2. PROGRESS TOWARDS A NATIONAL SYSTEM OF MONITORING AND ADAPTIVE MANAGEMENT FOR MALLEEFOWL

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Abstract

One of the main aspirations voiced at the last Malleefowl Forum in Mildura was to standardise and consolidate the monitoring and move toward a more dynamic phase in which monitoring is used to assess management in terms of its benefit to Malleefowl. Three years on, there is much to report and we are well on our way to reaching this goal. In particular, a multi-regional project was developed to standardise and improve the monitoring and to analyse the data collected so far. These data are impressive, totalling nearly 600 site-years at over 60 sites across Australia, and were analysed by Professor Richard Barker and Ryan Macfarlane (University of Otago, NZ) in regard to environmental factors such as rainfall, landscape, and management practices such as fox baiting. The results confirm that Malleefowl are declining nationally even in reserves set aside for their protection and challenge long-held views about management practices such as fox control which we found has not been effective at benefiting Malleefowl. The analysis has demonstrated that we do not know as much as we thought about how best to manage Malleefowl populations, and highlights the need for better ways of identifying management practices that are beneficial and effective. Improving, standardising and analysing the monitoring data over the past few years have provided a firm foundation on which to build such an 'adaptive management' system. The system being designed will be underpinned by the monitoring conducted by community groups and, by linking management and research, will provide a core action for Malleefowl recovery for many years to come. Current studies are providing a framework for this adaptive management system and developing the necessary databases. These developments represent a shared vision among community groups, managers and scientists, and have been fuelled by enthusiasm and a sense of purpose as much as funds. Further development will require even greater opportunities for community involvement in Malleefowl conservation and a high degree of collaboration between state governments and numerous Natural Resource Management organisations

Introduction

Within the past century the range of Malleefowl has contracted, particularly in arid areas and at the periphery of its former range, and severe declines have occurred in southern agricultural areas due to the clearing of the mallee for wheat and sheep production (see Benshemesh 2006c). The fate of Malleefowl within the remaining habitat is uncertain and declines have been described in many protected areas across Australia (Brickhill 1985, 1987, Priddel 1989, 1990, Priddel & Wheeler 1995, 2003, Benshemesh 2007b, Priddel *et al*. 2007), and the species is regarded as threatened in every state in which it occurs and is listed as Vulnerable nationally. While land management agencies and individuals grapple with ways of reversing these declines, few techniques have actually been proven to be effective and there remains considerable uncertainty about how best to benefit the species.

Against this worrying backdrop, the role of monitoring has become central to the Malleefowl conservation effort. Formal Malleefowl monitoring programs started in most states in the late 1980s and early 1990s, and provide fundamental information on trends in Malleefowl abundance at a number of sites across Australia. This information is needed in order to assess the conservation status of the species across their range and to identify areas in which the species is declining. Perhaps even more importantly, monitoring provides a means of measuring the effects of naturally occurring events and the effectiveness of management actions on Malleefowl numbers.

Monitoring populations involves obtaining reliable and repeated measures of their numbers in order to measure changes in population size. Malleefowl are shy and elusive birds and counts of the birds themselves are very difficult, but their mounds are conspicuous and provide a reliable means of measuring the abundance of breeding birds in areas where they are moderately common

(Benshemesh 2004). This is because Malleefowl tend to renovate old mounds rather than construct new mounds afresh each year (Frith 1959), so that each old mound is a potential site for breeding. Annually checking the known mounds each spring thus provides a good estimate of the trends in breeding numbers at each carefully delineated site. New mounds are occasionally built by the birds and a thorough re-search of monitoring sites is required every few years to record these and ensure accurate estimation of breeding numbers.

Monitoring Malleefowl is well suited to volunteer involvement, and volunteers have made, and continue to make, an enormous contribution to Malleefowl conservation through monitoring programs. In fact, most monitoring that occurs across Australia is undertaken by volunteers and in many areas volunteers are responsible for all aspects of organizing and conducting the monitoring, including data storage, vetting and analysis. Numerous volunteer groups, as well as government and non-government agencies, and individuals are involved in this effort and maintaining standards and efficiency in the face of this diverse interest has become a major challenge.

Here, I wish to overview some of the most important developments that have occurred in regard to Malleefowl monitoring since the last National Malleefowl Forum held in Mildura (Vic) in 2004 (Victorian Malleefowl Recovery Group 2004). At that time it was clear that the monitoring effort was severely fragmented across Australia and that monitoring methods varied, making comparisons difficult. Moreover, although there were nominally nearly 100 monitoring sites across Australia, there was no central list, let alone data that could be readily accessed, and after several decades of dedicated effort by volunteers and government agencies much of the data was not collated, verified or analysed.

