The National Malleefowl Recovery Plan: a framework for conserving the species across Australia

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The malleefowl *Leipoa ocellata* Gould, 1840, has declined substantially since European settlement of Australia just over 200 years ago. The species is now vulnerable and is threatened by the loss and degradation of suitable habitat by grazing, fire, and clearing, by the insidious effects of fragmentation of their populations that has resulted from clearing, and by predation by introduced foxes. Accordingly, a National Malleefowl Recovery Plan is being prepared to outline actions that are needed to both secure the species and provide the information necessary for effective management.
Conserving malleefowl will require improved management throughout its range and on a diversity of land tenures. Improving habitat quality is crucial and may be achieved by reducing grazing pressure from commercial stock and feral goats, by preventing the catastrophic effects of large wildfire, and by reducing the size and frequency of intentional fires. Reducing the abundance of foxes may also assist malleefowl recovery, particularly where the birds' populations are small and isolated or declining. Remaining malleefowl populations are highly fragmented, and there is a need in many areas for habitat links to facilitate dispersal of the species between nearby habitat patches. The retention and revegetation of habitat links would also slow the degradation of remnant habitats due to increasing soil salinity.
Considering the vulnerability of the species, it is especially important to monitor the distribution and abundance of malleefowl across Australia and over a number of years. Effective conservation will also require a better understanding of the species' population dynamics, habitat preferences and genetic variability.
Local communities have made a major contribution to protecting and understanding the malleefowl and interest in this popular species is growing rapidly. Many of the projects outlined in the Recovery Plan are suitable for community involvement, and the time is ripe to further encourage and promote this interest in malleefowl conservation.

Introduction

The malleefowl *Leipoa ocellata* Gould, 1840, the sole species in the genus *Leipoa*, is one of the most unusual and fascinating birds of the world. It is distinguished firstly as a megapode and thus one of the few birds to incubate its eggs using external sources of heat to produce super-precocious young, and secondly because the malleefowl is the only arid-zone megapode and has developed the most sophisticated incubator in the family. Apart from these scientific points of interest, the species is also important in the mythology of some Aboriginal cultures, and has become a popular flagship for conservation in rural communities to the degree that hundreds of people across Australia are currently members of grass roots organizations dedicated to its conservation.

Despite this level of interest, the malleefowl has declined substantially since white settlement of Australia just over 200 years ago and is threatened by a range of factors. Accordingly, a National Malleefowl Recovery Team was established comprising scientific, government, and community representatives involved in the conservation of the species across Australia. The National Malleefowl Recovery Plan (Benshemesh, 1997b) was commissioned to provide a framework for the Recovery Team and to detail actions required to conserve the species. This involved consultation with researchers, wildlife agencies, community groups and other interested individuals across Australia. Such plans are prescribed by legislation as a key approach to securing endangered and vulnerable species in the wild (Endangered Species Protection Act, 1992).

The National Malleefowl Recovery Plan conforms to a standard format and includes a review of the species' conservation and outlines management and research actions needed to improve and clarify the national conservation status of the species. But unlike most recovery plans which are funded by government, the drafting of this plan has been funded by the four major zoos in southern Australia as part of their commitment to the species' in situ conservation. It also differs slightly in its intended audience, which includes a wide cross-section of people and agencies that are or could be involved in the conservation of the species across Australia. Accordingly, the Malleefowl Recovery Plan aims to provide a resource document for these diverse groups comprising land and wildlife managers, community groups, rural industry, and researchers.

Here, I provide an overview of the recovery plan and the rationale for its approach. In the process, I also discuss the major threats to malleefowl and the actions needed to improve management of this species.

Distribution and conservation status

Far from being a geographically restricted curiosity, the malleefowl was possibly the most widely distributed of all megapodes in terms of land area occupied. The original range of malleefowl covered much of southern and central Australia and the species was widespread in every mainland state except Queensland (fig. 1). It occurred in various vegetation communities on sandy soils, especially shrublands and low woodlands dominated by mallee (various species of stunted, multi-stemmed eucalypts) and acacia scrubs in more than a quarter of the 80 major biogeographic regions of Australia (as defined by Thackway & Cresswell, 1995). This distribution was probably continuous with the exception of a gap of unsuitable habitat around the north of Spencer Gulf and across the Flinders Ranges (Copley & Williams, 1995), and a population along the coast of south-east Western Australia which appears surrounded by unsuitable habitat of the Nullarbor Plain.

Within the past century the range of the malleefowl has contracted, particularly in arid areas and at the periphery of its former range (fig. 1). Of 166 one-degree (lat./long.) grid cells across Australia in which the species has been recorded at some time in the past, malleefowl have only been recorded in 81 cells since 1981 (see below), suggesting a decline in range and distribution of up to 50%. In particular, there have been no confirmed sightings of the species for several decades in the Northern Territory, and only few and scattered records elsewhere in central Australia. Part of this decline of malleefowl in the remote centre may be due to a reduced survey effort rather than an absence of the species. There have been few attempts to locate the species in central Australia over the past 50 years (but see Robinson et al.,

