Biological Conservation 182 (2015) 102–108

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Perspective

Improving policy efficiency and effectiveness to save more species: A case study of the megadiverse country Australia

Jane A. McDonald [a,*], Josie Carwardine [b], Liana N. Joseph [a,c], Carissa J. Klein [d], Tracy M. Rout [e], James E.M. Watson [c,d], Stephen T. Garnett [f], Michael A. McCarthy [e], Hugh P. Possingham [a]

[a] School of Biological Sciences, University of Queensland, St Lucia, 4072 Brisbane, Australia
[b] CSIRO, Ecosystem Sciences, Boggo Rd, Dutton Park, Brisbane 4102, Australia
[c] Global Conservation Program, Wildlife Conservation Society, Bronx, NY 10460, USA
[d] School of Geography, Planning and Environmental Management, University of Queensland, St Lucia, Queensland 4072, Australia
[e] School of Botany, University of Melbourne, Parkville, Victoria 3010, Australia
[f] Research Institute for the Environment and Livelihoods, Charles Darwin University, Ellengowan Drive, Casuarina, NT 0909, Australia

ARTICLE INFO

Article history:
Received 18 April 2014
Received in revised form 17 November 2014
Accepted 18 November 2014
Available online 12 December 2014

Keywords:
Endangered species
Prioritization
Policy
Cost-effective
Threatened species
Australia

ABSTRACT

Native flora and fauna species continue to decline in the megadiverse, wealthy, economically and politically stable nation of Australia despite current efforts in policy and management. Ongoing research is examining these declines, their causes and the adequacy of current policy, but strategies for improving the outcomes for threatened species have attracted less attention. We discuss several key aspects of Australia's national threatened species management approach that potentially hinder the efficiency and effectiveness of management: the threatened species listing process is lengthy and biased; recovery plan development is resource intensive, restricted to a subset of species and often not effective; funding for threatened species management is not allocated efficiently or transparently; and management is not designed to incorporate uncertainties and adapt to changing future threats. Based on these issues we recommend four changes to current process: rationalize listing and assessment processes; develop approaches to prioritize species-based and threat-based responses cost-effectively; estimate funds required to recover species and secure longer term funding; and accommodate uncertainties and new threats into the current planning framework. Cost-effective prioritization for species and threats identifies which actions are likely to achieve the greatest benefits to species per unit cost, thereby managing more species and threats with available funds. These improvements can be made without legislative reform, additional funding or socio-economic shifts. If implemented, we believe more Australian threatened species will benefit from current efforts. Many of the challenges facing Australia are analogous to issues in other countries including the United States, Canada and the United Kingdom and these recommendations could assist in improving threatened species management.

Contents

* Corresponding author. Tel.: +61 410 204 880.
E-mail address: j.mcdonald9@uq.edu.au (J.A. McDonald).

http://dx.doi.org/10.1016/j.biocon.2014.11.030
0006-3207/

1. Introduction

Policy interventions in Australia have been unable to halt the loss of species and prevent further extinctions (Environment and Communications References Committee, 2013; Garnett et al., 2011; Woinarski et al., 2014). It is likely the challenges facing policy-makers will be even greater with accelerating climate change, continued population growth and land use change targeted toward increased food and fiber production (Millennium Ecosystem Assessment, 2005). Considerable research has measured species loss in Australia, identified causes of declines and assessed the effectiveness of current management and policy (Bottrill et al., 2011; Evans et al., 2011; Ford et al., 2001; Garnett et al., 2011; Kelly et al., 2003; Kingsford et al., 2009; Moseby and Read, 2006; Ritchie, 2013; Ritchie et al., 2013; Short and Smith, 1994; Steffen et al., 2009; Szabo et al., 2012; Taylor et al., 2011; Walsh et al., 2012; Watson et al., 2011; Woinarski et al., 2011). The recently released Action Plan for Australian Mammals, for example, warns that as well as the highest modern record of mammalian extinctions, a large proportion of extant mammals are under threat and urges urgent and targeted actions to avoid further extinctions (Woinarski et al., 2014). Although Australia is not alone in experiencing unprecedented rates of extinction (Mace, 2005), it presents a compelling example of how efforts to manage threatened species in a megadiverse country can be ineffective in avoiding species loss despite economic wealth, relatively good governance and globally recognized scientific expertise. We believe this situation needs urgent attention and recommend four feasible ways to improve national management of threatened species in Australia.

