of Aboriginal and Torres Strait Islander Studies, Canberra.

IUCN 2001. IUCN Red List Categories: Version 3.1.Prepared by the IUCN Species Survival Commission, IUCN, Gland, Switzerland and Cambridge, UK.

Jones, D. N., R. W. R. J. Dekker, and C. S. Roselaar 1995. The Megapodes. Oxford University Press, Oxford.

Kentish, and Westbrooke. 1994. Crop and gizzard contents of a road-dead Malleefowl. Emu **93**:130-132.

Kimber, R. G. 1983. Black lightning: Aborigines and fire in central Australia and the Western Desert. Archaeology in Oceania **18**:38-45.

Kimber, R. G. 1985. The history of the Malleefowl in central Australia. RAOU Newsletter **64**:6-8.

Korn, T. 1989. The Malleefowl of the Goonoo Forest, Dubbo. National Parks Journal.:22-24.

Land Conservation Council. 1987. Report on the Mallee Area review. Pages 1-465.Land Conservation Council, Melbourne.

Landsberg, J., C. D. James, S. R. Morton, T. J. Hobbs, J. Stol, A. Drew, and H. Tongway. 1997. The effects of artificial sources of water on rangeland biodiversity. Pages 1-208.CSIRO Division of Wildlife and Ecology, Lyneham, ACT.

Lawton, J. H. 1993. Range, population abundance and conservation. Trends Ecol. Evol. **8**:409-413.

Leigh, J., and W. Holgate. 1979. The response of the understorey of forests and woodlands of the Southern Tablelands to grazing and burning. Aust. J. Ecol. **4**:25-45.

Leigh, J. H., and J. C. Noble. 1981. The role of fire in the management of rangelands in Australia. Pages 471-495 in A. M. Gill, R. H. Groves, and I. R. Noble, editors. Fire and the Australian Biota. Aust. Acad. Sci., Canberra.

Liebenberg, L. 2003. A new environmental monitoring methodology. http://www.cybertracker.co.za/A%20New%20CyberTracker%20Methodology%20discussion%20document.pdf

Lunney, D., C. Esson, C. Moon, M. Ellis, and A. Matthews. 1997. A community-based survey of the koala, *Phascolarctos cinereus*, in the Eden region of south-eastern New South Wales. Wildl. Res. **24**:111-128.

Macdonald, J. D. 1973. Birds of Australia. Reed Books, Frenchs Forest (NSW).

MacLeod, N. D. 1990. An economic evaluation of the impact of conservation-orientated land use regulations on pastoral leases in mallee landscapes of Western New South Wales. Pages 287-292 in J. C. Noble, P. J. Joss, and G. K. Jones, editors. The Mallee Lands, a Conservation Perspective. CSIRO, Melbourne.

Manel, S., M. K. Schwartz, G. Luikart, and P. Taberlet. 2003. Landscape genetics: combining landscape ecology and population genetics. Trends in Ecology & Evolution 18:189-197.

Matthews, G. M. 1912. Reference list to the birds of Australia. Novit. Zool. **18**:171-455.

Mattingley, A. H. E. 1908. Thermometer bird or mallee fowl. Emu **8**:53-61, 114-121.

Mawson, P. R., and J. L. Long. 1995. Changes in the status and distribution of four species of parrot in the south of Western Australia during 1970-90. Pacific Conservation Biology **2**:191-199.

Muir, S. 1992. Managing the vegetation. Pages 29-39 in I. Simpson, editor. Rangeland Management in Western New South Wales. NSW Agriculture, Sydney.

Nei, M., T. Maruyama, and R. Chakraberty. 1975. The bottleneck effect and genetic variability in populations. Evolution **29**:1-10.

Newsome, A. E. 1989. Large vertebrate pests. Pages 406-417 in a. R. A. B. J.C. Noble, editor. Mediterranean Landscapes in Australia: Mallee Ecosystems and Their Management. CSIRO, Melbourne.

NHT National Malleefowl Monitoring Project 2007. National manual for the Malleefowl monitoring system. Victorian Malleefowl Recovery Group and Mallee CMA, Melbourne. http://www.malleefowlvictoria.org.au/monmanual.pdf.

Noble, J. C. 1984. Mallee. Pages 223-240 in G. N. Harrington, A. D. Wilson, and M. D. Young, editors. Management of Australia's Rangelands. CSIRO, Melbourne.

Noble, J. C. 1989. Fire studies in mallee (*Eucalyptus* spp.) communities of western New South Wales: the effects of fires applied in different seasons on herbage productivity and their implications for management. Aust. J. Ecol. **14**:169-187.

Noble, J. C., A. W. Smith, and H. W. Leslie. 1980. Fire in the mallee shrublands of western New South Wales. Aust. Rangel. J. **2**:104-114.

NSW National Parks and Wildlife Service. 2001. Threat abatement plan for predation by the Red Fox (*Vulpes vulpes*). NSW National Parks and Wildlife Service, Hurstville.

Parsons, B. 2008. Malleefowl in the fragmented Western Australian wheatbelt: spatial and temporal analysis of a threatened species. PhD Thesis. School of Animal Biology. University of Western Australia, Perth.

Parsons, B. C., Short, J. C. & Roberts, J. D. 2008. Contraction in the range of Malleefowl (*Leipoa ocellata*) in Western Australia: a comparative assessment using presence-only and presence-absence datasets. Emu, **108**:221-231.

Patford, R., A. Stokie, and P. Stokie. 2004. Ordinary people doing extraordinary things. Pages 146-153. Proceedings of the National Malleefowl Forum 2004, Mildura.Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Pech, R. P., and G. M. Hood. 1998. Foxes, rabbits, alternative prey and rabbit calicivirus disease: consequences of a new biological control agent for an outbreaking species in Australia. Journal of Applied Ecology **35**:434-453.

Perrins, C. M. 1970. The timing of birds' breeding seasons. Ibis **112:**242-255.

Peters, R. L., and J. D. S. Darling. 1985. The Greenhouse effect and nature reserves. BioScience **35**:707-717.

Pfeiffer, J. 2002. Biodiversity in the Murray Mallee. Final project report. Murray Mallee Local Action Planning Association.

Pickett, S. T. A., and J. N. Thompson. 1978. Patch dynamics and the design of nature reserves. Biol. Conserv. **13**:27-37.

Piggott, M. P., and A. C. Taylor. 2003. Remote collection of animal DNA and its applications in conservation management and understanding the population biology of rare and cryptic species. Wildlife Research 30:1-13.

Pittock, A.B. and D. Wratt (2001) Australia and New Zealand. In: *Climate Change 2001: Impacts, adaptation, and vulnerability*. The IPCC Third Assessment Report, Working Group II Report. in J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, editors. Cambridge University Press, Cambridge.