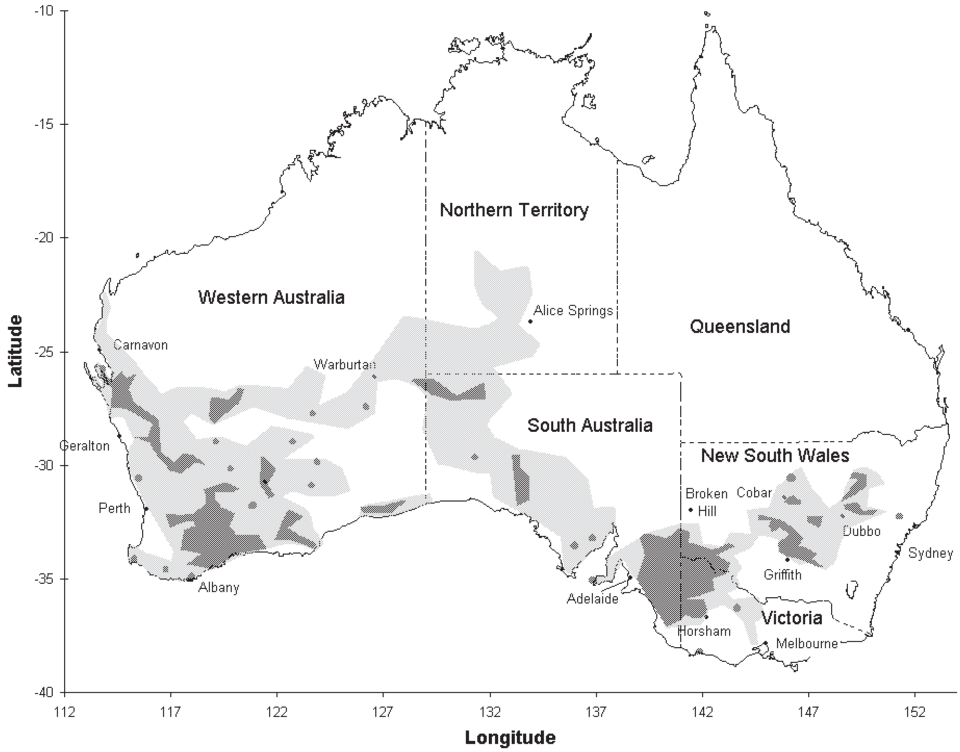

Fig. 1. Historical distribution (light shading) and distribution recorded since 1981 (dark shading) of the malleefowl in Australia based on over 3,300 records from museums, community groups, ornithological organizations and government wildlife authorities. Records since 1981 represent about 40% of all records.

1990; Copley et al., 1996; Benshemesh, 1997a; Pearson & Chapman, 1998). Moreover, the chance of locals or biologists reporting malleefowl in remote areas has probably been reduced by the shift from walking through areas to rapid vehicular transport along tracks.

In the semi-arid zone flanking central Australia, the species' range has also contracted in the far north and south-west of Western Australia, from most of the Yorke Peninsula in South Australia, and from the south-east of its former range in Victoria. These range contractions have mostly been associated with permanent habitat changes caused by clearing of the birds' habitat for agriculture, especially in the cereal-growing regions where malleefowl reach (or reached) their highest densities.

Clearing has also fragmented the distribution of malleefowl to the degree that over much of its current range the species now persists in small patches of habitat that are almost certainly inadequate for its long-term conservation. Numerous authors have described recent declines in the abundance of malleefowl in reserves within these fragmented landscapes (Brickhill, 1985; Gell, 1985; Brickhill, 1987b; Saunders, 1989; Priddel, 1990; Saunders & Curry, 1990; Priddel & Wheeler, 1995; Benshemesh, 1997c). However, not all sub-populations appear to be in decline and there are some positive signs of malleefowl showing stable or even increased breeding densities over periods of several decades in some areas (Benshemesh, 1997c). On balance though, there are grave concerns for the conservation of the species over most of its range.

Although malleefowl densities have been measured at dozens of monitoring sites across Australia, there have been few attempts to estimate population sizes. In the mid 1980s, the total malleefowl population in New South Wales was estimated to be only 750 pairs (Brickhill, 1987b), and was guessed (probably conservatively) to be less than 1000 pairs in Victoria (Land Conservation Council, 1987). In south-east South Australia, several thousand pairs are currently thought to exist (Cutten, 1997), but these are mostly in very small and isolated habitat fragments and their conservation is precarious at best. There are no estimates of population size in other states where malleefowl occur. Overall, a guesstimate of between 5,000 and 20,000 breeding pairs Australia-wide would seem reasonable, although this is based on very limited data. It is likely that the population has been reduced by 80% or more since European settlement, and most of this decline may be attributed to clearing and other forms of habitat degradation.

Malleefowl qualify as Vulnerable by the current criteria for threatened species (IUCN 1994, criteria VU a2) as it is likely that populations will continue to decline by at least 20% over the next three generations (30 to 50 years). This is because remaining sub-populations are mostly small and isolated with poor prospects of long-term conservation, and all sub-populations are threatened by introduced competitors and predators, and subject to recurrent catastrophic events of a scale that severely threatens the viability of populations and the quality of habitat. Regionally, the malleefowl is regarded as endangered in New South Wales and vulnerable in Victoria, South Australia and Western Australia (Garnett, 1992). In the Northern Territory the species may be extinct (Blakers et al., 1984; Kimber, 1985; Reid & Fleming; 1992) although recent unconfirmed reports suggest it might still occur in the southwest region.

Threats to malleefowl

The clearest threats to malleefowl, both past and current, are related to land management and introduced species and threaten a broad range of other native fauna and flora across the continent. Foremost amongst these threats are those that lead to habitat degradation (such as clearing and grazing), catastrophic events (such as wildfires) that have caused massive population losses, and factors that undermine the viability of populations such as predation by introduced carnivores and fragmentation.

Clearing and fragmentation

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, 1901; Mattingley, 1908; Bellchambers, 1916, 1918; Barrett, 1919; Chandler, 1934). Overall, about 80% of native vegetation in the southern wheat-belt has already been cleared (Glanznig, 1995). This clearing has been selective and concentrated on those areas of greatest soil fertility and rainfall, including areas where malleefowl were most numerous (Frith, 1962; fig. 2). Where malleefowl habitats remain within the fertile regions of the southern wheat-

Fig. 2. Satellite image of the southern wheat-belt in south-west Western Australia showing the broad range of malleefowl recorded since 1981 (black line). This area represents one of the highest densities of recent malleefowl records in Australia. Native habitats have mostly been cleared for agriculture (lighter regions) and within its current range malleefowl persist mostly in small and isolated habitat fragments (darker regions). Most of these fragments are too small to feature in this image. Landsat MSS mosaic acquired in 1990-1992 (Geoimage & the CSIRO Office of Space Science & Applications).

belt, they are mostly small and isolated (Brickhill, 1987b; Saunders, 1989; Saunders & Curry; 1990; Cutten, 1997). In contrast, large remnants occur in areas unsuitable for agriculture (Land Conservation Council, 1987; Sparrow, 1989) and are often of marginal quality for malleefowl (Frith, 1962; Brickhill, 1987b; Priddel, 1989, 1990; Benshemesh, 1992; Copley & Williams, 1995).