In acknowledgment of this growing problem, one of the main aspirations voiced at the Malleefowl Forum in Mildura in 2004 was to standardize, consolidate and analyse the monitoring at a national scale and to move toward a more dynamic phase in which monitoring is used to assess management in regard to its benefit to Malleefowl. In response to this wide community support, an application to Natural Heritage Trust was developed by Julie Kirkwood of the Threatened Species Network in collaboration with community groups, state and regional authorities and the Malleefowl Recovery Team. The application addressed much of Action 9 of the National Malleefowl Recovery Plan and was successful, with two years of funding being granted for a range of office-based and on-ground works. Work on the "National Malleefowl Monitoring Population Assessment & Conservation Action Project", which simply became known as the 'multi-regional Malleefowl project', started in 2006 guided by a national steering committee on which all monitoring groups were represented, and administered by the Mallee Catchment Management Authority (Victoria) in collaboration with the Victorian Malleefowl Recovery Group. Its main aims were to:

- improve monitoring and develop a consistent national monitoring system
- collate and analyse monitoring data in regard to management and environmental variables
- develop the monitoring program so that management actions that are most beneficial to Malleefowl can be identified, and
- advise regional Natural Resource Management bodies on how best to promote Malleefowl conservation within their region

This paper is largely an outline of the technical achievements of this project over the past two years towards the development of a national monitoring system for Malleefowl. However, it should be noted that I do not attempt to outline all the achievements of the project, which included on-ground works such as fencing, extensive training workshops and national round-table discussions (Ann Stokie, this volume, discussed some of these). It should also be noted that a large number of people from volunteer groups and agencies collaborated on this project and much of the success of this project was due to their guidance and the high degree of cooperation and enthusiasm with which they contributed. Indeed, the renewed spirit of cooperation and common aims across the country is perhaps one of the greatest achievements of the multi-regional Malleefowl project.

Improving the monitoring

Collating and over-viewing the data sets

One of the first actions of the tasks in the multi-regional project was to collate and review the data that had been collected to date. Collating the data turned out to be surprisingly difficult (Benshemesh 2006a) despite the willingness of data custodians, because data sets were often fragmented and were not readily accessible even within individual states or regions. Much of the data existed only on paper and was entered onto databases for the current project by teams of volunteers, while some original records could not be located at all. These difficulties in collating the monitoring data were frustrating, but most importantly also demonstrated the need for improvements in data management and strengthened the resolve of all those involved in the hunt for data to work toward a national database for Malleefowl monitoring records.

A 'gap analysis' of the collated data was also performed (Benshemesh 2006b) which examined the gap between the available data and the data we expected or would reasonably have liked to have for the two main tasks ahead: reviewing the effectiveness of the data routinely collected in the Malleefowl monitoring program, and analysing the trends in Malleefowl in regard to environmental variables. While over 20,000 mound visits had been recorded across Australia, the gap analysis basically looked at what was missing and how useful the data sets in their various forms were likely to be. For example, a relatively common problem in some datasets was that they were incomplete because observers only visited some of the mounds known in an area during a particular season. This meant that the actual number of breeding Malleefowl at a site was uncertain, and in some severe cases this rendered the data set useless for trend analyses. Overall, the assessment of the strengths and weaknesses of the collated data proved helpful for developing national standards (see below).

Apart from systemic problems in some monitoring data sets, it was also clear that information on past management practices (such as fox control) were difficult to obtain from state agencies and that it would be worthwhile for the Malleefowl monitoring program to obtain these records each year, and perhaps also monitor important environmental factors such as the abundance of predators and herbivores, food availability and habitat changes.

Review of the routinely collected data: streamlining and justifying the monitoring

The primary aim of the Malleefowl monitoring program is to track changes in the number of birds inhabiting specific areas. Observers (mostly volunteers) examine and categorise all the known mounds at each site as either 'active' (currently used as an incubator) or not active (Patford *et al*. 2004). To enable vetting of records and the detection of errors in judging the activity of mound, the size, shape and appearance of mounds is also described each time a mound is visited. These descriptors have been defined previously (Benshemesh 1997) and the resulting protocols have been used in both Victoria and South Australia from the early 1990s, and in Western Australia since 2005.