The need for improved threatened species management in Australia is urgent (Lindenmayer, 2008; Woinarski et al., 2014). Over 10% of mammal species (29) have already become extinct since European settlement in the late 18th Century (Woinarski et al., 2014) and 15% of remaining mammals are listed as Threatened (State of the Environment Committee, 2011). There is mounting evidence that small mammal populations in northern Australia – a region that is considered to contain the largest area of intact tropical savanna left in the world – are in rapid decline (Woinarski et al., 2011). Recently two species on Christmas Island in the Indian Ocean, a microbat (*Pipistrellus murrayi*) and a lizard (*Emoia nativitatis)* are now presumed to be extinct (Beeton et al., 2010; Woinarski and Cogger, 2013). The iconic Orange-bellied Parrot (*Neophema chrysogaster*) is close to extinction in the wild and 23 species of bird have become extinct and at least four other bird species are also possibly extinct since European settlement of Australia in 1788 (Garnett et al., 2011). The large majority of listed bird species continue to decline (Garnett et al., 2011). The few that have recovered (Gould's Petrel *Pterodroma leucoptera leucoptera* and Lord Howe Woodhen *Gallirallus sylvestris,* for example) represent significant success stories of what can be achieved when adequate resources and expertise are applied. Where assessments are conducted, very significant proportions of once common widespread amphibians, reptiles and plants are found to be threatened with extinction (up to 52%, 37% and 30% respectively (State of the Environment Committee, 2011). Outcomes to date indicate many species are becoming more threatened with few recovering (Watson et al., 2010). The extinction of the Christmas Island Pipistrelle and the poor outlook for threatened species in general has been the subject of renewed debate. In response, the Australian Senate established an inquiry in 2012–3 into the effectiveness of threatened species management in Australia to which the recommendations in this paper were submitted (Environment and Communications References Committee, 2013). Recently the Australian Government also appointed a Threatened Species Commissioner with a mandate to prevent further extinctions (DoE, 2014; http://www.environment.gov.au/biodiversity/threatened/commissioner).

The major threats to threatened species in Australia include habitat loss, introduced species, inappropriate fire regimes, over-exploitation and disease (Evans et al., 2011). In the long term, protection and recovery of threatened species in Australia depends on trends in socio-economic drivers such as population growth, per capital consumption and economic growth (Millennium Ecosystem Assessment, 2005; State of the Environment Committee, 2011), the strength of regulatory protection (Environment and Communications References Committee, 2013; Kingsford et al., 2009), the funds to enact protection and amelioration of impacts (Carwardine et al., 2012; McCarthy et al., 2008) and governance arrangements to ensure implementation (Hajkowicz, 2009; Morrison et al., 2010). Changing the level of any of these factors is a significant undertaking, requiring shifts in social and economic trends, increased political will, more funds and legislative reform. There are, however, gains to be made for threatened species that are feasible within the current policy arrangements and achievable in the short term at no extra cost. By improving the effectiveness and efficiency of Australia's existing national approach to threatened species, we propose that the outcomes for threatened species can be improved and thereby the reach of current protection extended to more species.

Threatened species (synonymous with "endangered species" in the United States) have been protected by national legislation since 1993 although evidence suggests more can be done to improve the current approach (Bottrill et al., 2011; Coates and Atkins, 2001; Possingham et al., 2002b; Walsh et al., 2012). The current national legislation is the *Environment Protection and Biodiversity Conservation Act* 1999 (*EPBC Act*) and requires approvals for any activity likely to significantly impact nationally listed threatened species. In this way the federal government can regulate impacts from developments such as new mining, agriculture, and housing estates. Threatened species habitat is also protected to a degree in the protected area network and under the Native Vegetation Framework (Environment and Communications References Committee, 2013). Threatened species are also protected under state and territory legislation. Recovery of nationally listed species is guided through Conservation Advices, a document assessing the status, threats and priority actions of each species or a Recovery Plan, a more comprehensive recovery framework. Recovery actions for threatened species are not automatically funded. There is no dedicated funding for threatened species (Environment and Communications References Committee, 2013) and the level of funding and the projects funded are dependent on governments' environmental objectives and priorities.

To date, the likely inefficiencies in threatened species management include the bias toward large, charismatic species in the listing and recovery process (Possingham et al., 2002b; Walsh et al., 2012), the resource-intensive development of Recovery Plans (Walsh et al., 2012), the ineffectiveness of many Recovery Plans (Bottrill et al., 2011), paucity of information on threatened species

management effectiveness (Taylor et al., 2011), inherent uncertainties in threatened species management (Burgman et al., 1999; McDonald-Madden et al., 2010), politicization of decisions (Morrison et al., 2010), a lack of long-term funding (Kirkpatrick, 2011) and the general lack of feasibility and cost considerations in prioritization (Coates and Atkins, 2001; Joseph et al., 2009; Possingham et al., 2002b). In addition, these issues will need to be considered in the context of the synergistic and additive impacts of rapid climate change (Garnett and Franklin, 2014; Kingsford et al., 2009; Lindenmayer, 2008; McAlpine et al., 2009). Australian environmental programs have not yet incorporated adaptive management processes (Lockwood et al., 2009; Morrison et al., 2010) to assist managers of threatened species and policy-makers, a major problem considering they are faced with unprecedented circumstances that will arise out of even the most optimistic climate change scenarios (Watson et al., 2013).