Clearing has also disrupted the continuity of malleefowl habitat across the continent with dire consequences for the viability of remnant populations. 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. The once nearly continuous distribution of malleefowl across Australia has now been fragmented into a large number of small populations. For example, in the south-east of South Australia Cutten (1997) reported malleefowl in 96 separate blocks of native vegetation of which only 36 were larger than 1000 ha and might harbour more than a dozen breeding pairs each if all the habitat were suitable. Only four were larger than 10,000 ha. As malleefowl are poor fliers and disperse mostly on foot, this fragmentation has presented an obstacle for dispersal between subpopulations. Small and isolated populations are especially vulnerable to local extinction by a range of processes that deplete the number of individuals or degrade the overall fitness of each population (Nei et al., 1975; Shaffer, 1981; Frankham, 1995). Moreover, 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 (exotic pests in Australia) are more abundant near cleared land (Saunders et al., 1995), and wildfire may completely consume fragments of mallee and cause local extinction where there are no sources for recolonization. In the longer term, the degree of clearing poses two other threats to malleefowl conservation. Firstly, many remnant malleefowl habitats are likely to be lost over the next few decades due to major rises in soil salinity caused by widespread clearing (Land Conservation Council, 1987; George et al., 1994; Agriculture Western Australia et al., 1996). Secondly, the combination of landscape fragmentation and climate change, such as that postulated by the 'enhanced greenhouse effect', may seriously threaten species such as the malleefowl that require continuous habitat for dispersal (Peters & Darling, 1985). This is especially the case considering the severe impact on malleefowl predicted in some regions (Bennett et al., 1991) and on mallee habitats in general (Greenwood & Boardman, 1989) under enhanced greenhouse scenarios.

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 most states (Mallee Vegetation Management Working Group, 1991; Department of Land and Water Conservation, 1997). As malleefowl are protected in every state in which they occur, clearing applications are unlikely to be granted for areas where important populations are known to exist. The catch is that the only available criterion for assessing a site's importance for malleefowl conservation is the obvious presence of the birds, but as malleefowl are elusive and rare their presence may easily be missed. Also, areas in which there are no resident malleefowl may nonetheless be important for the species' conservation, but may not be recognised as such. For example, fire may eradicate malleefowl from an area and render a habitat unsuitable for two decades or more, but the habitat is likely to become suitable again as it matures. Other areas without resident malleefowl that may be important to the species' conservation include habitat links that allow the birds to disperse between breeding populations.

Grazing

In areas grazed by sheep, Frith (1962) showed that malleefowl breeding densities were reduced to only 10-15% of that in similar ungrazed habitats. Apart from stock, 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 uncommon in malleefowl habitats, but feral goats are of particular concern for malleefowl conservation as they may be even more damaging to shrubs than sheep (Harrington, 1979, 1986). Feral goats are abundant in some mallee areas (Henzell & McLeod, 1984; Newsome, 1989; Pople et al., 1996), and some of the highest goat densities occur in reserves that support malleefowl populations, particularly in large reserves and pastoral leases in New South Wales and eastern South Australia north of the Murray River. 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. High numbers of kangaroos might also be a problem in some situations where artificial water sources have greatly increased their numbers.

The ecology of Australia's semi-arid and arid ecosystems has been profoundly altered by the new grazing regimes resulting from introduced animals, and this has probably contributed to the decline and extinction of many fauna (Burbidge & McKenzie, 1989; Morton, 1990; Recher & Lim, 1990; Dickman et al., 1993; Sadlier & Pressey, 1994). The effects of these herbivores are twofold. Firstly, grazing and browsing denies malleefowl of food that otherwise may be available to them. Secondly, when maintained at high densities these herbivores may effect long-term change to the structure and floristic diversity of habitats (Harrington, 1979; 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 (Priddel & Wheeler, 1997). Moreover, these changes may reduce not only the diversity and abundance of plants that malleefowl depend on for food, but also of invertebrates (Greenslade, 1992) which are another important food source for malleefowl. The deleterious effects of grazing are especially important after fire when vegetation is regenerating (Leigh & Holgate, 1979; Hopkins, 1982; Christensen & Maisey, 1987), during droughts, and where herbivore numbers are maintained at high levels by the provision of artificial water sources. By benefiting large grazing animals, artificial water sources greatly effect the distribution and abundance of native plants and animals for a radius of at least 10 km (Landsberg et al., 1997). As relatively few areas within the pastoral zone are more than this distance from artificial water sources, most malleefowl habitat in the pastoral zone is likely to be affected by artificially high grazing pressure.

Grazing by stock continues over vast areas of the species' habitat on public land (except in Victoria). Choate (1989), estimated that 90% of mallee habitat in New South Wales, and 20% of mallee in South Australia, was public land under pastoral lease. Most of this is dense mallee habitat on which sheep are grazed (Stanley & Lawrie, 1980), and that is likely to be malleefowl habitat. New reserves have recently been created in eastern South Australia (Calperum and Gluepot) and the removal of stock and control of goats in these large areas is likely to benefit malleefowl. However, only 9% of existing mallee habitat in southern New South Wales is in nature reserves (Freudenberger et al., 1997). A similarly low proportion of the species' original range is protected from commercial grazing in Western Australia and the Northern Territory.