No substantive changes have been made to the Malleefowl monitoring protocols since the early 1990s, although some new data fields have been added and others have been more rigorously defined to reduce confusion. This conservatism was necessary to enable comparisons through time, but as the usefulness of the data had never been assessed, some data collected each year may have been unnecessary and provided little useful information. Also, new technologies over the past decade or so have changed the ways that data may be validated and reduced the need for some types of descriptive data. GPS, digital photography, and digital data capture using Palm handheld computers and Cybertracker software have all been introduced to the monitoring program since 2001. These recent changes, and the goal of a unified national Malleefowl monitoring approach, made a review of the usefulness of monitoring data timely and provided an opportunity to consider improvements. The review (Benshemesh 2007c) focused on the data collected in Victorian since 1995 which provided a consistent and detailed data set and a good basis from which to examine the merits of the data routinely collected. The steering committee identified several questions which provided a focus for the review:

Are the descriptors useful in validating/vetting records of active nests?

As anyone involved in monitoring Malleefowl mounds will know, there are a lot of questions to answer in the field regarding the appearance of mounds and the necessity of these data is sometimes queried. Descriptor variables enable data-vetting, but the need for detailed descriptions has decreased over recent years with the availability of digital photos and accurate GPS technology. In the review, a statistical assessment of the descriptive data collected routinely at mounds showed that about half were valuable for corroborating breeding counts and should be collected annually, whereas other data fields were of less value and need only be used occasionally, such as to describe new mounds that are added to the monitoring program. The ensuing simplification and streamlining of the monitoring process would result in further emphasis being placed on the most important measures, and the increased efficiency would save time and effort that could be used more productively to measure other variables of interest such as habitat quality or predator numbers. We expect the streamlined protocols to be in use for the 2008/9 monitoring season.

Do the descriptors tell us much about how long it's been since a mound was active?

As mounds age they accumulate crust, herbs and moss, and lose eggshell and height. We found statistically significant relationships between the number of years since a mound was last active and each of these variables, but using these relationships to predict when a mound was last active results in fairly crude estimates of limited application. There seems little need to collect these data every year, although describing mounds in regard to these features would be useful when mounds are newly found and added to the monitoring lists for a site.

Could the efficiency of the monitoring program be improved by omitting very old mounds, or would this compromise the accuracy of the monitoring?

People involved in monitoring occasionally request very old and derelict mounds to be removed from monitoring lists as well, as structures that have been dubiously identified as mounds, and this is usually done in an *ad hoc* manner if the requests persist. This is a minor issue at most monitoring sites, but in a few sites very old mounds seem to be common and may provide an unnecessary burden on monitoring. To examine this question, we looked at the probability of mounds with different characteristics becoming active again in later years. We found that objective criteria could be used to identify mounds that were unlikely to be used again and that these mounds could be omitted with little sacrifice in the accuracy of monitoring breeding numbers, provided the number of mounds omitted was small. Nonetheless, it seems prudent to be selective and cautious in removing any mound from annual monitoring lists, and mounds that are identified as not requiring annual inspection should still be visited occasionally in order to check for changes.

How often should sites be re-searched?

This question has vexed the monitoring from the beginning as it is known that Malleefowl occasionally make new mounds, although the rate at which these are created has been unclear, especially at sites where Malleefowl populations are stable or increasing. The question also has a large bearing on the number of sites that can be adequately monitored by a group or agency because thoroughly searching a site requires at least ten times the effort compared to simply visiting the known mounds. Fortunately, it seems that re-searches of sites is not usually as important as previously supposed. Analysis of data from 30 re-searches of monitoring sites which resulted in the addition of over 170 mounds showed that re-searches tended to discover mounds that were actually old and inconspicuous, and had probably been missed during previous searches rather than having been newly constructed during the intervening years. There was no evidence to suggest that the number of newly found mounds was related to the number of years since sites were last searched, or with the number of times a site had been searched. At long-unburnt sites, previously known mounds were three times as likely to become active in later seasons as mounds that were newly found, although this was not the case at sites that were burnt 20-30 years previously where newly found mounds were more likely to be active in later years than known mounds. In light of these findings, re-searches every 3-5 years may be appropriate in sites burnt 20-30 years previous and wherever it is likely that there maybe a shortage of old mounds suitable for renovation at a time when Malleefowl numbers were increasing. At long-unburnt sites, routine re-searches every 5-10 years would seem to provide a reasonable compromise between effort and necessity.