Pople, A. R., G. C. Grigg, S. C. Cairns, P. Alexander, L. A. Beard, and R. P. Henzell. 1996. Trends in numbers and changes in the distribution of feral goats (*Capra hircus*) in the South Australian pastoral zone. Wildlife Research **23**:687-696.

Possingham, H. P. 2001. The Business of Biodiversity. Tela (issue 9).Australian Conservation Foundation, Melbourne. http://www.ecology.uq.edu.au/docs/publications/2001_Possingham_The_business_of_biodiversity.pdf

Priddel, D. 1989. Conservation of rare fauna: the Regent Parrot and the Malleefowl. Pages 243-249 in J. C. Noble, and R. A. Bradstock, editors. Mediterranean Landscapes in Australia: Mallee Ecosystems and Their Management. CSIRO, Melbourne.

Priddel, D. 1990. Conservation of the Malleefowl in New South Wales: an experimental management strategy. Pages 71-77 in J. C. Noble, P. J. Joss, and G. K. Jones, editors. The Mallee Lands, a Conservation Perspective. CSIRO, Melbourne.

Priddel, D., and R. Wheeler. 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.

Priddel, D., and R. Wheeler. 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.

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

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

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

Pulliam, H. R. 1988. Sources, sinks and population regulation. Am. Nat. **132**:652-661.

Recher, H. F. 2003. WildCountry. Pacific Conservation Biology **8**:221-222.

Reddiex, B., D. M. Forsyth, E. McDonald-Madden, L. D. Einoder, P. A. Griffioen, R. R. Chick, and A. Robley. 2004. Review of existing red fox, wild dog, feral cat, feral rabbit, feral pig, and feral goat control in Australia. I. Audit. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Melbourne. http://www.deh.gov.au/biodiversity/invasive/publications/feral-audit/pubs/audit-final.pdf

Reichelt, R. C., and T. W. May. 1997. Malleefowl eating fungi and orchid tubers. Vic. Nat. **114**:198.

Reilly, P.1990. Malleefowl – the Incubator Bird. Kangaroo Press, Kenthurst, NSW.

Richards, J. D., and J. Short. 1996. History of the disappearance of native fauna from the Nullarbor Plain through the eyes of long time resident Amy Crocker. West. Aust. Nat. **21**:89-95.

Roberts, J. 2006. 'Survivor' Malleefowl Style: zoo bred malleefowl survive release into the wild. Western Division Newsletter **112**: 12. NSW Department of Primary Industries and the Department of Natural Resources, NSW.

Robley, A., B. Reddiex, T. Arthur, R. Pech, and D. Forsyth. 2004. Interactions between feral cats, foxes, native carnivores, and rabbits in Australia. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Melbourne. http://www.deh.gov.au/biodiversity/invasive/publications/interaction/pubs/interaction.pdf

Robley, A., and J. Wright. 2003. Adaptive experimental management of Foxes. Annual Report for Year 2 July 2002-June2003.Arthur Rylah Institute, Department of Sustainability and Environment, Melbourne.

Rohwer, F. C. 1992. The evolution of reproductive patterns in waterfowl. Pages 486-539 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis.

Sanders, A., J. Benshemesh, and Malleefowl Preservation Group. 2003. WMC Operation Malleefowl Mulga to Mallee Research Project: A report on community searches for and monitoring of Malleefowl at Yeelirrie Station, August 2003. Malleefowl Preservation Group, Ongerup, WA.

Saunders, D. 2004. Ecological consequences of clearing and fragmentation of native vegetation. Pages 96-99. Proceedings of the National Malleefowl Forum 2004, Mildura.Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Saunders, D. A. 1989. Changes in the avifauna of a region, district and remnant as a result of fragmentation of native vegetation: the wheatbelt of Western Australia. A case study. Biol. Cons. **50**:99-135.

Saunders, D. A., and P. J. Curry. 1990. The impact of agricultural and pastoral industries on birds in the southern half of Western Australia: past, present and future. Proc. Ecol. Soc. Aust. **16**:303-321.

Saunders, G., B. Coman, J. Kinnear, and M. Braysher 1995. Managing Vertebrate Pests: Foxes. Australian Government Publishing Service, Canberra.

Shaffer, M. L. 1981. Minimum population sizes for species conservation. Bioscience **31**:131-134.

Short, J. 2004. Conservation of the malleefowl: are there lessons from the successful conservation of native mammals by intensive fox control? Pages 54-68. Proceedings of the National Malleefowl Forum 2004, Mildura.Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html

Short, J. & Parsons, B. (2008) Malleefowl conservation - informed and integrated community action. Final report to WWF and Avon Catchment Council May 2008. Perth.

Sparrow, A. 1989. Mallee vegetation in South Australia. Pages 109-124 in J. C. Noble, and R.A. Bradstock, editors. Mediterranean Landscapes in

Australia: Mallee Ecosystems and Their Management. CSIRO, Melbourne.

Specht, R. L. 1981. Major vegetation formations in Australia. Pages 163-297 in A. Keast, editor. Ecological Biogeography of Australia. Dr Junk, The Hague.

Stafford Smith, M. 1995. Deserts, Australian. Encyclopedia of Environmental Biology. Academic Press.

Stafford Smith, M., and S. R. Morton. 1990. A framework for the ecology of arid Australia. Journal of Arid Environments **18**:255-278.

Storfer, A., M. A. Murphy, J. S. Evans, C. S. Goldberg, S. Robinson, S. F. Spear, R. Dezzani, E. Delmelle, L. Vierling, and L. P. Waits. 2007. Putting the 'landscape' in landscape genetics. Heredity **98**:128-142.

Storr, G. M. 1985. Birds of the mid-eastern interior of Western Australia. Rec. West. Aust. Mus. Suppl. **22**:1-45.

Storr, G. M. 1986. Birds of the south-eastern interior of Western Australia. Rec. West. Aust. Mus. Suppl. **26**:1-60.

Storr, G. M. 1987. Birds of the Eucla Division of Western Australia. Rec. West. Aust. Mus. Suppl. **27**:1-81.

Storr, G. M. 1991. Birds of the South-West Division of Western Australia. Records of the Western Australian Museum.

Storr, G. M., and R. E. Johnstone. 1988. Birds of the Swan Coastal Plain and adjacent seas and islands. Rec. West. Aust. Mus. Suppl. **28**:1-45.

Tarr, H. E. 1965. The Mallee-fowl in Wyperfeld National Park. Austr. Bird Watcher **2**:140-144.

Thackway, R., and I. D. Cresswell, editors. 1995. An interim biogeographic regionalisation for Australia: a framework for establishing the national system of reserves, Version 4.0. Australian Nature Conservation Agency, Canberra.

Thompson, P. C., and R. Shepherd. 1995. Return to Eden. Landscope **10**:21-25.

