Animal Conservation

ZSL LIVING CONSERVATION

Animal Conservation. Print ISSN 1367-9430

RESPONSE

Integrating research, monitoring and management into an adaptive management framework to achieve effective conservation outcomes

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doi:10.1111/j.1469-1795.2012.00579.x

The outcomes of conservation management actions are not always as expected. Our study (Walsh *et al*., 2012) suggests that the past fox baiting in Australia has not been an effective method at increasing malleefowl populations or halting declines. We calculated the return on investment of fox baiting on increasing malleefowl population size and growth, by quantifying the benefits and costs of this management action at varying levels of baiting intensities. Despite the emphasis on fox control for malleefowl conservation, we found that fox baiting had no statistically significant impact on the bird's population growth. This seems contrary to the widely held belief that foxes are the major threat to malleefowl and fox baiting is an effective management strategy. We have shown that the assumed effectiveness of this action may have caused inefficient investment for several decades in conservation reserves across southern Australia.

In their commentaries, Garnett (2012) and Nichols (2012) highlight two different aspects of this study, describing the role of structured decision making (SDM) and adaptive management approaches for optimized conservation practice, and identifying future research and key management issues for the malleefowl. Here, we discuss how research, monitoring and management can be integrated into an adaptive management framework, to achieve greater conservation outcomes for the malleefowl and potentially other Australian threatened species.

Several studies have assessed the effectiveness of fox baiting on malleefowl, each producing different conclusions, creating confusing messages for conservation practitioners. Priddel & Wheeler (1997) used an experimental study to show increased survival of malleefowl chicks after fox baiting, but did not measure success at a population level. Garnett (2012) suggests that fox baiting at higher intensities than currently used in most monitoring sites may reverse malleefowl population declines, as Bode & Brennan (2011) demonstrated using a population viability analysis (PVA). However, the PVA was developed using model parameters estimated from a single malleefowl population, was based on multiple assumptions and did not use empirical data to test their model. Our results, based on correlative models parameterized using an extensive monitoring dataset, showed large variation in malleefowl responses to baiting across sites and years and no net benefit to malleefowl populations in most sites (Walsh *et al*., 2012), confirming similar findings of other analyses using the same dataset (Benshemesh, Barker & MacFarlane, 2007).

At this stage, we do not suggest that managers should stop fox baiting entirely, as there are multiple factors to consider in each context, including presence of other threatened species that may benefit from fox baiting, environmental conditions and past management regimes. Instead, the conflicting conclusions between these studies suggest that long-term experimental studies with control sites and more extreme management options are needed to properly understand if fox baiting is beneficial to malleefowl populations and under which circumstances, if any, would fox control be advisable as a management strategy.

Why is adaptive management the best strategy forward?

Conservation managers may be inclined to implement an action with an uncertain effectiveness, because urgent action may be needed. While it is important to consider the trade-offs between monitoring, research and management (Grantham *et al*., 2008; McDonald-Madden *et al*., 2010; Sutherland *et al*., 2011), our study has demonstrated that continuing to implement conservation actions over time without rigorous evaluation of their effectiveness is inefficient. Active adaptive management addresses these concerns by emphasizing the iterative feedback between implementation of management actions and assessment of their effectiveness, continuously improving knowledge on the

managements' impacts (Walters, 1986; McCarthy & Possingham, 2007; Keith *et al*., 2011).

The malleefowl is perfectly suited to adaptive management for several reasons. Essential research on malleefowl population ecology and the effectiveness of management actions can be facilitated through an adaptive management framework. The species has a wide distribution in Australia with reasonable population sizes, allowing for experimentation of multiple actions with replication and randomization across the existing monitoring sites. Many stakeholders, including scientists, reserve managers, monitoring volunteers and conservation organizations, strongly support this approach, which is necessary for such a project to succeed (Benshemesh & Bode, 2011). In fact, the planning process of an adaptive management project for the malleefowl is currently underway at the University of Melbourne, in partnership with the National Malleefowl Recovery Team, Victorian Malleefowl Recovery Group and Parks Victoria (Benshemesh & Bode, 2011). Those involved are developing the project's overall objectives, identifying possible management options for over 100 sites across Australia and are collating existing knowledge on the malleefowl to be used as inputs for adaptive management models (Benshemesh & Bode, 2011).

Modified monitoring for management and research under adaptive management

Planning and critical evaluation of any monitoring program is important to ensure it is as efficient and informative as possible (Reynolds, Thompson & Russell, 2011). With the help of dedicated volunteers, the National Malleefowl Monitoring dataset has enabled us to both estimate whether conservation objectives are being met and predict future outcomes, as Nichols (2012) mentioned. However, the monitoring dataset has yet to be used to inform real-time management decisions. This would be the major focus of the adaptive management framework, allowing managers to respond quickly to new information about management actions or environmental change. Given the impressive spatial and temporal extent of the current monitoring program, with some adjustments, it would be capable of providing data for all three purposes of monitoring (Nichols & Williams, 2006).

The focus of monitoring in the adaptive management project should be shifted toward data collection for more targeted strategic and specific research questions on the effects of multiple management actions on malleefowl population size and growth. For example, the long-term response of malleefowl populations to fox baiting should be evaluated using experimental plots with a range of preselected treatment intensities, including extremely high intensities, which are currently underrepresented in the monitoring sites, control areas where baiting has never occurred and areas where the baiting regime targets foxes and cats (Garnett, 2012).

Lack of data on the effects of fire management and exclusion or control of introduced and native herbivores prevented us from accurately estimating the effectiveness of these management actions in our study. The new adaptive management framework should test the effects of management for other threats, such as fire and grazing, through similar experimental plots. It would then be possible to prioritize the allocation of investment towards management actions that achieve the greatest outcome, as described in the final step of the SDM framework (Nichols, 2012). It should also account for management differences across subpopulations (McDonald-Madden, Baxter & Possingham, 2008) and test the interactions between multiple threats and actions (Evans, Possingham & Wilson, 2011). This can then be used to inform cost-effective management decisions for malleefowl populations across Australia.

Adaptive management in the wider context

Combining the efforts of research, management and monitoring through an integrated national adaptive management approach would improve the conservation outcomes for the malleefowl (Benshemesh & Bode, 2011; Nichols, 2012). Monitoring the response of other threatened or declining species in Australia, such as the southern scrub-robin *Drymodes brunneopygia* or regent parrot *Polytelis anthopeplus*, to relevant management actions may add conservation value to the adaptive management project. It may also increase potential funding opportunities, given the trend in Australia toward multispecies or community-based conservation. If fox baiting or another management action targets other threatened species in an area, then the malleefowl may not be the most cost-effective indicator species to detect improvements across all species (Tulloch, Possingham & Wilson, 2011). However, adding further complexity into the adaptive management project may not be feasible and this additional challenge may reduce the probability of successful and rigorous implementation.

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