Are data on animal signs at mounds useful?

The frequency of prints and scats of animals at Malleefowl mounds is information that is incidental to the main objective of monitoring, but which is nonetheless collected because it is potentially useful for interpreting changes in Malleefowl populations. These animals include predators (foxes, cats, dogs) and possible competitors (kangaroos, rabbits, goats, emus) of Malleefowl, and large changes in their abundance may affect Malleefowl populations. The abundance of fox sign is especially important because of the direct threat that this introduced predator may pose to Malleefowl. The frequency of fox scats on mounds has been used as an indirect means of assessing trends in fox abundance and appears sensitive to control efforts (see below), suggesting it does provide a useful index of fox numbers. However, it is generally unclear whether signs of other animals at mounds also provide an index of their abundance. In any case, given the importance of monitoring other species in order to understand Malleefowl trends, other more conventional techniques such as sand-pad monitoring are warranted at Malleefowl monitoring sites and these could be carried out by volunteers with suitable training.

Developing a national manual

A major achievement in the past year has been the development and publication of a thorough national Malleefowl monitoring manual written by representatives of monitoring groups from around Australia (Natural Heritage Trust National Malleefowl Monitoring Project 2007). This democratic process was guided by Peter and Ann Stokie (see elsewhere in this volume) who brought representatives together in round-table discussions and collated and circulated their contributions.

The production of the manual tapped into the collective experience of a large number of people, as well as the analyses outlined above, and was achieved by consensus. While discussions were always lively and many viewpoints were expressed, the group managed to achieve this goal with an extraordinary spirit of mutual purpose and harmony.

Improving data management

The introduction of electronic data capture in the field, using handheld computers and Cybertracker software, was a major improvement in data collection. However, the difficulty in collating monitoring records from around Australia for the multi-regional project showed that data management is a major weakness of the monitoring system. On a more routine level, data custodians in each state still struggle every year with the same issues of entering, downloading, screening, summarizing and filing the data collected. Given this degree of duplication and effort each year, and the inadequacies in data retrieval, a centralised database for the Malleefowl monitoring project is desirable and is currently being planned with additional funding support from Australian Government Department of the Environment and Water Resources. Richard and Margaret Alcorn, whom many people have met in national meetings, will develop the database over the next few months under the guidance of representatives from each state who have been involved in data management.

The database is being modelled on basic functionality of the current Victorian Malleefowl database, but it will also be designed to conduct many of the routine tasks that are currently done manually. We plan for it to be web-based to provide easy access from anywhere in Australia. Its main purpose is to provide a service to coordinators of monitoring in each state by assisting them in managing the large volume of data that is routinely collected while maintaining the standards and operational procedures of the monitoring program. Where possible, the intention is to enable volunteers to manage the data they collect and to download information required to monitor Malleefowl in their area.

Another important task of the new database will be in providing a means of feedback and reporting in a secure environment. By default, data will be confidential and access to sensitive data, such as the locations of mounds, will be controlled by the people who collect and submit data. The focus will be on developing an efficient system of moving monitoring data from the field to a central database where the data can be inspected for errors, corrected if need be and stored for later use. Another priority will be to build a feedback system into this for the volunteers involved in monitoring, as well as more general reporting on Malleefowl trends at the site, regional, state and national scales. We envision a series of structured reports, and possibly even individualized reports, so that people get the data in the form that is most useful to them.

In short, the database will be designed to service users across Australia while maintaining the integrity of the data and providing community volunteers, managers, and state wildlife authorities with the data they require in the form they require it.

Analysis of monitoring data: Are Malleefowl populations declining, and if so, what environmental factors might be responsible?

A major aim of the multi-regional Malleefowl project was to collate and analyse the data on Malleefowl trends that had been collected to date. This data had accumulated since the late 1980s when monitoring programs were initiated in most states, but had never before been collated let alone collectively analysed. This rich treasure of data describes the trends of Malleefowl at numerous monitoring sites in New South Wales, South Australia, Victoria and Western Australia over many years, and thus shows the influence that environmental factors (such as rainfall) and management actions (such as fox control) may have had on Malleefowl populations. After thoroughly vetting and screening all the data on Malleefowl trends from the national monitoring effort, we were left with high-quality data from over 60 sites across Australia spanning up to four decades and representing 590 counts of Malleefowl breeding (and over 20,000 mound inspections). However, the data-set was also complex due to the variable amount and quality of data from each site, and consequently sophisticated statistical analysis was required. This expertise was provided by Professor Richard Barker and his student Ryan Macfarlane (University of Otago, New Zealand) who undertook the analysis using a statistical modelling technique known as hierarchal Poisson (loglinear) regression.