In this paper we review these issues, all of which hinder the potential of national threatened species management in Australia. Based on our assessment, we make four recommendations: rationalize the species listing and assessment systems, prioritize cost-effective actions for species-based and threat-based responses, estimate the resources required to recovery species and invest in actions as part of adaptive management programs to incorporate uncertainties. These recommendations to improve the efficiency of the Australian threatened species management could be relevant to improving or creating threatened species legislation in other countries.

2. Rationalize the assessment and listing of species

Australia's national environmental legislation aims to identify, classify and list species that are threatened with extinction so that threats are abated and recovery is undertaken. While the *EPBC Act* intends to encompass all aspects of biodiversity, the threatened species list is biased toward particular taxa and charismatic species (Walsh et al., 2012), reflecting social and economic preferences (Tisdell et al., 2007). Of Australia's birds, amphibians and mammals 12–24% are listed as threatened, while only 0.04% of known invertebrates are listed (under comprehensive listing this figure is expected to be 4000 times higher) (Walsh et al., 2012). Less than 8% of the species that are threatened might actually be listed (Walsh et al., 2012). Threatened species lists are designed to assess risk but often influence which species receive funding and regulatory protection (Farrier et al., 2007). The consequence of a biased list can be that it becomes a default prioritization approach, without regard to unlisted species, recovery potential, costs of recovery or likelihood of success (Farrier et al., 2007; Harvey et al., 2002). A biased list can mean the number of species that receive attention will be less because more threatened species typically require greater recovery effort with smaller chances of successful recovery (Possingham et al., 2002b). This problem is common in other countries, including the United States (Metrick and Weitzman, 1996), Canada (Findlay et al., 2009) and the United Kingdom (Laycock et al., 2009).

To resolve the issues around bias and incomplete lists, the process of listing species can be rationalized. Current listing efforts occur at many overlapping scales: global, national, state/province, often using different criteria. Firstly, guidelines for the IUCN Red List of Threatened Species and the current national list could be aligned. Current *EPBC Act* guidelines for listing differ from those of the IUCN in several small but important ways such as omitting IUCN criterion Vulnerable D2 and category Near Threatened and including the category Conservation Dependent. Secondly, one consolidated listing process would immediately improve the timeliness of listing and the comprehensiveness of the lists. National listing will then benefit from assessments done at a global scale.

3. Prioritize cost-effective actions for species-based and threat-based responses

The two broad groups of approaches for prioritizing species conservation are a species-based response (targeting species-specific actions) (Joseph et al., 2009) and a threat-based response (mitigating threats to benefit a group of species) (Carwardine et al., 2012). Site-based responses are inherently a location-specific version of one or both. Prioritization, using one of these approaches, is part of the decision-making process. The efficacy of employing species-based responses versus a more landscape-wide, threat-based response to threatened species management has been debated in the literature (Likens and Lindenmayer, 2012; Simberloff, 1998) and successive Australian governments have preferred one to the other. For example, the former Australian government actively moved away from the species-based response model to "a whole-of-ecosystem approach" (Garrett, 2009). As there are many processes that threaten several species (e.g. feral cat predation, altered fire regimes (Evans et al., 2011) there are likely to be benefits in managing threats to multiple species in the landscape (Carwardine et al., 2012). There are also risks associated with this approach as threatened species can require specific and sometimes conflicting management actions (Caughley et al., 1996). Both species-based and threat-based response actions can be prioritized using a cost-effectiveness analysis approach (Marris, 2007), where the expected benefit to the species is divided by the expected cost of the response action. Given that it is likely that a combination of these approaches is better that just one or the other (Likens and Lindenmayer, 2012), the following sections detail both the species-based and threat-based response to preventing extinctions and declines.

3.1. Species-based response to prevent extinctions

The current approach to species-based responses is an unsystematic actioning and funding of Recovery Plans and management based on Conservation Advices (Environment and Communications References Committee, 2013). Recovery Plans collate information about a species' biology, distributions and threats and should identify objectives of recovery and management responses within a set timeframe. Once the plan is adopted, stakeholders or the conservation agencies may use Recovery Plans to guide decisions about management actions for which to seek funding. Because state and federal governments had neither the time nor resources to meet their legislative commitment to produce Recovery Plans for all listed species, in 2007 it became at the discretion of the Minister to develop a plan. New, shorter documents called Conservation Advices, have been developed for all nationally listed species (Commonwealth of Australia, 2010). Their effectiveness is yet to be determined but there is evidence that, to date, the more comprehensive Recovery Plans have rarely improved a species' status (Bottrill et al., 2011).