Thompson, S. & Thompson, G. (2008) Monitoring Malleefowl mounds using their thermal profile. *Malleefowl Matter,* 45**,** 4-6.

Tyndale-Biscoe, H. 1994. The CRC for biological control of vertebrate pest populations: fertility control of wildlife for conservation. Pacific Conservation Biology **1**:163-168.

van der Waag, J. A. E. 2003. Aspects of behaviour in mound tending Malleefowl *Leipoa ocellata*.Curtin University of Technology, Western Australia.

van der Waag, J. A. E. 2004. Chicks, food and fragmentation. Pages 100-102. Proceedings of the National Malleefowl Forum 2004, Mildura.Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. **47**:893-901.

Victorian Malleefowl Recovery Group. 2004. Proceedings of the National Malleefowl Forum 2004, Mildura.Victorian Malleefowl Recovery Group, http://www.malleefowlvictoria.org.au/seminar.html.

Vleck, D., C. M. Vleck, and R. S. Seymour. 1984. Energetics of embryonic development in the megapode birds, Malleefowl, *Leipoa ocellata* and Brush-turkey, *Alectura lathami*. Physiol. Zool. **57**:444-456.

Ward, M. J. & Clarke, A. (2007) Monitoring Nganamara in the southern Alinytjara Wilurara NRM region. Department for Environment and Heritage, Adelaide.

Walters, C. J. 1986. Adaptive management of renewable resources. MacMillan, New York, USA.

Weathers, W. W., D. L. Weathers, and R. S. Seymour. 1990. Polygyny and reproductive effort in Malleefowl *Leipoa ocellata*. Emu **90**:1-6.

Wilderness Society. 2003. WildCountry website, http://www.wilderness.org.au/campaigns/wildcountry.

Williams, S. L. 1994. Malleefowl as a flagship species for conservation on farms in the Murray Mallee of South Australia. Pages 316-320 in D. A. Saunders, J. L. Craig, and E. M. Mattiske, editors. Nature Conservation 4: The Role of Networks. Surrey Beatty and Sons, Chipping Norton.

Woinarski, J. C. Z. 1989a. Broombush harvesting in southeastern Australia. Pages 362-378 in J. C. Noble, and R. A. Bradstock, editors. Mediterranean Landscapes in Australia: Mallee Ecosystems and Their Management. CSIRO, Melbourne.

Woinarski, J. C. Z. 1989b. The vertebrate fauna of Broombush *Melaleuca uncinata* vegetation in north-western Victoria, with reference to effects of broombush harvesting. Aust. Wildl. Res. **16**:217-238.

Woinarski, J. C. Z. 1999. Fire and Australian birds: a review. Pages 57-112 in A. M. Gill, J. C. Z. Woinarski, and A. York, editors. Australia's biodiversity - responses to Fire: plants, birds and invertebrates. Biodiversity Technical Paper No.1. Environment Australia, Canberra. http://www.deh.gov.au/biodiversity/publications/technical/fire.

Wright, H. E. 1974. Landscape development, forest fires, and wilderness management. Science **186**:487-495.

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Appendix I Aboriginal Names for Malleefowl

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

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

Language	Nearby Town	Aboriginal name for Malleefowl
DESERT		
Kokatha	Tarcoola	
Yankuntjatjara	Fregon	*Nganamara (3)*
Pitjantjatjara	Pipalyatjara	*Nganamara (3)*
Luritja	Papunya	
Arrernte	Alice Springs	*Ngamarre (3,4) Ngamerre (5), Unematye (5), Anthelkarlwilenhe (5)*
Alyawarre		
Anmatyerre	Coniston	
Warlpiri	Tanami	*Warntu(6,7) , Nguumarra/Ngaamarra (7), Ngama (female), (6)*
Ngarti		
Pintupi		
Ngatatjara		
Nakako		
Ngalea		
Ngaanyatjarra	Warburton	*Nganarmara (10)*
Mandjindja		
Nyanganyatjara	Rawlinna	
Wawula		
Nana		
Tjalkanti	Laverton	
Wangkathaa	Kalgoorlie	
Kuwarra	Leinster	
Tjupany	Wiluna	
SPENCER		
Peramangk		
Kaurna		
Narangga	York Pen.	
Nukunu	Port Pirie	
Banggarla	Whyalla	
Nawu	Port Lincoln	
Wirangu	Ceduna	*Gabiny(1), Nganamara (1)*
SOUTHWEST		
Mirning	Eucla	*Ngauoo (8), Ngauoig (8)*
Ngatjumay	Balladonia	

Language	Nearby Town	Aboriginal name for Malleefowl
Malpa	Norseman	
Wudjari	Ravensthorpe	
Nyaki-nyaki	Newdegate	
Kalaamaya	Southern Cross	
Goreng	Gnowangerup	*Gnow*
Minang	Albany	
Bibbulman	Manjimup	
Wardandi	Busselton	
Kaniyang	Bunbury	
Pinjarup	Pinjarra	
Wajuk	Perth	
Balardung	Goomalling	
Yuat	Moora	
Amangu	Geraldton	
NORTHWEST		
Badimaya	Mount Magnet	
Nhanta	Northampton	
Watjarri	Wilga Mia	
Malkana	Denham	
Yinggarda	Carnarvon	
Maya	Carnarvon	
Payungu		
Thalanyji	Exmouth	

Sources:

1 Louise Hercus pers. comm. (Linguistics Department, Australian National University, Canberra)

2 Thieberger, N & W. Mc Gregor (eds) (1994) Macquarie Aboriginal words: a dictionary of words of Australian Aboriginal and Torres Strait Islander languages. Macquarie Library, Sydney

3 C. Goddard, P. Everard, and T. Tjampu (1996). Aboriginal Bird Names of the Yankunytjatjara People of Central Australia. IAD Press, Alice Springs.

4 Kimber, R. G. 1985. The history of the Malleefowl in central Australia. RAOU Newsletter 64:6-8.

5 Gavin Breen pers. comm. (Central Australian Dictionaries Program, Institute for Aboriginal Development, Alice Springs)

6 Nash in Kimber (1985) as above.

7 Mary Laughren pers. comm. (Department of English, University of Queensland, Brisbane)

8 Daisy Bates in Mary Laughren pers. comm. (as above)

9. Peter Thompson (Wilcannia), per. comm.

10. Glass, Amee and Dorothy Hackett (compilers). (2003). *Ngaanyatjarra and Ngaatjatjarra to English Dictionary*. IAD Press, Alice Springs.

Appendix II Distribution Tables and Maps

The distribution of Malleefowl across Australia is represented here in several ways:

- Table 1 shows the sources of the data;
- Table 2 shows the number of records in recognised NRM areas;
- Table 3 shows records in the recognised biogeographic zones;
- Figures 1 to 3 provide maps of the combined data in WA, in NT and SA, and in NSW and VIC; and
- Figure 4 shows the first and last (most recent) record of Malleefowl in one degree grid cells.