While the main body of data comprised annual counts of mounds that were used for breeding each year for each of these monitoring sites, we also collated information regarding fox control efforts, rainfall, landscape fragmentation, and fire history in order to examine the effects of these variables on Malleefowl breeding numbers. Many people contributed to this pooling of information, including Sharon Gillam and Peter Sandell (fox control), Dr Kate Callister (fire history), Roman Urban (fragmentation), Dr Graham De Hoedt (rainfall modelling), as well as numerous rangers, land managers/holders and volunteers. A few of the monitoring sites considered in this study were within landscapes that are known to have sizeable goat and/or kangaroo populations, but we were unable to obtain reliable information on the abundance of these grazers/browsers at many sites and were unable to examine the possible effects in our analysis. Most of the monitoring sites are within reserves, and none was believed to be routinely grazed by sheep.

On the basis of previous observations and studies of Malleefowl ecology reported in the literature, we expected breeding densities to gradually decline where foxes were abundant and where the landscape was highly fragmented, and to decline more suddenly during dry seasons and following wildfires. Conversely, we expected to see Malleefowl counts increase in areas where fox baiting was more intensively practised, and in the decades following an area being burnt.

The results of the analysis confirmed that, on the whole, Malleefowl have declined nationally even in reserves set aside for their protection. This downward trend was most evident in South Australia (142 counts of breeding numbers at 23 sites) where the decline was statistically significant, and Western Australia (36 counts at 6 sites) where it was not significant (possibly due to low sample sizes). In Victoria (365 counts at 29 sites) no clear trend was evident despite the large number of sites and monitoring records. In New South Wales (47 counts at 6 sites) we found a significant positive trend in Malleefowl, although it should be noted that we only obtained monitoring data from two large reserves in the south-west corner of New South Wales (Tarawi and Mallee Cliffs). Elsewhere in central and western New South Wales several studies have documented declining breeding numbers, especially in very small (<500 ha) isolated remnants (Brickhill 1985, 1987; Priddel 1989, 1990; Priddel & Wheeler 1995, 2003) and it would appear that the Malleefowl trends in Tarawi and Mallee Cliffs are an exception in New South Wales and not representative of the remainder of that state.

Of greater interest were the results of the analysis of the environmental factors that were associated with these population trends. Populations go up and down for a variety of reasons, and the large amount of data that was collated for this project provided a unique and powerful opportunity to identify which factors were most responsible for the Malleefowl trends at the 64 sites in the analysis. This number of sites and seasons is necessary to distinguish with any confidence between different factors operating in differing geographic and climatic regions.

Fire

As expected, we found that fire had a negative effect on Malleefowl numbers and that Malleefowl tended to increase thereafter. These findings broadly agree with previous studies on the short and longer term responses of Malleefowl to fire; that Malleefowl breeding densities are lower in areas burnt within the last few decades than in old-growth mallee has been established in several studies (Woinarski 1989, Benshemesh 1990, Clarke 2005), and the mitigating effects of patchy or incomplete fires has also been documented (Benshemesh 1990). Fire is clearly a threat to Malleefowl, often occurring on a vast scale in mallee when it may depress breeding numbers for several decades. However, despite the strong effects of fire shown in this study, fire does not provide a satisfactory explanation for the declines evident in Malleefowl populations as very few sites in this study were burnt during the course of monitoring.

Landscape configuration

We used two site variables to investigate the effect that landscape configuration may have on Malleefowl populations: the size of the block of habitat in which the monitoring sites was located (Patchsize), and the proportion of cleared land within five kilometres of the centre of the monitoring sites (5kClr). Neither of these variables was significantly related to trends in Malleefowl populations. Thus, contrary to our expectations, there was no evidence in our analysis that small isolated patches were more prone to Malleefowl declines than larger patches in the short to medium term. In the long term, small and isolated populations are subject to genetic deterioration and chance extinctions due to low numbers, and it seems likely that populations in these small reserves would inevitably decline without careful management to ensure that Malleefowl populations are not completely isolated.