There is little doubt that past and present grazing has damaged malleefowl habitat and that continued grazing by sheep is keeping these populations much lower than would otherwise be the case. Much of this land may be of relatively low quality for malleefowl (Frith, 1962; Brickhill, 1987b), but the size of these grazed areas suggests that they may still be of great importance for malleefowl conservation.

Extensive fires

Fire is a natural part of the ecology of all malleefowl habitats. However, habitat fragmentation and clearance have so modified the scale of wildfire in relation to available habitat that extensive fires are now a major threat to the conservation of the species. Mallee habitats in particular are highly flammable (Gardner, 1957; Noble, 1984) and are the stronghold for malleefowl.

The effects of fire on malleefowl populations are twofold. Firstly, large fires probably kill most birds in their wake as malleefowl are poor fliers and do not appear to disperse widely as fires approach (Benshemesh, 1992). This is a problem for conservation because wildfire may consume hundreds or even thousands of square-kilometres despite active suppression, and because large fires occur at approximately 20-year cycles in mallee (Cheal et al., 1979; Leigh & Noble, 1981; Day, 1982). The catastrophic effect of wildfire on malleefowl populations is exacerbated by the fragmentation of the landscape caused by clearing. Fires that burn entire habitat patches may cause the local extinction of malleefowl where surrounding areas no longer provide a source of recolonization, and this appears to have occurred at Lincoln National Park in South Australia (Cutten, 1997).

Secondly, fire in the mallee typically kills and removes all above ground vegetation and thus 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 over a decade (Tarr, 1965; Cowley et al., 1969), and even 20-40 years later their abundance is less than in neighboring old-growth habitat (Woinarski, 1989; Benshemesh, 1990, 1992), probably due to the slow recovery of habitat structure. Somewhat ironically, the accumulated litter that is used for incubation is also the major fuel-bed in most mallee habitats (Noble, 1984), so that mallee habitat may be able to sustain large fires every 10-20 years (Leigh & Noble, 1981). Habitats much older than 30 years post-fire are consequently rare, at least in eastern Australia.

These devastating effects of fire are related to their size and shape, and there is some evidence that patchy burns are much less damaging to the species. For example, malleefowl persisted in several small patches of unburnt habitat after a large fire in 1985 and readily fed in the surrounding burnt habitat (Benshemesh, 1990, 1992). Although malleefowl abundance was greatly reduced by the fire, ten years later breeding density had almost returned to its original value (Benshemesh, 1997c; Benshemesh & Burton, 1998), whereas the species was still very rare or absent in other areas where the fire had not burnt patchily. Unfortunately, patches of unburnt habitat that are suitable for malleefowl are only rarely left after large wildfires.

Fire exclusion is neither feasible nor desirable for mallee shrublands, and 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 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). For example, in New South Wales most mallee has been burnt within the last 25 years, the majority in wildfires that consumed well over a million hectares of mallee during the summer of 1974/75 (Noble et al., 1980; Pickard, 1987). Thus, during one season as much as a third of the entire New South Wales malleefowl population may have been killed or displaced in a few weeks, and their current abundance may still be depressed due to the effect of those fires.

Apart from wildfires, intentional broad-scale burning of malleefowl habitat is practized in some states. Frequent burning is a means of producing permanent habitat change by reducing tree and shrub density to benefit sheep grazing (Noble, 1989) and may more than double the productivity of pastoral mallee habitats for sheep (MacLeod, 1990). For these reasons intentional broad-scale burning was promoted in the past by agricultural extension services in New South Wales (Choate, 1989; Muir, 1992). Indeed, some authors suggest that much of the mallee under leasehold in that state was burnt on a 10-20 year cycle to increase forage production, eliminate shrubs unpalatable for sheep, and for fuel reduction (Hodgkinson et al., 1984; Noble, 1984). Even if only portions of an area were burnt each year, such a fire regime would devastate malleefowl populations (Benshemesh, 1990, 1992). There is a clear need for community awareness of the threat posed by fire, especially amongst pastoralists who may wish to conserve malleefowl on their leases.

Predation by introduced carnivores

Predation of malleefowl by introduced carnivores is a major concern. The European red fox *Vulpes vulpes* (Linnaeus, 1758) was introduced into Australia in the 1860s and spread rapidly through the eastern range of malleefowl by the turn of the century and through the west by the 1930s (Jarman, 1986). The feral cat *Felis catus* Linnaeus, 1758, was introduced even earlier and spread throughout the continent (Jones, 1983). Whereas foxes prey upon all stages of the malleefowl's life cycle from eggs through to adults, cats are much less of a threat to malleefowl and only occasionally prey upon chicks and juveniles (Priddel & Wheeler, 1994, 1996, 1997). Whether the dingo *Canis familiaris dingo* Blumenbach, 1892, a primitive dog introduced to the continent at least three thousand years ago, preys upon malleefowl to any appreciable extent is not known as most malleefowl studies have been conducted in eastern Australia where dingoes are now very rare. Given that dingoes are much less common than foxes over most of the birds' range and have coexisted with malleefowl for thousands of years, it is unlikely that they present a major threat to malleefowl.

The fox presents the greatest concern as it is the most common predator of malleefowl and frequently preys upon malleefowl eggs, chicks, juveniles and adults. Foxes are the only confirmed predator of malleefowl eggs apart from humans, and have been known to kill over a third of all eggs laid in some areas (Frith, 1959; Priddel, 1990; Benshemesh & Burton 1997). But predation on eggs is often negligible (Booth, 1987; Brickhill, 1987a; Benshemesh, 1992) and there is now evidence to suggest that high egg predation by foxes is linked to sudden crashes in rabbit populations (Benshemesh & Burton, 1997).

