28. Analysing the effects of ongoing and historical fox control on Malleefowl population viability

Cindy E. Hauser, The University of Melbourne; Member National Malleefowl Recovery Team

Authors: José J. Lahoz-Monfort and Cindy E. Hauser, School of Botany, The University of Melbourne, Parkville, Victoria

Abstract

Although fox baiting is commonly applied to boost Malleefowl breeding activity, the performance of this intervention is contentious, with arguments and evidence on both sides of the debate. Reaching consensus is particularly difficult because historical data on fox baiting is uncertain, and has poor spatial resolution. We explore the logistics of what might be required in an adaptive management program to determine the effectiveness of fox baiting as a Malleefowl conservation tool. We calculate (1) how large the project should be (i.e. how many sites need to be observed), and (2) how long the experiment should be (i.e. how long they have to watch the sites for). A technique known as a ‘power analysis’ can be used to provide answers to these questions in advance, based on information already gathered by the National Database.

Introduction

The concept of experimentation is inherent to the adaptive management framework and relates to the need to monitor outcomes of management actions (Walters 1986, Runge 2011, see also Hauser *et al.* 2014 for an overview of the adaptive management project). Adaptive management sees management actions as experiments, chances to learn about the system. By monitoring the response of the system to ‘experimental manipulation’ in a way that is informative about our hypothesis, adaptive management seeks to reduce those aspects of uncertainty that impede clear decision-making so that we can be more confident about future management decisions.

Malleefowl conservation is a multifaceted and complex case. The ecosystem models elicited during an expert workshop (see Figure 2 in Hauser *et al.* 2014) reflect this fact. The adaptive management team is investigating mathematical modelling techniques to understand coarse scale relationships from these complex ecosystem networks (Bode *et al*. 2014). But decision-making regarding management actions related to specific links in an ecosystem within an adaptive management framework require more directed investigation based on experimental design and statistics. We select one of these ecosystem links (fox predation on Malleefowl) to showcase how experimental manipulation can be planned within the adaptive management framework.

Foxes and Malleefowl

There is ample evidence that foxes prey on Malleefowl at different stages of their life, from egg to adult (Benshemesh 2007). From the conservation management point of view, however, the real question is whether such predation compromises the long term survival of Malleefowl populations. This effect is uncertain (Bode & Brennan 2011). A population could withstand some level of predation, as long as during their reproductive lifetime each Malleefowl couple manages to produce on average two chicks that recruit into the population to replace them.

One of the main conservation actions currently undertaken in mallee areas where Malleefowl live is baiting to kill foxes and other predators. Whether this action actually contributes to the recovery of Malleefowl has been the subject of debate. The evidence in the scientific literature regarding these questions is rather mixed (Gates 2004, Walsh *et al.* 2012). The National Malleefowl Recovery Plan identifies the fox-Malleefowl ecosystem link as a high priority for investigation, because baiting is an expensive option but has the potential to prevent Malleefowl declines in some areas under some circumstances (Benshemesh 2007). We therefore selected fox predation to showcase an experimental approach for a single threat, within an adaptive management framework.

An experimental approach

The basic principle of the experimental approach is simple: we assume that a fox population in an area affects the Malleefowl population. Baiting for foxes takes place in an attempt to reduce fox density. The 'system response' (in this case the Malleefowl population) is observed, and statistical methods are used to try to find evidence in the collected data of whether the Malleefowl population has benefited from this action at the population level in the long term. Since measuring Malleefowl abundance (the ultimate reflection of the status at a population level) is in practice difficult, 'breeding activity' can be used as a proxy of how well a Malleefowl population is faring in a given area and year. For this species, breeding activity can be monitored through mound activity, a type of data that is already being collected by volunteers across the species' range and stored in the National Malleefowl Monitoring Database.