Total conservation outcomes can be maximized for a limited budget if planning simultaneously considers ecology, technical constraints and economics for ranking management of species conservation actions (Briggs, 2009; Joseph et al., 2009; McCarthy et al., 2008, 2010; Szabo et al., 2009). An example of such an approach is the Project Prioritization Protocol (PPP) (Joseph et al., 2009), a structured decision-making framework that utilizes cost-effectiveness analysis. The highest-ranked projects are those with the largest expected conservation benefit per dollar. It considers the species' values and the costs, benefits and likelihood of success of management actions. Joseph et al. (2009) demonstrated that this process, which has been implemented in New Zealand and in New South Wales in Australia where it is tailored to local conditions and policy,

substantially increased the number of species that could be managed with the threatened species budget compared with ranking species by threat status or value alone. This process was rapid, inexpensive and transparent, took less than three years to develop and cost only NZ$600,000 to devise and rank actions for approximately 660 of New Zealand's most threatened species (less that $900 per species). Each step in the approach and the resulting list of management priorities can be examined transparently, highlighting gaps in knowledge of the species and uncertainty in the success of threat mitigation. It also can provide a tool to evaluate successes, failures of management and research priorities.

3.2. Threat-based response to prevent declines

Threats to species and ecosystems pervade the majority of landscapes in Australia (Evans et al., 2011). For example, introduced herbivores and predators cover over 60% of the landscape, there are 400 alien invasive plant species (NRMMC, 2006) and 44% of Australia's listed species are threatened by inappropriate fire regimes (Evans et al., 2011). While threatened biodiversity often requires specific responses, restoring and maintaining intact landscapes across tenure types can be useful for managing threatened species and ecosystems and avoiding declines in more common ones (Woinarski et al., 2007). Broad-scale threat management can be used alongside species- or ecosystem-specific actions to achieve overall conservation goals.

Significant efforts are invested in threat-based management responses in Australia (DEWHA, 2009). However, these initiatives are rarely informed by cost-effectiveness approaches for prioritizing when, where and how to implement mitigation actions based on expected benefits to biodiversity (Carwardine et al., 2012; Wilhelm-Rechmann and Cowling, 2011). Hence, current efforts and funds could be spent more efficiently for achieving biodiversity outcomes. As with species prioritization, a cost-effectiveness approach to threat management would indicate which mitigation strategies, in which locations, are likely to achieve the greatest benefits to species and/or ecosystems per unit cost, and how much it will cost to avoid species declines within a particular region. For example, an analysis of threat management strategies in the Kimberley region of north-western Australia estimated that the likely functional loss of 45 species across the region could be avoided with an investment of $40 million per year over 20 years, with an additional $95 million in the first year, strategically spent on fire, introduced herbivores, predators and weeds (Carwardine et al., 2012). Threat-based approaches typically focus on existing threats, but there is an increasing need to consider the dynamic threat of climate change.

There are significant opportunities for managing landscape-scale threats cost-effectively to improve threatened species persistence, without adverse impacts on existing economic land usage. Whilst at a global scale agricultural intensification is a major driver of biodiversity loss (Tilman et al., 2001), at a landscape scale agriculture can benefit from native biodiversity and in some instances also contribute to some aspects of biodiversity conservation (Tscharntke et al., 2005). With careful examination of the trade-offs and synergies between threat management, ecosystem services provision and production activity, threat-based responses can generate a range of co-benefits such as improved agricultural production, increased ecosystem services and opportunity for employment (Carwardine et al., 2011; Possingham et al., 2002a). For example, landscape-wide fire management can result in increased production, reduced carbon dioxide emissions, income opportunities for the local community and improved outcomes for threatened species (Carwardine et al., 2011). With a unified, defensible threat management prioritization approach, Australia can maximize the maintenance of functioning landscapes with intact species, populations and ecosystems (Watson et al., 2009). Further, it is likely to be much less expensive to protect existing healthy populations of species than to recover these species once they are declining or down to low numbers of individuals (Garnett et al., 2003).