Although high predation rates on adult malleefowl have been recorded (Booth, 1987), most adult malleefowl appear to live on average for 10 to 20 years and perhaps longer despite high numbers of foxes (Frith, 1962; Benshemesh, 1992, see also Benshemesh, 1997b). Young birds are much more vulnerable to predation by foxes, even though they are capable of flight within a day or so of hatching and habitually roost in trees. Chicks released within a day of hatching (Benshemesh, 1992), and captive-reared young of various ages (Priddel & Wheeler, 1994, 1996, 1997), experience heavy mortality due to predation by foxes, although mortality also occurs due to predation by raptors and starvation. This mortality is especially severe during the first few days after release. Sub-adult birds (14-28 months old) survive better, but fox predation may still account for 70% of captive-reared birds unless intensive fox baiting is conducted, in which case malleefowl mortality may be greatly reduced (Priddel & Wheeler, 1997). This high predation by foxes provides much cause for concern, although whether such high predation is typical of wild birds is still uncertain (eg. Dowell, 1990; Putaala et al., 1997). The long life and high reproductive output of malleefowl also makes the importance of high mortality in young difficult to evaluate (Frith, 1962), especially considering that the Australian arid and semi-arid zone inhabited by malleefowl is inherently variable by world standards (Stafford Smith & Morton, 1990).

While it is clear that foxes pose a threat to malleefowl, it is also clear that malleefowl populations in some areas appear stable despite high fox abundance. Foxes are most common near agricultural land (Saunders et al., 1995), but many of the highest malleefowl densities are in such areas and often appear stable unless their habitat is disturbed (Frith, 1962; Benshemesh, 1992; Copley & Williams, 1995). Declines have occurred in many areas, and are more common than increases (Benshemesh, 1997c), but whether these have been due to changes in habitat suitability, landscape configuration, stochastic events or predation remains uncertain. Where fox control has been conducted over periods of time in which some response by malleefowl might be expected, results have usually been disappointing. Of five sites across Australia where intensive fox baiting has conducted for four to nine years by various agencies, an increase in malleefowl abundance has only been noted at one site (Benshemesh, 1997b). It is still uncertain whether available methods of fox control provide any measurable increase in malleefowl populations.

Despite these uncertainties, it is likely that foxes pose a significant threat to malleefowl and may lead to their decline. There is clearly a need to assess the benefits of long-term fox reduction programs on malleefowl abundance. In the meantime, it would be prudent to reduce fox numbers where malleefowl populations show signs of decline, where rabbit numbers are suddenly reduced, or when captive-reared malleefowl are released to the wild.

Recovering malleefowl

In general, local extinction or severe decline of malleefowl populations has mostly been associated with habitat changes caused by clearing, large fires, and grazing by introduced animals. Foxes are probably also contributing to the decline of malleefowl populations, especially in marginal habitats and small remnants. Malleefowl are expected to continue to decline due to these threats and the long-term consequences of the fragmentation and isolation of populations unless remedial action is taken soon.

The primary objective of the Malleefowl Recovery Plan is to secure the species by ensuring that viable populations persist across the species' original range. To achieve this objective, management of malleefowl habitats and populations must be improved. In particular, there is a need to identify and protect important habitats, reduce the isolation of fragmented populations, and reduce the deleterious effects of introduced herbivores and predators.

Governments and local communities have reduced threats in many areas, but only a small proportion of malleefowl habitat across Australia is managed primarily for conservation. Malleefowl are still widely distributed across four states and occur on various land tenure types including private property, leaseholds, public land controlled by State and Commonwealth Governments, and on Aboriginal land. As only a small proportion of the species' distribution is protected in conservation reserves, the species is likely to benefit most from improved management on other types of land tenure as well. There is considerable potential for such off-reserve improvement in the species' conservation as the malleefowl is a popular animal and most landholders are interested in its conservation.

While improved management will benefit malleefowl, further information is also needed to identify important sites, examine the viability of remaining populations, and to plan the most effective and efficient management for self-sustaining populations.

Many management and research actions would benefit from participation by interested individuals, communities and organizations in the conservation of malleefowl. Community groups have made major contributions to malleefowl management and research (Blyth et al., 1994; Orsini et al., 1994; Williams, 1994), and are also well placed to assist in long-term research into the stability and dynamics of populations. Just as importantly, local groups are able to raise their communities' awareness of the processes threatening malleefowl and effect improvements in management outside reserves that may have profound benefit to the species.

These issues of management, research, and community participation are briefly dealt with below. The Recovery Plan provides further details and reviews past and present management.

Securing existing populations

Reducing habitat loss

Permanent loss of habitat has been the major factor in the decline of malleefowl in agricultural areas and continues to be a threat on arable land, although the excessive clearing of the past century has abated. Native vegetation clearance controls exist in most states and specifically protect habitats where threatened species such as malleefowl occur. Nonetheless, there are current plans to clear substantial areas of mallee in New South Wales (Department of Land and Water Conservation, 1997), and clearing also continues in many other areas in a piecemeal fashion.

Reducing the threat of further clearing will require the identification of areas that are important for the species so that they are protected under existing legislation. This should include not only areas that are known to harbour malleefowl, but also habitat links and additional habitats that may support the species with appropriate management. Areas so identified should be protected in the long-term, and there are a variety of mechanisms available for achieving this ranging from voluntary property agreements to acquisition by conservation agencies.

Salinisation of the land also threatens malleefowl and their habitats, particularly in Western Australia and south-east South Australia, and is one of the most critical environmental problems facing dryland agriculture in southern Australia. Programs that reduce further deterioration of the land will benefit malleefowl as well as the economic and social viability of rural landscapes.