Another reason for the lack of measurable effect of patch size is that Malleefowl may obtain some benefit from cleared land, especially crop lands that usually surround small habitat patches. Malleefowl are frequently observed feeding on herbs and fallen grain on cleared land at the edge of reserves, and this additional food source may be especially important during droughts and times of food shortage and mitigate the negative effects of small patch size and fragmentation. It is also worth noting that sites near cleared land may also naturally support higher numbers of Malleefowl: clearing was concentrated toward more fertile soils in higher rainfall areas suitable for agriculture, and this is also where Malleefowl densities tend to be highest. In our analysis, the amount of cleared land within five kilometres of monitoring grids had a positive effect on Malleefowl trends, although this effect was not significant.

That Malleefowl have persisted over the medium term in small patch sizes and in fragmented landscapes is an encouraging result and suggests that, with appropriate management to avoid population and genetic bottlenecks, such sites will continue to be of importance to Malleefowl conservation.

Rain

Winter rain has a pronounced effect on Malleefowl breeding numbers and this was evident in our analysis. We found significant positive effects of winter rain on Malleefowl, and this was expected as the birds often skip breeding in dry years. What was more surprising was that there were significant lag effects for the following two, three and four years (the one year lag effect was weakly positive but not significant), meaning that the number of Malleefowl breeding at a site is influenced by the winter rainfall not just in the current year, but in the previous four years (at least). Exactly why this is the case is unclear and may be related to food production, recruitment of young into the breeding population, or both of these factors.

The importance of this finding can hardly be overstated. Lower than expected winter rainfall has characterised most monitoring sites over the past decade or so, and may provide an explanation for the declines in Malleefowl described in this study. More than 80% of the sites in this study experienced lower winter rain over the past 10 years, and 95% over the past five years, compared with long term averages between 1961-90 (a period which is accepted as a recent meteorological standard). Given the lag effects for winter rain on Malleefowl of up to four years shown in this study, the average four-year winter rainfall deficit (Figure 1) is especially pertinent to Malleefowl and graphically shows that while winter rain was higher in the early 1990s than the average for the previous 30 years, since 1996 the four year deficit has increased steadily and in 2004-5 was nearly 20% below that expected.

Given the significant relationships between winter rain and Malleefowl numbers, current predictions of climate change for Australia (Pittock & Wratt 2001) provide considerable cause for concern. The predictions show a decline in winter rain in most semi-arid habitats that support Malleefowl, while the results of analysis of monitoring records suggest that each relatively dry winter will have negative ramifications on Malleefowl breeding populations for at least four years. If current climate predictions are correct, and if climate change is not arrested, substantial declines in Malleefowl populations are likely in the future.

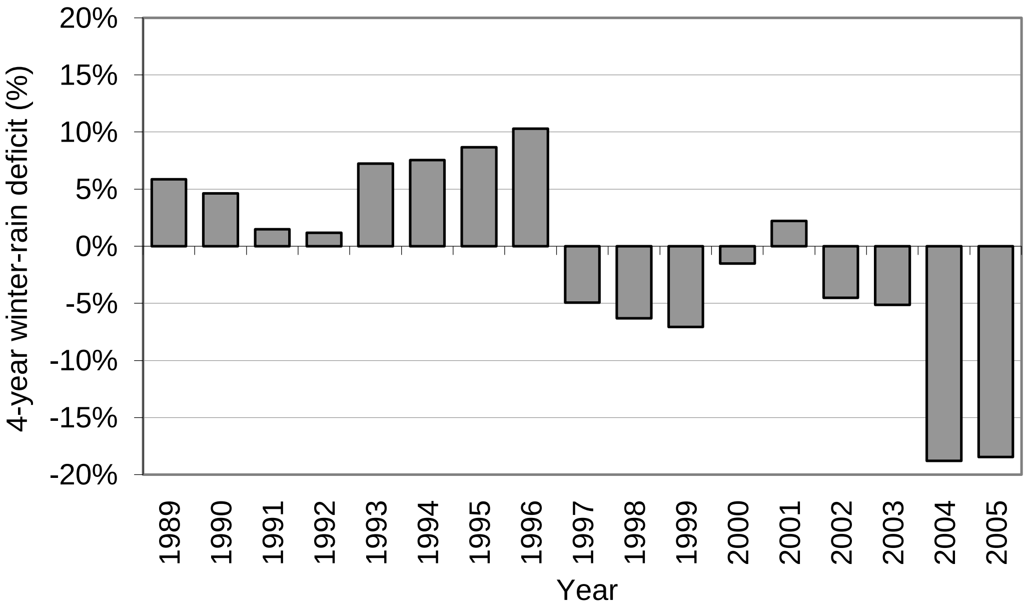

Figure 1. Average four-year winter rainfall deficit for the monitoring sites in this study. For each site and year, the deficit was calculated as the average winter (May-September) rainfall over the past four years, minus the expected rainfall (average winter rain for the period 1961-90), divided by the expected rainfall.