4. Estimate resources required to recovery species

Although investment in the environment more generally has increased dramatically over the last few decades (Hajkowicz, 2009), Australia has followed the course of most countries and not allocated sufficient resources to biodiversity conservation to halt species declines (Balmford et al., 2003; Garnett et al., 2003; McCarthy et al., 2012). Australia is ranked in the bottom 40 countries in the world for the funding of its proportion of global biodiversity given its governance, size and wealth (Waldron et al., 2013). A comprehensive estimate of the funds and efforts required to recover all threatened species in Australia and prevent further declines does not exist. An estimate of the total costs to undertake all species-specific management and threat-based management can be made evident by carrying out species-based and threat-based prioritization analyses as described above. Partial funding, assuming all other necessary factors are in place, while often the reality, can only ever result in partial security of species. The diminishing returns of securing the most threatened and most difficult to recover species (Garnett et al., 2003; Possingham et al., 2002b) mean it might not be feasible to fully fund the recovery of all threatened species. Nevertheless, this should be explicit in funding decisions and on the public record so that the true consequences of these budgetary decisions and political priorities are clear (Miller et al., 2002).

The processes that result in a species becoming threatened often take decades. It follows that recovery can take just as long – quick fixes are rare. For example, it took over three decades of research and management to improve the status of the Noisy Scrub-bird (*Atrichornis clamosus*) (Danks, 1997). Threatened species projects are often not funded for a sufficient length of time to allow recovery (Environment and Communications References Committee, 2013; Kirkpatrick, 2011). For threatening processes, any gap in funding can undo much of the good work done previously. For instance, seedlings of the invasive prickly mimosa (*Mimosa pigra*) must be removed annually for at least ten years after removal of adults otherwise re-infestation cannot be prevented (Likitsch and Elliott, 2012). Guaranteed funding for threatened species projects for 8–10 years with rolling reviews and the potential for renewals may allow recovery programs to deal with problems at a scale commensurate with that needed to remediate most threats.

5. Incorporate uncertainties with an adaptive management program

Natural systems are complex, dynamic, and incompletely observable, which means uncertainty needs to be considered in decisions relating to managing natural systems (McCarthy et al., 2010). Australia's environmental programs have so far lacked the mechanisms and sufficient funds to foster an adaptive management approach (Lockwood et al., 2009; Morrison et al., 2010; State of the Environment Committee, 2011). Within the planning process, uncertainty may arise because of lack of information about a species' status (abundance, trends), lack of information about the benefit or probability of success of different management actions, or because of the inherent complexity, dynamism and unpredictability of the system. New threats, such as human-induced climate change, only exacerbate this. Such uncertainties can be accommodated in decision-making (McCarthy et al., 2010), but for planning

processes to be effective into the future, management should be implemented as part of an adaptive, iterative framework that acknowledges these uncertainties and uses new information as it becomes available (Runge, 2011; Walters, 1986).

Within each iteration of the planning process, we recommend decisions are made using the best available information, based on the most likely outcomes, and with explicit statements of uncertainty. Outcome-focused monitoring should then be used to estimate the effectiveness of management actions, the current status and dynamics of species, and to identify new threats and management challenges. This should be integrated with prior information, ready for the next iteration of the planning process. Managing adaptively not only reduces uncertainty through time, but also assists with the challenges of managing dynamic systems and is particularly useful when facing unpredictable and irreversible effects of novel threats such as climate change (Conroy et al., 2011; Watson et al., 2013). It also helps focus research on aspects of the recovery process where a reduction in uncertainty will make the greatest difference to minimizing risk.

6. Discussion

We have identified four major potential improvements to the effectiveness of threatened species management: rationalizing listing, introducing cost-effective prioritization of management actions, increasing funding transparency and accountability for what can be achieved with those funds, and incorporating uncertainty. There are clearly many other facets of species recovery that can be improved to avoid extinctions (e.g. increasing funds and public engagement). Fortunately, evidence indicates that if funds are spent effectively, a relatively modest increase in Australia can make a real difference (Carwardine et al., 2012; McCarthy et al., 2010). For example, one study showed that increasing the resources allocated to Australia's threatened bird species from $3 million to $10 million per year could significantly reduce the number of species facing extinction over the next 80 years (McCarthy et al., 2008). Approximately 70% of Australia is under private tenure, and many threatened species depend on non-federal land for habitat (Natural Heritage Data Centre Network, 1993). This means that the success of implementing any federal Act is contingent on how well people are engaged in and support species management (Balmford and Cowling, 2006; Brook et al., 2003; Cocklin et al., 2007; Stokstad, 2005). Other challenges to address include: assessing the most effective governance arrangement to implement threatened species interventions (Hajkowicz, 2009); assessing the best ways to tackle pervasive threats like cat predation (Woinarski et al., 2014); analyzing how funds should be divided between ecosystem and species-based responses (Likens and Lindenmayer, 2012); and determining how many extinctions will be avoidable if the drivers of change continue on their trajectory (Millennium Ecosystem Assessment, 2005). Whilst addressing these challenges are key to improving the overall capacity of threatened species management to save species, the recommendations in this essay will help reach the potential of what can be implemented immediately with available policy provisions and funds.