Reducing grazing

Grazing by introduced animals is perhaps the most difficult issue confronting the conservation of malleefowl because there is often a direct conflict between the livelihood of people and conservation. On pastoral leases, sheep, cattle and goats are grown for commercial gain over vast areas of malleefowl habitat, and their effects are almost certainly keeping malleefowl populations much lower than would otherwise be the case. Many pastoralists are interested in conserving malleefowl, and much can be gained by their involvement and by raising their awareness. In south-west New South Wales where most mallee is under lease, there are plans for pastoralists to manage portions of their leaseholds for conservation in exchange for permission to clear and crop other areas. Such initiatives should be encouraged where there are net benefits to malleefowl and other species conservation, and graziers should be helped by government extension services to design grazing regimes with a minimal impact on malleefowl.

Feral goats are common on public land and conservation reserves in every state, especially north of the Murray River and in Western Australia, and should be removed from those that harbour malleefowl. Successful techniques that are being used in some areas include closing off or removing artificial watering points, harvesting, culling and providing adequate fencing.

Linking patches

The future for malleefowl in small (<1000 ha) and isolated reserves is grim. Population sizes are often very small, numbering less than a dozen pairs, and many remnant patches of habitat are surrounded by cleared land that is a hostile environment for malleefowl to traverse or survive in. A large body of evidence and theory shows that species are rapidly lost from such isolated remnants.

Corridors of native vegetation that link remnants may benefit malleefowl greatly by facilitating movement of animals between habitat patches. These may be created by planting suitable vegetation, and programs exist in each state to provide community groups with materials and incentives to revegetate areas.

There are few data from which to deduce the effectiveness of such corridors for malleefowl, or what their attributes should be, but there is evidence that malleefowl use even narrow roadside strips of suitable habitat for dispersal in preference to crossing open ground. Narrow corridors may increase the bird's vulnerability to predation and road traffic, and maximizing the width and minimizing the length of corridors would reduce these threats. Strategic road signs and fox baiting (see below) may also reduce the vulnerability of malleefowl dispersing along corridors. In any case, these threats are likely to be offset by the advantages of greater habitat connectivity which may enable populations to persist despite stochastic population fluctuations and prevent inbreeding problems. However, malleefowl should be discouraged from dispersing along existing corridors of habitat that do not lead to other patches of suitable habitat, perhaps by forming strategic gaps in the corridor.

Corridors are unlikely to be a workable solution for facilitating dispersal between widely separated remnants, but restoring links is the best long-term, cost effective solution where patches are within a few kilometres of other suitable malleefowl habitat. Translocation of eggs, chicks or adults is an option for maintaining genetic variability in small and widely dispersed subpopulations, and for mitigating against stochastic effects, but such programs are likely to be expensive and require regular and long-term intervention. In terms of the national conservation of malleefowl, very small and isolated populations are only rarely likely to warrant long-term commitments to on-going translocation programs unless they can be conducted at low expense (e.g. by community groups).

Reducing large fires

Large fires destroy malleefowl populations in their wake, and diminish the suitability of habitat for malleefowl for at least 30 years thereafter. Such large fires have clearly devastated malleefowl populations over the last few decades, and there is an urgent need to prevent their occurrence in the future.

Fire management plans are needed for all reserves in which malleefowl occur, and these should consider ways of minimizing the risk to malleefowl. Fire is an important issue for other species, and for people that live in rural areas, and as a consequence fire management plans have been produced for many reserves across Australia. However, these plans only rarely consider the distribution or habitat preferences of malleefowl.

In large reserves, areas that are most important for malleefowl should be identified and fire management plans should include strategies for protecting these in particular. Complete fire exclusion is neither feasible nor desirable, and in the long term may actually increase the size and severity of wildfires by increasing the continuity of fuels. Rather, fire management plans should focus on ways of limiting the spread of large fires when they occur and encouraging them to burn more patchily.

In central Australia, traditional burning practices by Aborigines should be encouraged where they do not threaten habitats used by malleefowl (such as in dense stands of mulga or mallee). Such burning disrupts the continuity of fuels and thereby reduces the risk of large fires, and may also benefit malleefowl by stimulating the growth of food plants. These fires should be mapped and their effect on malleefowl monitored.

Reducing predation

Foxes are efficient predators of malleefowl and reducing fox numbers probably benefits the birds' populations. This is especially the case in small reserves and near the edges of large reserves. Nonetheless, it is still unclear how important fox predation is in determining malleefowl abundance or how effective fox control techniques are at increasing malleefowl populations or reversing declines. Accordingly, details of the method, intensity and success of fox control should be reported whenever fox control is conducted. Malleefowl breeding density and the frequency of malleefowl sightings should also be monitored to gauge the effectiveness of fox control at benefiting the birds.

Fox numbers should be reduced where malleefowl populations show signs of substantial decline despite continuing habitat suitability, and when captive-reared malleefowl are released in the wild. Fox control is most efficiently achieved using baits containing 1080, a poison that occurs naturally in some Western Australian plants and to which too much of the Australian vertebrate fauna is tolerant, especially malleefowl (King et al., 1996). However, managers should be aware that measurable benefits to malleefowl may not occur for several years as the birds are unlikely to breed until four years of age, and that fox control should continue for at least this period of time. As foxes are common throughout the landscape and rapidly reinvade areas, widespread programs that reduce fox abundance over a radius of many kilometres are likely to be much more effective than localised efforts. Fox numbers should also be reduced where rabbit numbers are reduced because when rabbits become uncommon foxes are most likely to switch their predation to malleefowl and other native species. Poisoning of rabbits immediately before fox control efforts are begun may also cause significant secondary poisoning of foxes and make fox control more effective (McIlroy & Gifford, 1991).

Reducing road kills

In some areas malleefowl may be killed on roads where they often feed on spilt grain. In some cases, such mortality may be substantial and damaging to a small population. For example, during one year 13 malleefowl were apparently killed along a two-kilometre stretch of road in Western Australia (G. McNiel pers. comm., 1997).

Where malleefowl are often seen on roads, effective measures should be taken to minimize the amount of grain spilt during transport, and signs should be erected warning drivers that malleefowl may be on the road ahead and that they are a threatened species. Such signage also has benefits in raising public awareness of malleefowl conservation.