One powerful way of conducting the experiment is to use pairs of 'treatment' and 'control' sites, statistical terms for sites where the management action (here: baiting) is applied and sites where no action is applied, respectively. The mallee environment is variable, both temporally and geographically, and pairing similar sites in that way ensures that the comparison is as fair as possible.

Pairs of baited and unbaited sites should be selected with care. Within a pair, they should be close enough to share the same environmental conditions and their fluctuations over time (e.g. rainfall patterns). On the other hand, the sites should not be so close that the potential effect of baiting in a site influences the fox population at the unbaited site. For example, if foxes from the unbaited site end up poisoned at the nearby baited site, Malleefowl in the unbaited site will accidentally suffer lower predation and data will indicate that the baiting does not have a strong effect. Or if Malleefowl chicks born in the baited site (hopefully under lower predation pressure) end up eaten by foxes at the nearby unbaited site (where predation is high), it will again look like the baiting does not have a strong effect. A final practicality to keep in mind is that both control and treatment sites must have mound activity monitoring in place or starting for the experiment, in order for the system response to be observed.

In order to allow good statistical modelling and give the experiment a fair chance at disentangling the potential effect of fox baiting on Malleefowl abundance from the temporal and geographical fluctuations in environmental conditions that may also affect their abundance, we need replication. Replication simply means that several pairs of baited-unbaited sites are required, to capture that nuisance variation that is not of interest thus giving the best chance to detecting the true effect of fox baiting. In simple words: if the same reaction to baiting is observed again and again at many pairs of sites, conclusions can be drawn with more confidence.

In practice, the overall effect of foxes on Malleefowl can be divided in two parts or questions:
1. Is baiting effective to reduce fox densities?
2. Does a reduced fox density help increase Malleefowl population in the long term?

An important modifier could be added: under which geographic and environmental circumstances do the answers to these question matter most? What our current experimental approach attempts to find is whether there is an overall effect of fox baiting on Malleefowl abundance. Hopefully in the future we can use data from camera traps (Benshemesh *et al.* 2014, van Hespen *et al.* 2014) to collect data and understand the intermediate step: whether baiting is effective to reduce fox densities.

Preliminary power analysis

The next question when planning the experimental approach is how many pairs of baited-unbaited sites are needed to be able to make some useful inference about fox baiting. The adaptive management team conducted a simple 'statistical power analysis' to help answer that question. This statistical procedure requires lengthy computer simulations and analyses, but the basic principle behind it is quite simple. If the increase in Malleefowl breeding activity due to fox baiting is very large, then observing it at a few sites would be enough. At the other end of the spectrum, if the effect of baiting is very small, it will take many sites to detect it in a statistical analysis. Furthermore, a very small effect might not matter because it would indicate that fox baiting is not an efficient way of increasing Malleefowl breeding activity.
In order to conduct the power analysis, we first assumed a model that describes differences in mound activity between baited and unbaited sites in a statistical way (i.e. we created a 'system model').

Although the model was simple (e.g. it assumes all sites have 30 mounds, close to the average in the historic data) and does not reflect actual existing sites, we chose the parameters for the model based on historical data from the National Database. We then used a computer to simulate mound activity monitoring randomly using that system model, assuming a given effect of baiting (described as an X% increase in mound activity) and a number Y of pairs of baited-unbaited sites. We analysed the simulated monitoring data using the same system model and checked in what percentage of these analyses we would have detected (statistically speaking) a difference between baited and unbaited sites. That is, given that the effect did exist in the simulated data, how frequently our experiment would have been able to conclude it did exist: this percentage represents the power to detect that effect size. We then repeated the process for different scenarios representing combinations of: i) different strength of the effect of baiting (X%), ranging from very strong to negligible effects; ii) different number of pairs of baited-unbaited sites; iii) different number of years monitoring the system. Although not describing the procedure in detail, this is conceptually the idea behind a statistical power analysis.

The results of all these computer simulations can be plotted to show how power to detect an effect varies with the number of sites and the strength of the effect, for a given number of monitoring years (Figure 1).