Foxes

The most surprising result from our analysis concerned the effect of fox control and fox abundance on Malleefowl breeding populations. While there is no doubt that foxes eat Malleefowl, the degree to which predation by foxes influences Malleefowl numbers has long been controversial and unresolved. This study represented the first attempt to examine this question at the population level across multiple sites. As baiting with 1080 is generally used to control foxes, we estimated the number of baits laid each year within a $100km^2$ area with the monitoring site at its centre to provide an index of fox control intensity. Such an area is generally regarded as a minimum for effective fox control. To estimate the effect of fox control on fox abundance, we used data on the frequency of fox scats on Malleefowl mounds; these data were routinely collected in South Australia and in Victoria since the early 1990s.

Our analysis showed a strong and significant negative effect of fox control (i.e. baiting) on the incidence of fox scats on mounds, suggesting that baiting did indeed lead to a decline in fox numbers and that more baiting was associated with fewer foxes. However, we found no evidence at all of a significant effect of fox control on Malleefowl breeding numbers either in the year that baiting occurred, or for the following four years.

Although, the four-year lag effect did approach statistical significance, the direction of this effect was positive (i.e. more foxes resulting in more Malleefowl) rather than negative, suggesting that baiting in the longer term might actually be associated with Malleefowl decline rather than recovery (although this was not statistically significant). Thus, while 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 declines.

This result was surprising as fox predation has been considered a major cause of Malleefowl declines, and the conservation of Malleefowl is one of the most common reasons managers provide for fox baiting campaigns (Reddiex *et al*. 2004). However, the evidence that suggests fox predation is linked to Malleefowl declines is far from compelling (Benshemesh 2005), and is based largely on three lines of argument: (1) the fact that foxes eat Malleefowl eggs, chicks, juveniles and adults, (2) the vulnerability of captive reared Malleefowl to foxes, and 3) an analogy with medium sized mammals whose populations have been shown to be sensitive to fox numbers.

Our study has been the first to examine this issue directly by comparing trends in Malleefowl with fox-control intensity, as well as measures of fox abundance. We failed to find any evidence that fox control, as it has been practiced over the past two decades around Malleefowl monitoring sites, has been of benefit to Malleefowl abundance. It should be noted, however, that most baiting that occurs in and around Malleefowl monitoring sites is low intensity. Since 1990, about half the sites in this study were baited to some degree, but only about 10% of sites were baited at an intensity which is generally regarded as a minimum for an effective reduction of fox predation on native mammals (>4 baits/km^2). Nonetheless, the failure of any clear response by Malleefowl to fox baiting indicates that we have placed too much emphasis on fox control and not enough effort has been directed at discovering the true causes of decline or to find ways of benefiting wild populations.

Conserving Malleefowl in light of management uncertainties: Why we need adaptive management

So where does all this leave us in terms of management? Superficially, it may seem that the multi-regional project has merely concentrated on strengthening the monitoring effort rather than on management actions that might reduce threats to the species. Even the analysis may seem of questionable value given that it has refuted the reasonable and popular idea that fox control is necessary for Malleefowl conservation and provided no clear direction. However, both these positions miss the point and misunderstand the central role that monitoring plays in the recovery of threatened species. Monitoring provides the crucial feedback we need to assess the effectiveness of management actions, as well as the conservation status of the species. Without this feedback, we would be locked into applying management indefinitely, based on conviction rather than empiricism, and there would be little opportunity for testing or improving our practices. The failure of fox-baiting at mitigating Malleefowl declines is a case in point and indicates that we should change our practices.

While the monitoring has already proven to be of great value to Malleefowl conservation, to fulfil its potential the monitoring system needs to be integrated with management and research. Ideally the network of monitoring sites would be used to conduct management experiments with appropriate levels of replication, randomisation and experimental control. Carefully designed management experiments provide more reliable information than descriptive studies (such as our analysis) and the current Malleefowl monitoring system would seem well-suited for such experiments, particularly as the monitoring information is already being collected by agencies and an army of dedicated volunteers. This could be achieved by adopting an active adaptive management approach using the monitoring sites to provide a framework for the monitoring effort at a national level and to better integrate monitoring, management and research. Adaptive management is a pragmatic and collaborative process of 'learning by doing' that confronts uncertainties in management and seeks to gain reliable knowledge through experimental management. Key components of the adaptive management approach include experimental design and modelling, field management treatments and monitoring, structured in such a way that the success of management alternatives can be evaluated with confidence (Walters and Holling 1990). Management actions that are proven to be effective are adopted, and in the case of Malleefowl may be applied broadly or at least where they are most needed.