Reporting rates are influenced by many social and environmental factors in addition to the distribution of the species in question and care should be exercised in interpreting these data. In order to best represent the changing distribution of Malleefowl, time periods were selected that contained approximately equal numbers of records. Records from monitoring programs are not included in the distribution tables and maps as these programs accumulate large numbers of records for small areas that are visited each year. For example, in the Victorian Mallee NRM between 1981 and 2005, there were only 197 records of Malleefowl in various databases (Table 2), yet 1259 breeding records alone were obtained from the monitoring program from that area during the same period. Also excluded from most tables and maps (but listed in Table 1) are undated records, records of old and disused nests, or records that could not be assigned to a locality with any confidence.

Table 1. Sources for the Malleefowl records used in the production of the tables and maps for this recovery plan. The time periods (columns) were selected to contain similar numbers of dated records across Australia. “Undated” includes undated records, records of old nests and records for which the location was unclear.

SOURCE	Undated	Before 1963	1964-1976	1977-1980	1981-1991	1992-1995	1996-1999	2000-2005	Total Dated
Australian Museum	5	31	-	-	-	-	-	-	31
Birds Australia Atlas	54	237	252	402	69	-	166	322	1448
Malleefowl Preservation Group*	2	-	5	1	8	275	65	-	354
Atlas of New South Wales Wildlife (DECC)	4	3	33	71	176	46	76	49	454
South Australian Atlas (DEH)	162	19	52	17	144	69	96	112	509
South Australian Museum	6	34	3	1	8	16	5		67
Atlas of Victorian Wildlife (DSE)	12	78	58	119	71	35	38	43	442
Atlas of Western Australian Wildlife (DEC WA)	103	10	18	4	20	43	95	86	276
Western Australian Museum	59	148	143	43	135	48	-	-	517
Other sources	1	31	5		6	4	8	4	58
Total	408	591	569	658	637	536	549	616	4156

* The MPG collected further records between 1999 and 2005 but these were not available for this review

Table 2. Number of Malleefowl records (to 2005) in the NRM areas across Australia sorted by time periods that contain similar numbers of records across Australia. Shaded rows indicate a total of less than ten records in an NRM. Numbers are indicative only and may contain records duplicated across different databases. Data sources are shown in Table 1.

NRM region name	Before 1963	1964-1976	1977-1980	1981-1991	1992-1995	1996-1999	2000-2005	Total
NSW								
Central West	19	7	18	20	3	13	17	97
Hawkesbury/Nepean	-	1	-	-	-	-	-	1
Hunter/Central Rivers	-	-	-	2	-	1	-	3
Lachlan	15	30	33	75	13	17	11	194
Lower Murray/Darling	8	17	25	27	29	72	51	229
Murrumbidgee	8	29	36	46	1	3	2	125
Namoi	-	3	5	5	-	2	1	16
Western	6	5	3	12	-	-	-	26
NT								
Northern Territory	19	1	-	-	-	-	-	20
SA								
Aboriginal Lands	10	4	3	12	17	8	40	94
Eyre Peninsula	26	23	21	36	23	53	37	219
Mount Lofty Ranges and Greater Adelaide	3	-	-	-	-	-	-	3
Murray Darling Basin	74	66	84	64	34	37	96	455
Northern and Yorke Agricultural District	5	8	2	14	3	9	19	60
Rangelands (SA)	8	8	1	4	-	1	16	38
South East (SA)	17	21	21	52	6	59	29	205
VIC								
Glenelg Hopkins	-	-	-	6	-	-	-	6
Mallee	107	88	172	63	26	37	71	564
North Central	20	-	2	3	1	4	-	30
Port Phillip and Westernport	2	-	-	-	-	-	-	2
Wimmera	13	22	42	11	10	24	33	155
WA								
Avon	49	99	59	21	100	97	73	498
Northern Agricultural	26	33	29	27	15	18	52	200
Rangelands (WA)	81	74	58	99	37	32	30	411
South Coast Region	25	12	28	26	199	51	31	372
South West Region	47	14	13	12	19	11	6	122
Swan	3	4	3	-	-	-	1	11
Total	591	569	658	637	536	549	616	4156

Table 3. Number of Malleefowl records (to 2005) in the biogeographical regions across Australia (Environment Australia 2000) sorted by time periods that contain similar numbers of records across Australia. Shaded rows indicate a total of less than ten records for a Bioregion. Data sources are shown in Table 1. Numbers are indicative only and may contain records that are duplicated across different databases.

	Biogeographical region	Before 1963	1964-1976	1977-1980	1981-1991	1992-1995	1996-1999	2000-2005	Total
AW	Avon Wheatbelt (WA)	67	75	28	19	27	37	80	333
BBS	Brigalow Belt South (NSW)	11	7	11	17	2	15	17	80
BRT	Burt Plain (NT)	3	-	-	-	-	-	-	3
CAR	Carnarvon (WA)	17	3	3	9	-	4	8	44
CR	Central Ranges (NT,SA,WA)	16	2	-	-	1	1	6	26
CP	Cobar Peneplain (NSW)	15	39	50	67	4	9	3	187
CO	Coolgardie (WA)	10	12	36	14	8	4	5	89
DRP	Darling Riverine Plains (NSW)	4	1	8	7	1	-	-	21
ESP	Esperance Plains (WA)	9	8	21	23	187	46	29	323
EYB	Eyre Yorke Block (SA)	31	31	23	47	24	60	68	284
FIN	Finke (NT)	2	1	-	-	-	-	-	3
FLB	Flinders Lofty Block (SA)	3	1	-	-	-	-	-	4
GAS	Gascoyne (WA)	1	-	-	-	-	2	1	4
GA	Gawler (SA)	6	7	1	3	-	3	4	24
GS	Geraldton Sandplains (WA)	4	18	18	22	2	8	13	85
GD	Gibson Desert (WA)	2	-	-	-	-	-	-	2
GSD	Great Sandy Desert (NT)	5	-	-	-	-	-	-	5
GVD	Great Victoria Desert (SA,WA)	21	12	2	14	20	10	35	114
HAM	Hampton (WA)	1	2	3	36	27	4	1	74
JF	Jarrah Forest (WA)	21	11	10	7	7	3	6	65
KAN	Kanmantoo (SA)	15	11	-	1	-	-	-	27
MAC	MacDonnell Ranges (NT)	1	-	-	-	-	-	-	1
MAL	Mallee (WA)	22	44	56	30	104	89	32	377
MUR	Murchison (WA)	14	23	8	15	1	6	5	72
MDD	Murray Darling Depression (NSW,SA,VIC)	195	189	311	200	107	187	270	1459
NCP	Naracoorte Coastal Plain (SA,VIC)	10	19	20	48	3	54	20	174
NSS	NSW South Western Slopes (NSW)	8	15	14	26	2	-	1	66
NUL	Nullarbor (SA,WA)	5	1	2	3	-	-	-	11
RIV	Riverina (NSW,SA,VIC)	22	6	25	12	3	-	-	68
SEH	South Eastern Highlands	1	-	-	-	-	-	-	1
STP	Stony Plains (SA)	1	-	-	-	-	-	-	1
SWA	Swan Coastal Plain (WA)	4	3	-	1	-	-	-	8
SB	Sydney Basin (NSW)	-	1	-	2	-	-	-	3
TAN	Tanami (NT)	1	-	-	-	-	-	-	1
VM	Victorian Midlands (VIC)	8	-	2	5	1	4	-	20
VVP	Victorian Volcanic Plain (VIC)	-	-	-	1	-	-	-	1
WAR	Warren (WA)	18	4	-	3	2	-	-	27
YAL	Yalgoo (WA)	13	23	6	3	2	3	11	61
	Total	587	569	658	635	535	549	615	4148