Regional plans

A site-specific approach to malleefowl conservation and population management is required but is beyond the scope of the National Recovery Plan. Malleefowl still occupy an enormous range across the continent and threats to local populations vary with time and location. Regional conservation plans for malleefowl are needed to identify key areas for conservation, summarize likely threats relevant to each site where malleefowl occur, and develop site-specific measures to secure the species in the long-term. In fragmented landscapes it may be unrealistic to attempt to conserve the species in every patch, but the plans should examine the need and feasibility of producing networks of interconnected patches, and consider where and how resources may best be directed.

Information for management

Apart from securing existing populations by lessening threats, to conserve malleefowl in the long term the fundamental issues of population extent, size and trends must be tackled on a national scale. This information is important as a basis for a coordinated and effective national approach, and so that scarce resources are directed to areas where they most benefit the species' conservation. An understanding is also required of the habitat requirements of malleefowl, and some aspects of their population dynamics, to interpret changes in abundance that occur in populations and to model their long-term viability.

Monitoring population trends and evaluating management actions

Knowledge of the stability of malleefowl populations is fundamental to their conservation across Australia. Monitoring the number of breeding pairs at selected sites will show where changes are occurring and how rapidly they are proceeding, and provide a means of assessing the benefits of a range of management actions. In particular, the monitoring program will provide the opportunity to assess the impact of introduced predators and the effectiveness of control of these predators in a statistically designed experiment.

Monitoring grids are the most cost-effective way of measuring the stability of malleefowl populations as only one person is required, and because both the monitoring of the mounds and the establishment of grids are suited to community involvement. A manual for grid based monitoring and a database application has been produced in Victoria to facilitate the program and community participation. The database is available to all agencies and community groups involved in monitoring and provides for the centralization of data at Birds Australia (the national ornithological organization).

So far, there are 24 monitoring grids in Victoria, eleven in South Australia, and five in Western Australia, but another six grids are expected to be completed in each of New South Wales, South Australia and Western Australia by the end of 1998. These will provide benchmark estimates of malleefowl abundance for future reference and a selection will form the basis for long term monitoring of malleefowl populations.

Distribution

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, relying for the most part on incidental sightings of the birds that are recorded in wildlife atlases and museum records in each state. A more systematic approach to recording the distribution of malleefowl is required.

A systematic and thorough bird atlas project by Birds Australia is currently underway (Ambrose, 1998) and will involve bird watchers across Australia for several years. However, malleefowl are cryptic and secretive, and are often missed in generalised bird surveys. Accordingly, Birds Australia has agreed to include special procedures for recording malleefowl footprints and this may provide a more reliable method of detecting the presence of the species rather than relying on sightings of the birds or their mounds.

Other programs will also be employed to describe the current distribution of malleefowl across Australia. In agricultural areas, postal survey is a cost-efficient means of collecting distribution data on remnants of native vegetation and such surveys have been successful in the past (Brickhill, 1987b; Cutten, 1997). Postal surveys are recommended for Western Australia, New South Wales, and on Eyre Peninsula (South Australia) where the current distribution of malleefowl is not well known and where declines are suspected. Similarly, programs that record incidental sightings of malleefowl by local people are recommended and provide another means of describing the species distribution. Incidental sightings may be especially valuable for providing data on the birds' use of vegetation corridors, data that are very difficult to obtain otherwise. Such programs are currently run by community groups in Western Australia (Harold & Dennings, 1997) and in Victoria, and should be encouraged in other areas.

In remote areas, postal surveys and general bird surveys are unlikely to successfully encounter malleefowl even if the species exists in the area, due to the size and remoteness of the sites. Malleefowl are known to occur patchily in the Great Victoria Desert, in the Western Australian Goldfields, and north and east of the wheat belt in Western Australia, but little is known of their distribution and abundance in these areas. Similarly, it is not known whether these sparse populations are declining, or even what types of habitat the birds use. Most of these habitats are marginal for malleefowl, but the likely low densities over potentially enormous areas suggest they may be of great importance for malleefowl conservation.

Systematic searches for the birds' footprints in likely areas is the most reliable method of obtaining information on the distribution, abundance and habitat preferences of malleefowl in these remote areas. Local communities, many of which are Aboriginal, should also be informed of the interest in malleefowl and invited to collaborate and share their knowledge.

Population dynamics

The adequacy of recruitment in malleefowl populations is of central concern to the conservation of the species, particularly considering the vulnerability of young birds to fox predation. Assessing the adequacy of recruitment will require firm measures of the breeding life span of wild malleefowl and estimates of the rate of recruitment of young birds into the breeding population. These data are essential for modelling the viability of malleefowl populations and should be measured at several sites across the species' range.

Longevity of adults is best measured by marking individuals in small and isolated populations where all breeding birds can be located by searching for mounds, and where emigration and immigration are minimized. Malleefowl may be permanently marked with durable colour bands and their continued presence at sites checked by observation of active mounds. However, as malleefowl are often shy and females may only occasionally appear at their mound, such observation can become very time consuming. An alternative method is to implant a PIT (passive implanted transponder) into each bird when they are captured and banded, and to use automatic PIT readers to identify malleefowl as they excavate their mounds. This could greatly reduce the amount of time required to monitor the survival of individual birds in a small population and need not be expensive, but may require some development to assess the best configuration and placement of the PIT reader's antenna.

This long-term project is suitable for volunteers who may eventually run the project under the guidance of the Recovery Team.

Habitat requirements

Despite the increasing rarity of malleefowl, surprisingly little is known about the habitat features that are important for the persistence and success of the species; only two studies of very limited scope have examined the species' habitat preferences

(Frith, 1962; Benshemesh, 1992). A detailed analysis of these features would provide a basis for understanding the distribution and trends of malleefowl populations, elucidate limiting factors, and may enable land managers to improve habitats for the species. The ability to identify suitable habitat is also important, particularly in regard to assessing sites for re-introduction/translocation programs.