Although developed to address specific issues in Australia, we believe these recommendations could be useful for other countries with threatened species legislation. The United States of America, for example, faces very similar challenges to Australia, with continuing threats to species, increasing numbers of listed species and few recoveries, inherent and increasing uncertainties, un-transparent species prioritisation and a constrained budget (Restani and Marzluff, 2001; Rohlf, 1991; Stokstad, 2005). In the United States, species whose recovery conflicts with economic interests receive a higher priority (Restani and Marzluff, 2001). This effectively increases the economic burden of species recovery (Restani and Marzluff, 2001). The *Endangered Species Act* has the potential to conserve more species with available funding if species that cost less to recover were prioritized (Brown and Shogren, 1998), rather than those that cost more, as is the current approach (Restani and Marzluff, 2001). Australia may potentially also learn from the successes of the *Endangered Species Act* experience in the United States where a higher number of species have a recovery plan (83% of the species listed by the United States Fish and Wildlife Service and 32% by National Marine Fisheries Service compared to 31% by the *EPBC Act*) and more species have their critical habitat protected (44% compared to 0.3%) (DoE, 2013a,b; Suckling and Taylor, 2005; USFWS, 2013; Walsh et al., 2012). The relative effectiveness of the *Endangered Species Act* and the *EPBC Act* in species recovery needs further investigation before any clear lessons can be deduced.

Australia is well placed economically to fund and manage biodiversity. Spending available funds cost-effectively using the best available information should improve the success of threatened species management. Future biodiversity efforts should aim to avoid the criticism of previous biodiversity programs, that is that there has been no discernible outcome for the public expenditure (ANAO, 2008). Successful recovery has certainly occurred in Australia. Adopting rational, transparent, cost-effective decision-making and implementation of conservation management responses could increase the number of these successes and help avoid further extinctions.

Acknowledgements

This research was conducted with funding support from the Australian Government's National Environmental Research Program and the Australian Research Council Centre of Excellence for Environmental Decisions. J.A. McDonald is supported by the National Environmental Research Program. C.J. Klein is supported by an Australian Research Council Postdoctoral Fellowship (Project number DP110102153). R. Maloney also provided valuable assistance. We are grateful to A. Sheppard, F. Brown, M. Lonsdale and A. Whitten for providing comments and suggestions.

References

ANAO, 2008. Regional Delivery Model for the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality. Audit Report 21 2007–08 Performance Audit. Department of the Environment, Water, Heritage and the Arts, Department of Agriculture, Fisheries and Forestry. Australian National Audit Office (ANAO), Canberra.

Balmford, A., Cowling, R.M., 2006. Fusion or failure? The future of conservation biology. Conserv. Biol. 20, 692–695.

Balmford, A., Gaston, K.J., Blyth, S., James, A., Kapos, V., 2003. Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. Proc. Natl. Acad. Sci. 100, 1046–1050.

Beeton, B., Burbridge, A., Grigg, G., How, R., McKenzie, N., Woinarski, J.C.Z., 2010. Final Report Christmas Island Expert Working Group to Minister for the Environment Protection. Heritage and the Arts, Canberra.

Bottrill, M.C., Walsh, J.C., Watson, J.E.M., Joseph, L.N., Ortega-Argueta, A., Possingham, H.P., 2011. Does recovery planning improve the status of threatened species? Biol. Conserv. 144, 1595–1601.

Briggs, S.V., 2009. Priorities and paradigms: directions in threatened species recovery. Conserv. Lett. 2, 101–108.

Brook, A., Zint, M., De Young, R., 2003. Landowners' responses to an endangered species act listing and implications for encouraging conservation. Conserv. Biol. 17, 1638–1649.

Brown, G.M., Shogren, J.F., 1998. Economics of the endangered species act. J. Econ. Perspect. 12, 3–20.

Burgman, M.A., Keith, D.A., Walshe, T.V., 1999. Uncertainty in comparative risk analysis for threatened Australian plant species. Risk Anal. 19, 585–598.

Carwardine, J., O'Connor, T., Legge, S., Mackey, B., Possingham, H., Martin, T., 2011. Priority Threat Management to Protect Kimberley Wildlife. CSIRO Ecosystem Sciences Brisbane.

Carwardine, J., O'Connor, T., Legge, S., Mackey, B., Possingham, H.P., Martin, T.G., 2012. Prioritizing threat management for biodiversity conservation. Conserv. Lett. 5, 196–204.