Figure 1. Records of Malleefowl in Western Australia. Records are grouped in time periods that contain similar numbers of records across Australia. More recent records overlie older records. Data sources are shown in Table 1.

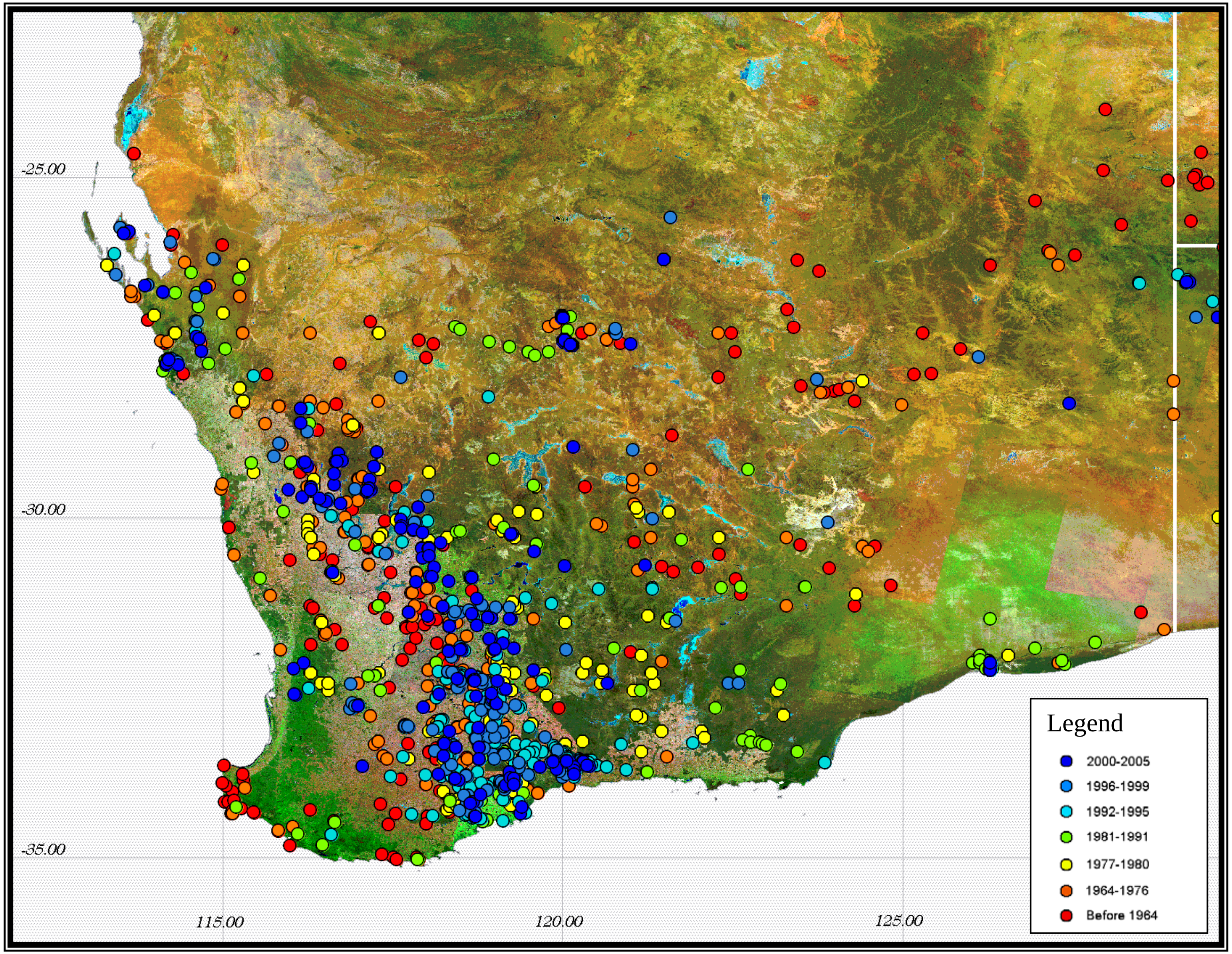


Figure 2. Records of Malleefowl in the Northern Territory and South Australia. Records are grouped in time periods that contain similar numbers of records across Australia. More recent records overlie older records. Data sources are shown in Table 1.