The 50 or so monitoring sites across Australia, and the data collected over many years, provide an excellent opportunity to conduct a sensitive analysis of malleefowl habitat requirements without the need to search new areas to determine breeding density. This short-term project may be suitable for MSc or PhD students, or professional biologists.

Genetic management units

The geographic distribution of genetic variability in malleefowl is not known, but it is essential information if this genetic diversity and the species in general is to be conserved. In particular, an understanding of the genetic structure of the species is essential for the management of its fragmented populations. Reasons to suspect that genetic differentiation of populations may have occurred include the enormous range and low vagility of the species, fragmentation of its range, and because morphological differences between western and eastern birds have been suggested by some authorities in the past.

The South Australian Museum has begun genetic analysis of malleefowl from across their range (S. Donnellan, pers. comm.). However, further analysis is required to examine mitochondrial and nuclear DNA for a definitive description of the genetic variation in malleefowl.

Completion of the genetic analysis will provide an objective measure of the appropriate units of management for the species and an assessment of whether current and proposed management units (such as key biogeographic regions) represent biological units of management.

Community involvement

Communication and participation

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, protecting and revegetating habitat links, fencing out stock, providing distribution records, reducing fox abundance, raising public awareness and providing education services to schools (e.g. Harold & Dennings, 1997). In general, these contributions are not well documented, or given the recognition they deserve. Nonetheless, interest in malleefowl conservation has increased greatly over the past decade, and hundreds of people across Australia are members of organizations dedicated to the species' conservation.

The participation of community groups in the conservation of malleefowl should be encouraged, and this may be facilitated by improving avenues of communication so that community groups communicate effectively between themselves, with the Recovery Team, and with other interested individuals. Community groups often work in isolation due to the geographic range of malleefowl, 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.

The national malleefowl conservation newsletter "Around the Mounds" should continue to provide biannual updates of progress toward malleefowl conservation across Australia, particularly in terms of the Recovery Plan. This newsletter provides a national overview and complements some excellent local newsletters such as "Malleefowl Matter" in Western Australia, and "Lowan Behold" in Victoria.

The Internet has revolutionized communication and most people across Australia are able to gain access through their local community centres and schools, Internet cafes, at work, or at home. The Internet provides an opportunity for a central point of reference for information exchange that would benefit education, community awareness and participation, and provide advice on undertaking conservation projects such as monitoring and reducing the threats to malleefowl. This home page should also explain the National Malleefowl Recovery Plan and report on its progress, and provide links to related Internet sites and newsletters.

An Internet discussion group would also facilitate communication between community groups, members of the Recovery Team, land managers and other interested individuals. As well as providing for a free exchange of advice, such a system is likely to foster a nationwide community attitude, facilitate links with a variety of people, and provide direct access to the Recovery Team.

Publicizing the role of community involvement

Public recognition of the contributions of community groups is important for maintaining the enthusiasm and interest of these groups. This publicity also assists groups in recruiting members, and raises public awareness of conservation in general, and malleefowl in particular. In this regard, the malleefowl is a useful flagship species as most of the management actions required to secure the species are of a general benefit to conservation.

Zoos that display malleefowl should also display information about the malleefowl recovery effort and emphasise the role of community involvement. A number of public zoos have already made substantial contributions to malleefowl conservation, and their media and education units could further assist the recovery effort by working with community groups and helping to publicize their activities. In terms of public relations, this collaboration would provide mutual advantages for zoos and community groups.

Conclusion

Malleefowl are threatened by the loss and degradation of suitable habitat by clearing, grazing, and fire, by the insidious effects of fragmentation of their populations that has occurred as a result of clearing, and by predation by foxes. Many of these threats are being tackled within some conservation reserves, and in general governments have a responsibility to ensure that appropriate management is conducted on land under their control. These threatening processes are not unique to malleefowl and for the most part apply to a suite of species, especially mammals, many of which have already disappeared from most of their former range. Due to the wide distribution and typically low population density of malleefowl, reducing these threats on a diversity of land tenures is required to conserve the species across its range.

While securing the existing populations of malleefowl is of utmost priority in the Recovery Plan, it would be naïve to assume that an adequate understanding of the species' biology has already been obtained to design the most cost-effective and successful management strategies. While some of this information could be obtained by short-term projects, such as determining the habitat requirements and genetic units of management, long-term projects are also required and present a special challenge in the current climate of scarce and sometimes volatile funding arrangements. Nonetheless, there is an urgent need for better understanding of trends in malleefowl numbers and their population dynamics, especially in regard to fox predation, and these will require projects that continue for at least a decade to reflect the average breeding lifetime of the birds. These long-term projects will also provide a cornerstone for experimental management whereby the benefits of management actions are monitored and reported to enable further improvements.

There is currently substantial community interest in malleefowl conservation and this appears to be growing rapidly. The time would seem ripe to further encourage and promote this interest. Community groups and individuals have already made an enormous contribution to monitoring malleefowl populations and the management of fragmented rural landscapes, and have provided a model for community partnership in both management and research. Many of the projects outlined in the Recovery Plan are suitable for community involvement and have been designed with such involvement in mind. Indeed, long-term projects such as monitoring and examining the population dynamics of the species may be difficult to sustain without community involvement. While this involvement should be encouraged, it will also require coordination by the Recovery Team at national and regional levels to standardize techniques and produce an overview of the results obtained from various management initiatives.

The Recovery Plan is far from being the final word in malleefowl conservation. Rather, the plan presents a framework of recommendations and projects that are designed to secure the species across its range and provide a firm and progressively improving basis for management in the future. This framework should be reviewed as new information becomes available. Although the implementation of much of the plan will depend on direct funding, it is also hoped that its recommendations will influence land management wherever malleefowl occur and provide a framework within which community involvement in the species conservation can flourish.

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