Caughley, G., Gunn, A., Ralls, K., 1996. Conservation Biology in Theory and Practice. Blackwell Science, Cambridge, MA.
Coates, D.J., Atkins, K.A., 2001. Priority setting and the conservation of Western Australia's diverse and highly endemic flora. Biol. Conserv. 97, 251–263.
Cocklin, C., Mautner, N., Dibden, J., 2007. Public policy, private landholders: perspectives on policy mechanisms for sustainable land management. J. Environ. Manage. 85, 986–998.
Commonwealth of Australia, 2010. Conservation Advices. Department of the Environment, Water, Heritage and the Arts, Canberra, Australia.
Conroy, M.J., Runge, M.C., Nichols, J.D., Stodola, K.W., Cooper, R.J., 2011. Conservation in the face of climate change: the roles of alternative models, monitoring, and adaptation in confronting and reducing uncertainty. Biol. Conserv. 144, 1204–1213.
Danks, A., 1997. Conservation of the Noisy Scrub-bird: a review of 35 years of research and management. Pacific Conserv. Biol. 3, 341.
DEWHA, 2009. Managing the threats to Australia's biodiversity. Assessment of Australia's Terrestrial Biodiversity 2008. Report prepared by the Biodiversity Assessment Working Group of the National Land and Water Resources Audit for the Australian Government. Department of the Environment, Water, Heritage and the Arts (DEWHA) Australian Government, Canberra (Chapter 6).
DoE, 2013a. Register of Critical Habitat. Biodiversity – Species Profiles and Threat Databases. Australian Department of Environment.
DoE, 2013b. SPRAT EPBC Threatened Species Lists in Species Profile and Threats Database. Department of the Environment, Canberra, Australia. <http://www.environment.gov.au/sprat>.
DoE, 2014. Threatened Species Commissioner. Department of the Environment, Canberra, Australia. <http://www.environment.gov.au/biodiversity/threatened/commissioner>.
Environment and Communications References Committee, 2013. Senate Inquiry – Effectiveness of Threatened Species and Ecological Communities' Protection in Australia. Senate Printing Unit, Parliament House, Canberra.
Evans, M.C., Watson, J.E.M., Fuller, R.A., Venter, O., Bennett, S.C., Marsack, P.R., Possingham, H.P., 2011. The spatial distribution of threats to species in Australia. Bioscience 61, 281–289.
Farrier, D., Whelan, R., Mooney, C., 2007. Threatened species listing as a trigger for conservation action. Environ. Sci. Policy 10, 219–229.
Findlay, C.S., Elgie, S., Giles, B., Burr, L., 2009. Species listing under Canada's species at risk act. Conserv. Biol. 23, 1609–1617.
Ford, H.A., Barrett, G.W., Saunders, D.A., Recher, H.F., 2001. Why have birds in the woodlands of Southern Australia declined? Biol. Conserv. 97, 71–88.
Garnett, S., Crowley, G., Balmford, A., 2003. The costs and effectiveness of funding the conservation of Australian threatened birds. Bioscience 53, 658–665.
Garnett, S., Franklin, D., 2014. Climate Change Adaptation Plan for Australian Birds.
Garnett, S., Szabo, J., Dutson, G., 2011. Action Plan for Australian Birds 2010.
Garrett, P.M., 2009. Opening Address Tenth International Congress of Ecology. Minister for the Environment, Heritage and the Arts, INTECOL, Brisbane.
Hajkowicz, S., 2009. The evolution of Australia's natural resource management programs: towards improved targeting and evaluation of investments. Land Use Policy 26, 471–478.
Harvey, E., Hoekstra, J.M., O'Connor, R.J., Fagan, W.F., 2002. Recovery plan revisions: progress or due process? Ecol. Appl. 12, 682–689.
Joseph, L.N., Maloney, R.F., Possingham, H.P., 2009. Optimal allocation of resources among threatened species: a project prioritization protocol. Conserv. Biol. 23, 328–338.
Kelly, C.L., Pickering, C.M., Buckley, R.C., 2003. Impacts of tourism on threatened plant taxa and communities in Australia. Ecol. Manage. Restor. 4, 37–44.
Kingsford, R., Watson, J., Lundquist, C., Venter, O., Hughes, L., Johnston, E., Atherton, J., Gawel, M., Keith, D., Mackey, B., 2009. Major conservation policy issues for biodiversity in Oceania. Conserv. Biol. 23, 834–840.
Kirkpatrick, J., 2011. The political ecology of soil and species conservation in a 'Big Australia'. Geogr. Res. 49, 276–285.