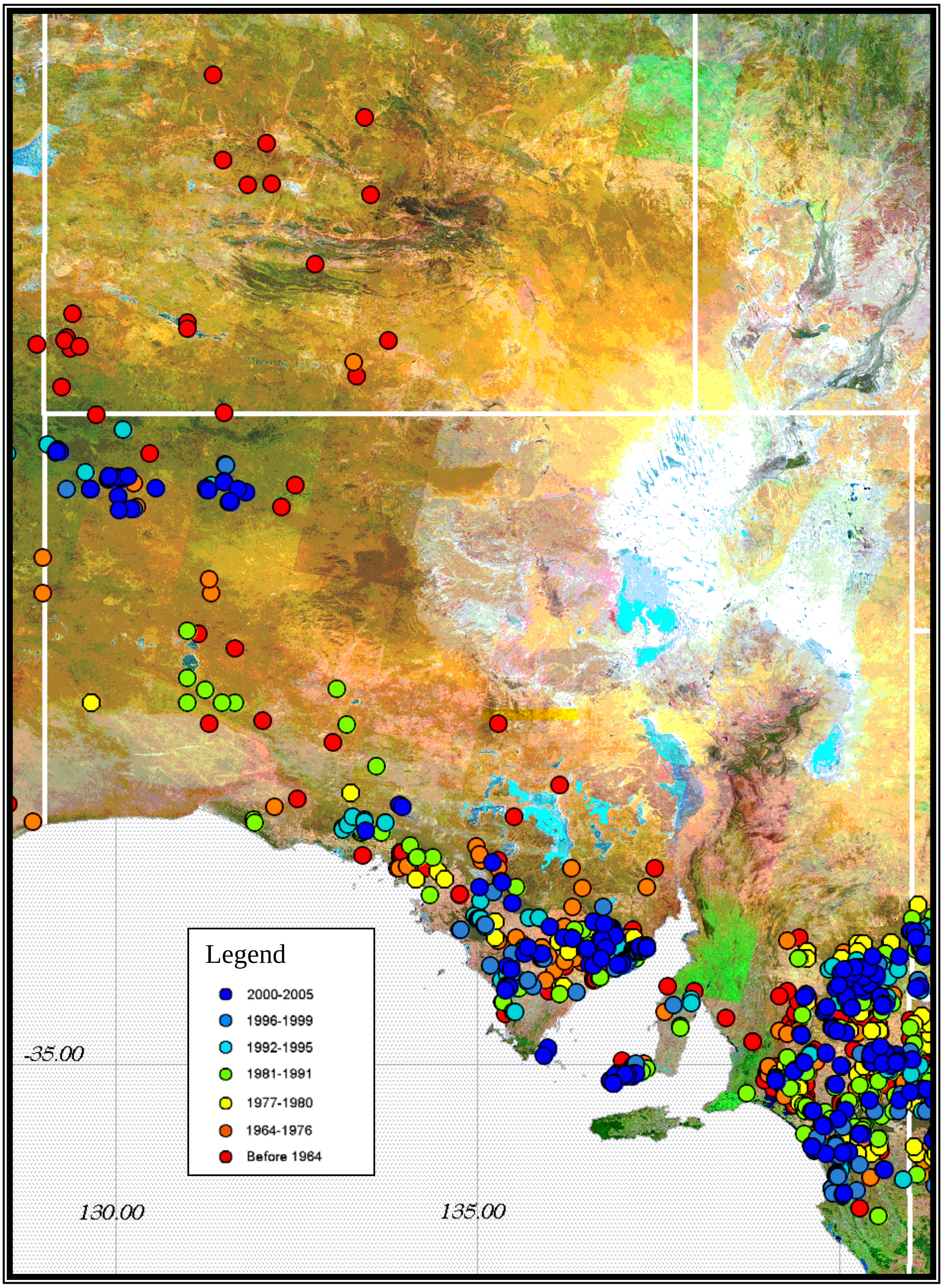


Figure 3. Records of Malleefowl in New South Wales and Victoria. Records are grouped in time periods that contain similar numbers of records across Australia. More recent records overlie older records. Data sources are shown in Table 1.