Adaptive management is an approach well-suited to Malleefowl conservation for a number of reasons. Firstly, as demonstrated in this study there is considerable uncertainty about the effectiveness of management actions in reversing Malleefowl declines and in the role of environmental factors. This uncertainty is likely to increase dramatically if climate change predictions are correct. Adaptive management embraces such uncertainty and provides a means of identifying best management practice in a coherent and statistically meaningful way. Secondly, Malleefowl still occur over much of their 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 varying management treatments at these sites is unlikely to compromise the conservation of the species. Thirdly, there is already a strong community involvement in Malleefowl conservation at a national scale and a general enthusiasm for collaboration with agencies and land managers. That most of these sites are monitored by an army of volunteers each year is especially valuable and relieves agencies of this critical, but time-consuming and potentially expensive task. Indeed, monitoring is often the most expensive part of carefully designed and replicated management experiments.

Further collaboration between community volunteers, land managers, scientists, and other stakeholders will be required across political boundaries to develop and implement an adaptive management plan for Malleefowl management. We are currently collaborating with scientists and mathematical modellers from the Applied Environmental Decision Analysis research hub and Arthur Rylah Institute (Melbourne) to develop a suitable framework for adaptive management using the monitoring sites. Once this framework is complete, we hope to involve all stakeholders in discussion, planning, and implementation.

While these national plans are underway, it is essential that the many Natural Resource Management bodies across Australia are aware of the importance of the monitoring effort and that they need to look beyond their regional borders and collaborate on a national adaptive management program in order to obtain the maximum benefit for Malleefowl. Natural Resource Memanagement bodies (called Catchment Management Authorities or Catchment Councils) have recently become major conduits for conservation funds flowing from commonwealth agencies, and while there are advantages of this regional focus, there is also a danger that large scale conservation programs will suffer unless Natural Resource Mandagement bodies are made aware of these programs and work collectively and collaboratively toward common goals. In a sense, bureaucratic and administrative fragmentation threatens Malleefowl conservation as much as geographic fragmentation.

To this end, the final phase of the multi-regional project was to provide a concise document advising Natural Resource Management bodies of the national plans and providing them with brief summaries of Malleefowl records, monitoring sites and major issues in each region (Benshemesh 2007a). There are about 15 Natural Resource Management regions that contain Malleefowl monitoring sites, out of about 20 in which Malleefowl occur, and the document also advises these organizations of plans of the Malleefowl Recovery Team to implement adaptive management across monitoring sites (Benshemesh 2005) and the need to collaborate if adaptive management is to be effective.

Concluding comments

The past three years since the last Malleefowl Forum has been a busy time for those involved in Malleefowl conservation, particularly in regard to the multi-region project which has developed national standards, disseminated protocols, reviewed practices and begun to establish central databases, analysed past data, and generally facilitated the monitoring effort on a national scale through meetings, workshops and documents. Here, I have attempted to give an overview of the technical achievements of the past three years which have been largely guided by community aspirations and were only made possible by the dedication of volunteers and agencies in collecting, questioning and sharing the monitoring data over the past two decades.

The future looks bright too, and the shared vision of conserving Malleefowl effectively and efficiently has gained momentum over recent years and, in turn, has provided those involved in monitoring with a greater sense of purpose and necessity. The community of volunteers in particular has proven to be a major driving force in Malleefowl conservation and seems to grow stronger each year. As important as volunteers are to the monitoring effort, volunteers cannot implement management treatments, and the active collaboration, involvement and commitment of agencies and land managers will be essential to manipulate the management of monitoring sites according to national plans. Likewise, we need the involvement of ecological modellers and statisticians to tell us how to structure management at monitoring sites so that we progressively gain reliable knowledge of how best to conserve Malleefowl.

Further progress will, then, depend largely on the willingness of Natural Resource Management bodies, state authorities and land managers, as well as community groups, researchers and academics, to work collaboratively toward improved conservation outcomes for Malleefowl.

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