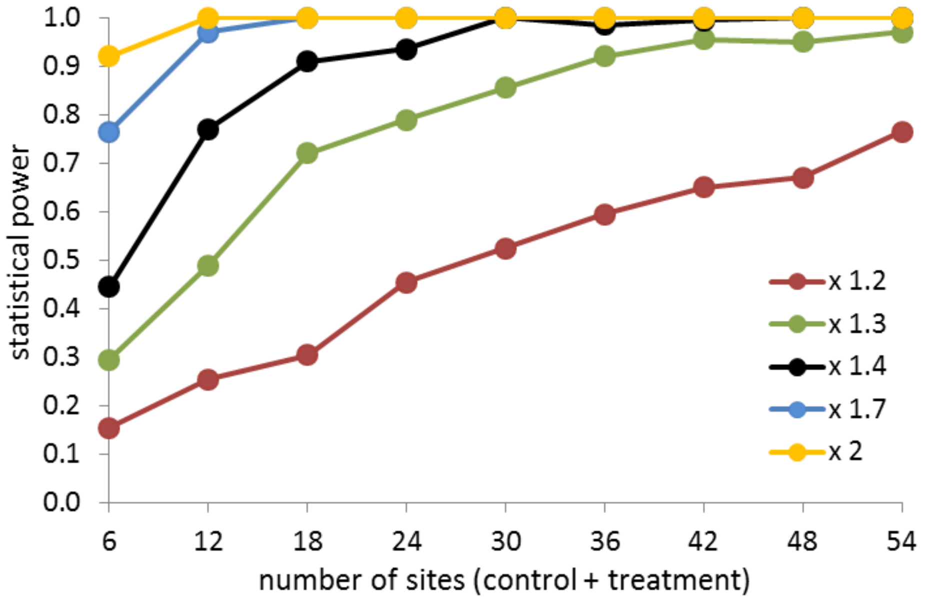

Figure 1. Statistical power after 4 years of experiment as a function of the number of experimental sites (significance level α=0.05). The curves represent different strengths of the effect of baiting on mound activity (increase in mound activity under baiting, compared to a baseline mound activity of 11%, the historic average of monitoring sites in Victoria). The horizontal red line marks the level of 80% power and the vertical line the power achieved for 18 sites (nine pairs of baited and unbaited sites).

The curves in Figure 1 show, for a given effect size, what is the statistical power that we can expect to achieve given a number of sites in the experiment, where statistical power represents the probability of detecting an effect of that size, if it exists. This is an important point: we are not saying it does, but estimating the power if that was the true value. The figure shows how the number of pairs of sites required for achieving a given level of power depends on how strong an effect of baiting we want to be able to detect: for a given number of sites, the stronger the effect, the fewer the numbers needed. For example, the horizontal line that marks 80% power indicates that around 12 sites (i.e. six pairs of baited/unbaited sites) are needed if the effect of baiting was an increase of 1.4 times in mound activity (black curve), but 24 sites if the true effect was an increase of 1.3 times (green curve). Conversely, for a fixed number of sites, higher power is achieved for stronger effects of baiting, as expected (see vertical red line). Note how it is rather 'easy' (high power) to detect large effects (e.g. approximately a doubling of mound activity; yellow or blue curves), and very 'hard' (low power) to detect small effects (even 50 sites are not enough if the effect is 20% increase (red curve).

Also, the longer the experiment is run, the higher power is achieved for a given number of sites, and different figures can be produced for different lengths of time.

Conducting experiments with natural systems is often trickier than in a laboratory. Ecosystems are always messier and more nuanced than the simplified model used in our power analysis. It is also difficult to find pairs of sites that experience exactly the same environmental conditions over time. Furthermore baiting can be conducted at different regimes of intensity and timing, and the experimental sites will be located within a broader geographic landscape in which other landowners may conduct baiting. As we begin incorporating real sites into the experiment, we can collect more detailed information and conduct a more detailed power analysis based on the specific conditions of the proposed sites, so that part of that real-world variability can be accounted for.