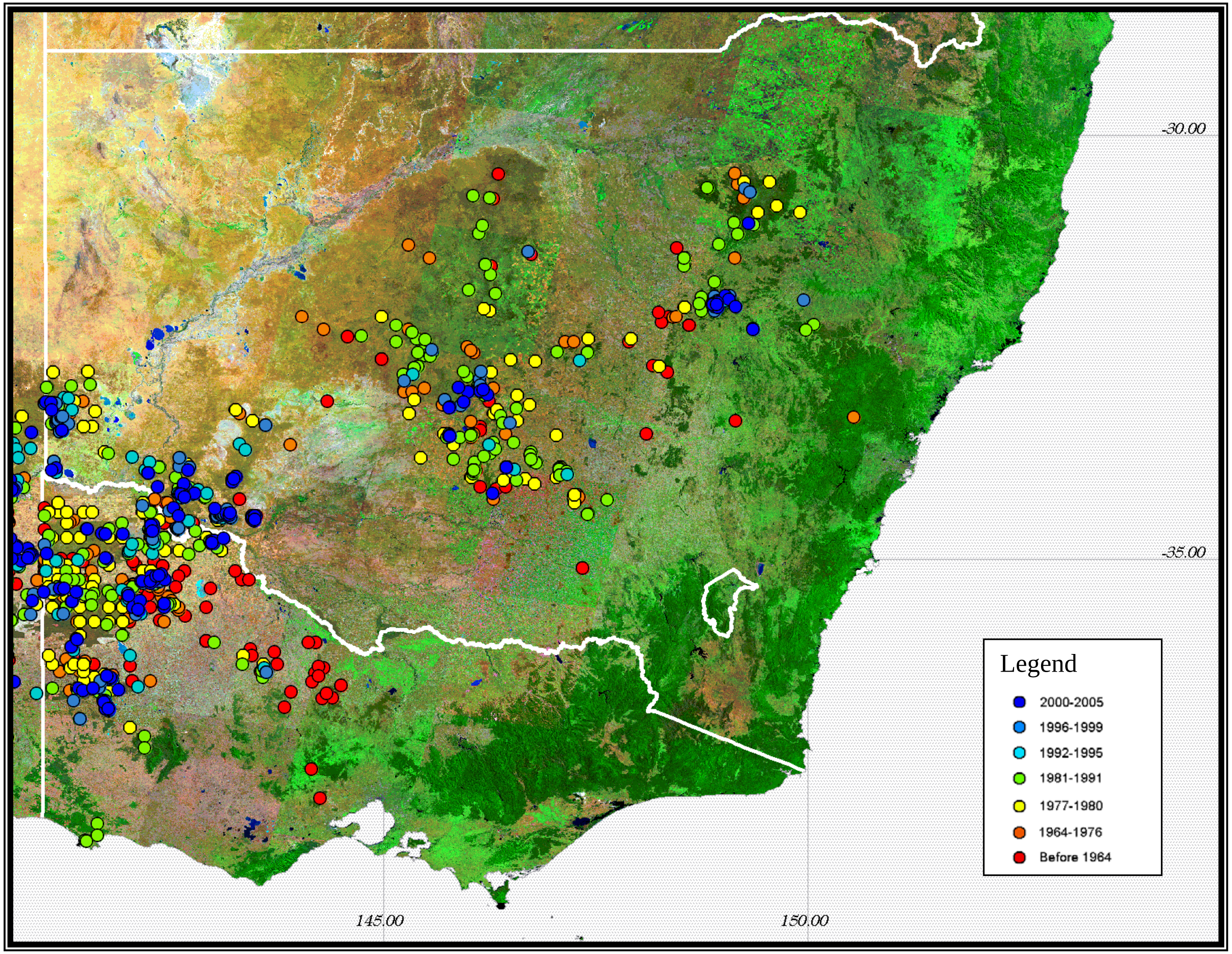
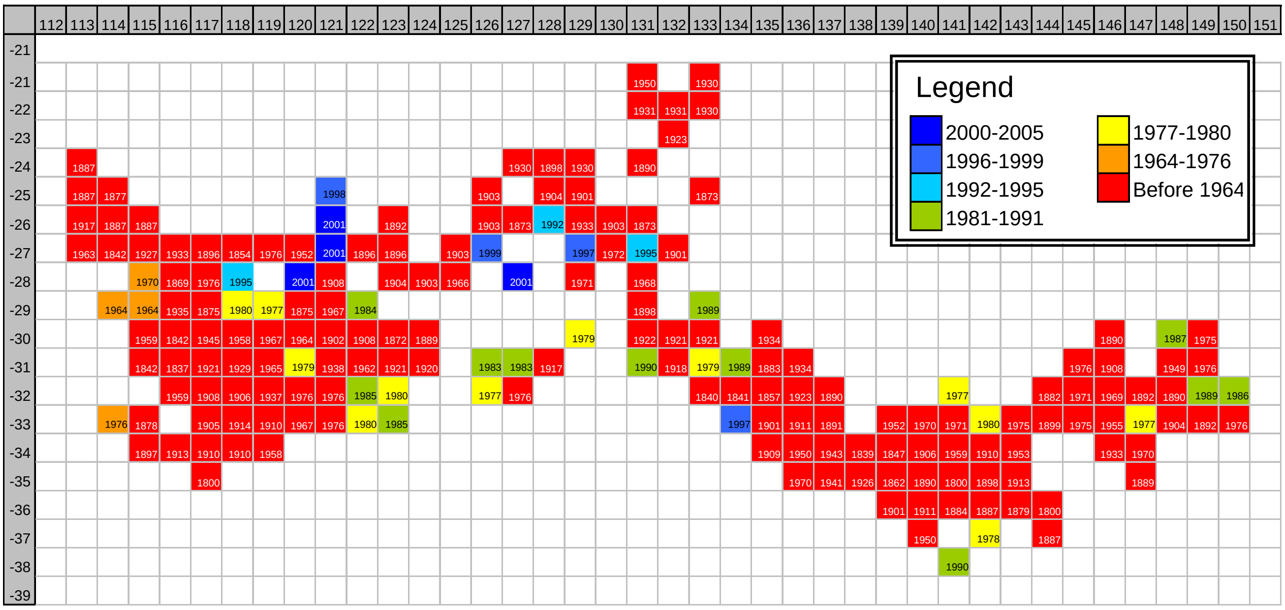
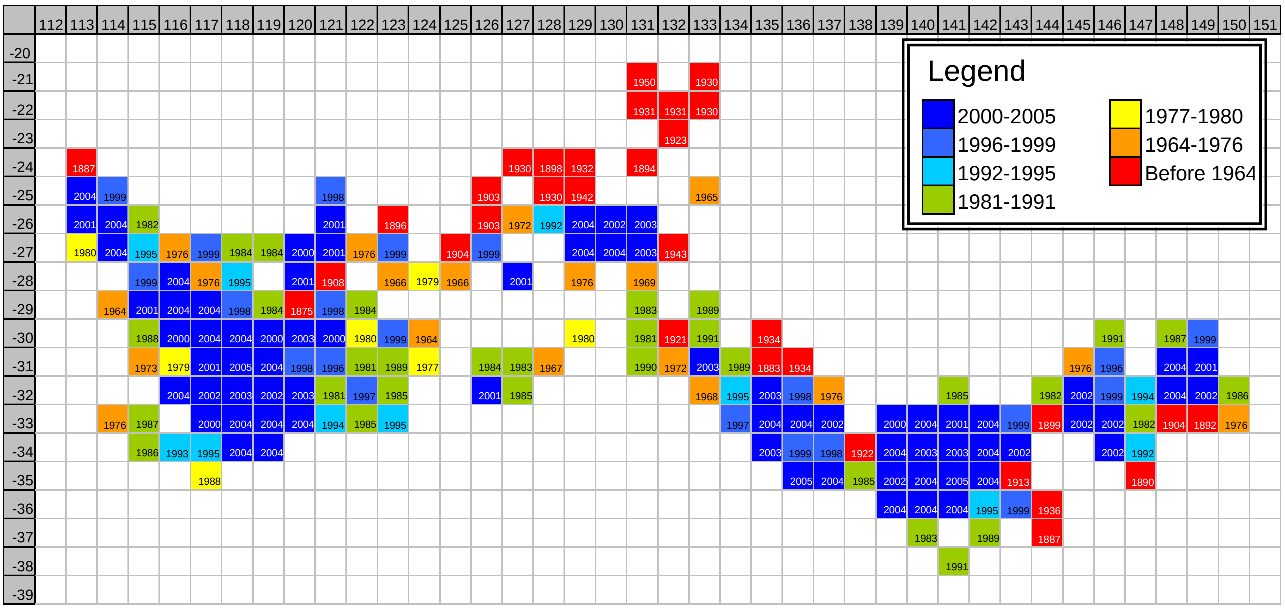


Figure 4. First (a) and last (most recent), b) records of Malleefowl in one degree grid cells across Australia. Each cell is defined by its latitude and longitude and colour coded to represent time periods that contain similar numbers of records across Australia. The year of the first and last record is also indicated in each cell. Data sources are shown in Table 1.

a) First Malleefowl record per one degree grid cell



b) Most recent (to 2005) Malleefowl record per one degree grid cell



Appendix III Some Important Legislation, Policy and Programs

Commonwealth

Clearing Controls

The *Environment Protection and Biodiversity Conservation Act 1999* regulates the clearance of Malleefowl habitat by requiring that projects or activities that are likely to have a significant impact on "matters of national environmental significance" (e.g. threatened species and communities listed under the Act) be referred to the Commonwealth Environment Minister for consideration. If the Minister decides that an action is likely to have a significant impact on a matter of national environmental significance, then the action requires approval under the EPBC Act (it is a "controlled action").

Funding of conservation works

The Caring for our Country program grants funds for a wide range of conservation purposes across Australia, especially those involving on-ground works that have a lasting benefit to conservation. Incorporated community groups are eligible for funds.

Wildlife conservation

In addition to regulating "controlled actions", the *Environment Protection and Biodiversity Conservation Act 1999* provides for the preparation and implementation of recovery plans for threatened species and communities listed under the Act, and threat abatement plans (to address key threatening processes listed under the Act (e.g. predation by foxes and cats).

New South Wales

Clearing controls

The *Native Vegetation Act 2003* sets the legislative framework for clearing controls, and uses voluntary agreements between landholders and Catchment Management Authorities to achieve conservation outcomes. The *Environment Planning and Assessment Act 1979* is also relevant to conservation of native vegetation, threatened species and critical habitat in NSW.

Conservation covenants

Voluntary Conservation Agreements are in perpetuity statutory covenants created under Section 69 of the *National Parks and Wildlife Act 1974*. Landholders who enter a Voluntary Conservation Agreement may apply for funding to cover costs and for assistance in management. Landholders may also be eligible for rate relief from local government.

Non-binding voluntary conservation agreements

Wildlife Refuges may be gazetted under Section 68 of the *National Parks and Wildlife Act 1974* and provide formal recognition of conservation values on private land.