Furthermore, when analysing in the future the real data collected from the experimental sites, we will incorporate in the model information on the environmental variation to increase its power. We therefore expect that an effect of baiting will probably be slightly easier to detect than what is indicated by the current preliminary power analysis based on a non-tailored ‘standard design’.

Conclusions

In summary, the ideal way of conducting such an experiment would be to find pairs of neighbouring sites where: a) one site can be baited and the other left unbaited as a reference; b) Malleefowl mound activity (the ‘response’ of the species) is being monitored or monitoring can be started; and c) paired sites are close enough to share the same environmental variability (such as how much rain falls in a given year), but not so close that baiting can affect what happens at the non-baited site. Finding pairs of sites that fulfil these conditions is challenging. The adaptive management team at the University of Melbourne, together with Tim Burnard and Joe Benshemesh, have set out to plan and organize such an experiment across the species’ range. The process of contacting managers of potential sites has already started, with several potential sites in Western Australia and South Australia already under consideration.

Despite the challenges mentioned in the previous section, the experimental approach we propose is still our best shot to obtain a robust answer to the question of fox baiting as a management tool for Malleefowl conservation. A growing network of experimental sites will establish a solid base to provide the learning we need to improve management practices. And the methodology can be used more broadly, as it will serve as a blueprint to tackle other management uncertainties in Malleefowl conservation, such as the effect of fire regimes on Malleefowl populations.

It will take several years to gather enough data, so the sooner we start the better. In the adaptive management team, we are really excited to see the progress so far, and we are certainly open to suggestion regarding potential sites and participation in this large-scale fox baiting experiment.

Acknowledgements

This research project has been funded by an Australian Research Council Linkage grant (LP120100490) in partnership with Parks Victoria, the Victorian Malleefowl Recovery Group and Iluka Resources Ltd. We are also grateful for the ongoing support of the National Malleefowl Recovery Team and the enthusiasm of the broader Malleefowl conservation community.

References

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

Benshemesh J., Stokie P., Thompson D., Irvin J., Macfarlane N., Willis K., Willis C. and Cattanach P. (2014) Motion-sensitive cameras for monitoring a range of animals in Malleefowl monitoring sites. 'Proceedings of the 5th National Malleefowl Forum 2014, Dubbo, NSW.'

Bode M. (2014) Predicting Malleefowl dynamics using decision theory and qualitative ecosystem modelling. 'Proceedings of the 5th National Malleefowl Forum 2014, Dubbo, NSW.'

Bode M. and Brennan K.E.C. (2011) Using population viability analysis to guide research and conservation actions for Australia's threatened Malleefowl *Leipoa ocellata*. *Oryx* **45,** 513-521.

Hauser C.E., Bode M., Rumpff L., Lahoz-Monfort J.J., Benshemesh J., Burnard T., van Hespen R. & Wintle B. (2014) Applying adaptive management principles to Malleefowl conservation. 'Proceedings of the 5th National Malleefowl Forum 2014, Dubbo, NSW.'

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

Runge M.C. (2011) An introduction to adaptive management for threatened and endangered species. *Journal of Fish and Wildlife Management* **2,** 220-233.

van Hespen R., Hauser C.E., Lahoz-Monfort J.J., Rumpff L. (2014) Designing a camera trap arrangement to monitor fox populations in the mallee. 'Proceedings of the 5th National Malleefowl Forum 2014, Dubbo, NSW.'

Walsh J.C., Wilson K.A., Benshemesh J. & Possingham H.P. (2012) Unexpected outcomes of invasive predator control: the importance of evaluating conservation management actions. *Animal Conservation* **15,** 319-328.

Walters C.J. (1986) 'Adaptive Management of Renewable Resources.' Blackburn Press, Caldwell NJ.