Wildlife conservation

The *National Parks and Wildlife Act 1974* deals with threatened species and conservation agreements, and protects critical habitats.

The *Threatened Species Conservation Act 1995* deals with the preparation and implementation of threatened species recovery plans. Malleefowl are listed as endangered under Schedule 1 of this Act, and predation by foxes is listed as a threatening process in Schedule 3.

South Australia

Clearing controls

The Native Vegetation Act 1991 and *Native Vegetation Regulations 2003* provide legal protection for native vegetation in South Australia. Any clearance, unless specifically exempt under the Native Vegetation Regulations, requires the consent of the Native Vegetation Council. Approvals to clear native vegetation, including approvals under some of the Regulations, are subject to conditions including offsets, e.g. revegetation elsewhere or formal protection of existing vegetation, which are designed to ensure a 'Significant Environmental Benefit'.

Covenants

Heritage Agreements are in perpetuity statutory covenants that are voluntarily entered into by landholders. A range of incentives are offered to landowners who enter into these agreements, including financial assistance for the management of the land, rate rebates, and fencing assistance if required.

Non-binding voluntary conservation agreements

The Sanctuary Scheme is a voluntary scheme administered by the Department for Environment and Heritage. Its aim is to encourage and assist landholders to manage their property in ways that maintain and enhance wildlife, or integrate nature conservation with other land management objectives.

Wildlife conservation

The *National Parks and Wildlife Act 1972* provides for the listing of threatened species, the establishment and management of parks and reserves, and regulation of the use of wildlife through a permit system.

Victoria

Clearing controls

The *Planning and Environment Act 1987* - Clause 52.17 provides legislative control over clearing native vegetation, and *Victoria's Native Vegetation Framework 2002* provides the government's policy. The *Planning and Environment Act 1987* also protects habitat for native plants and animals through local planning schemes.

Covenants and management agreements

Trust for Nature Covenants are in perpetuity statutory covenants that are voluntarily entered into by landholders. The Trust for Nature has also established a revolving fund which purchases land, places a covenant protecting nature conservation values, and then re-sells the land to a sympathetic landholder.

The Department of Sustainability and Environment administers a BushTender program, whereby landholders can bid for funding to undertake activities on their land.

Non-binding voluntary conservation agreements

Land for Wildlife allows landholders to register their property if parts of it are actively managed for conservation. The program offers recognition of conservation effort, a network of interested landholders, extension support and management advice.

Wildlife conservation

The *Wildlife Act 1975* establishes procedures to regulate the sustainable use of and access to wildlife.

The *Flora and Fauna Guarantee Act 1988* is the primary legislation relating to biodiversity conservation in Victoria. Under this legislation, which applies to both private and public land, species and ecological communities may be listed as threatened, and processes listed as threatening. Following listing, an Action Statement must be prepared to identify actions that have been or will be taken to conserve the species, or community, or manage the potentially threatening process.

Western Australia

Clearing controls

Native vegetation clearance in Western Australia is regulated under the *Environmental Protection Act 1986* and the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004.* Non-exempt clearance requires approval from the Department of Environment and Conservation (DEC). Applications are assessed against principles which consider biodiversity, land degradation and water quality.

Covenants and management agreements

In Western Australia, different types of conservation covenants are available through schemes administered by DEC, the Department of Agriculture, and the National Trust. These programs assist private landowners with the conservation of bushland of high nature conservation value by placing a protective covenant on the land's title, and by providing management advice and assistance through incentives and a stewardship program.

A Bushland Benefits program, administered by DEC, invites landholders to tender bids for funding to undertake conservation activities on their land, according to an agreed management plan.

Non-binding voluntary conservation agreements

The Department of Environment and Conservation also administers a voluntary *Land for Wildlife* program to encourage and provide advice on the management of private land for wildlife habitat.

Wildlife conservation

The *Wildlife Conservation Act 1950* provides for the listing and protection of threatened species.

Northern Territory

Wildlife conservation

Territory Parks And Wildlife Conservation Act provides for the study, protection, and conservation of threatened wildlife and habitat.

Appendix IV Contacts

Australian Government

Recovery Planning and
Implementation Section
Department of the Environment,
Water, Heritage and the Arts
GPO Box 787
Canberra, ACT, 2601

New South Wales

Threatened Species Network
Coordinator
GPO Box 528
Sydney, NSW, 2001

Biodiversity Conservation Section
Department of Environment and
Climate Change
PO Box 2115
Queanbeyan NSW 2620

Threatened Fauna Ecology Unit
Environment and Conservation
Science Branch
Department of Environment and
Climate Change
PO Box 1967
Hurstville, NSW, 2220

Northern Territory

Threatened Species Officer
Biodiversity Conservation
Department of Natural Resources,
Environment and the Arts
PO Box 1120
Alice Springs 0871
Telephone: 08 8951 8249

Threatened Species Network
Coordinator (Arid Rangelands)
PO Box 2796
Alice Springs NT 0871

South Australia

Department for Environment and
Heritage
GPO Box 1047
Adelaide 5001

Community Land Management Inc
PO Box 90
Renmark, SA 5341

Riverland Biosphere Reserve
Riverland Biosphere Community
Committee
PO Box 142
Glossop, SA 5344

Gluepot Reserve
PO Box 345, Waikerie, SA 5330

Monarto Zoological Park
Princes Highway
Monarto, SA 5254

Threatened Species Network
Coordinator
120 Wakefield St
Adelaide, SA 5000

Nature Foundation SA
32 Holden St
Hindmarsh, SA, 5007

Native Vegetation Council
GPO Box 2834
Adelaide 5001
SOUTH AUSTRALIA

Victoria

Victorian Malleefowl Recovery Group
5 Selma St
Corio VIC 3214
www.malleefowlvictoria.org.au

Malleefowl Preservation Society
PO Box 35
Nichols Point, VIC 3501

Parks Victoria
PO Box 5065
Mildura, VIC 3502

Threatened Species and Communities
Section
Department of Sustainability and
Environment
Freecall 136 186

Threatened Species Network
Coordinator WWF – Australia
C/-Victorian National Parks Association

Level 3, 60 Leicester St
Carlton, VIC 3053

Birds Australia
415 Riversdale Rd,
Hawthorn East VIC 3123

Western Australia

WA Malleefowl Network Facilitator
WWF – Australia
Panda Cottage, Herdsman Lake
PO Box 4010, Wembly WA 6913

Threatened Species Network
Coordinator WWF – Australia
Panda Cottage, Herdsman Lake
PO Box 4010,
Wembly WA 6913

Malleefowl Preservation Group
PO Box 29
Ongerup, WA 6336

North Central Malleefowl Preservation
Group
Box 23, Wubin, WA 6612

Western Australian Museum
Perth Cultural Centre
James St Mall
PERTH, WA 6000