Laycock, H., Moran, D., Smart, J., Raffaelli, D., White, P., 2009. Evaluating the cost-effectiveness of conservation: the UK Biodiversity Action Plan. Biol. Conserv. 142, 3120–3127.
Likens, G.E., Lindenmayer, D.B., 2012. Integrating approaches leads to more effective conservation of biodiversity. Biodivers. Conserv. 21, 3323–3341.
Likitsch, B., Elliott, L., 2012. Developing solutions to evolving weed problems. In: 18th Australasian Weeds Conference. Weed Science Society of Victoria Inc., Frankston, Australia, Melbourne, Victoria, Australia.
Lindenmayer, D., 2008. Ten Commitments: Reshaping the Lucky Country's Environment. CSIRO Publishing.
Lockwood, M., Davidson, J., Curtis, A., Stratford, E., Griffith, R., 2009. Multi-level environmental governance: lessons from Australian natural resource management. Aust. Geogr. 40, 169–186.
Mace, G., 2005. Biodiversity in Ecosystems and Human Wellbeing: Current State and Trends. Nature Publishing Group, pp. 79–115.
Marris, E., 2007. Conservation priorities: what to let go. Nature 450, 152–155.
McAlpine, C., Syktus, J., Ryan, J., Deo, R., McKeon, G., McGowan, H., Phinn, S., 2009. A continent under stress: interactions, feedbacks and risks associated with impact of modified land cover on Australia's climate. Glob. Change Biol. 15, 2206–2223.
McCarthy, D.P., Donald, P.F., Scharlemann, J.P.W., Buchanan, G.M., Balmford, A., Green, J.M.H., Bennun, L.A., Burgess, N.D., Fishpool, L.D.C., Garnett, S.T., Leonard, D.L., Maloney, R.F., Morling, P., Schaefer, H.M., Symes, A., Wiedenfeld, D.A., Butchart, S.H.M., 2012. Financial costs of meeting global biodiversity conservation targets: current spending and unmet needs. Science 338, 946–949.
McCarthy, M.A., Thompson, C.J., Garnett, S.T., 2008. Optimal investment in conservation of species. J. Appl. Ecol. 45, 1428–1435.
McCarthy, M.A., Thompson, C.J., Hauser, C., Burgman, M.A., Possingham, H.P., Moir, M.L., Tiensin, T., Gilbert, M., 2010. Resource allocation for efficient environmental management. Ecol. Lett. 13, 1280–1289.
McDonald-Madden, E., Probert, W.J.M., Hauser, C.E., Runge, M.C., Possingham, H.P., Jones, M.E., Moore, J.L., Rout, T.M., Vesk, P.A., Wintle, B.A., 2010. Active adaptive conservation of threatened species in the face of uncertainty. Ecol. Appl. 20, 1476–1489.
Metrick, A., Weitzman, M.L., 1996. Patterns of behavior in endangered species preservation. Land Econ., 1–16.
Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being – Biodiversity Synthesis. World Resources Institute, Washington, D.C.
Miller, J.K., Scott, J.M., Miller, C.R., Waits, L.P., 2002. The endangered species act: dollars and sense? Bioscience 52, 163–168.
Morrison, T., McAlpine, C., Rhodes, J., Peterson, A., Schmidt, P., 2010. Back to the future? Planning for environmental outcomes and the new caring for our Country program. Aust. Geogr. 41, 521–538.
Moseby, K., Read, J., 2006. The efficacy of feral cat, fox and rabbit exclusion fence designs for threatened species protection. Biol. Conserv. 127, 429–437.
Natural Heritage Data Centre Network, 1993. In: Conservancy, T.N. (Ed.), Perspective on the Species Imperilment: A Report from the Natural Heritage Data Centre Network. Arlington, VA.
NRMMC, 2006. Australian Weeds Strategy – A National Strategy for Weed Management in Australia. Natural Resource Management Ministerial Council (NRMMC) developed by the Australian Weed Committee. Australian Government Department of the Environment and Water Resources, Canberra, ACT.
Possingham, H., Ryan, S., Baxter, J., Morton, S., 2002a. Setting Biodiversity Priorities – A Paper Prepared As Part of the Activities of the Working Group Producing the Report Sustaining our Natural Systems and Biodiversity for the Prime Minister's Science, Engineering and Innovation Council.
Possingham, H.P., Andelman, S.J., Burgman, M.A., Medellın, R.A., Master, L.L., Keith, D.A., 2002b. Limits to the use of threatened species lists. Trends Ecol. Evol. 17, 503–507.
Restani, M., Marzluff, J.M., 2001. Avian conservation under the endangered species act: expenditures versus recovery priorities. Conserv. Biol. 15, 1292–1299.
Ritchie, E.G., 2013. Conservation: relaxed laws imperil Australian wildlife. Nature 498, 434.
Ritchie, E.G., Bradshaw, C.J., Dickman, C.R., Hobbs, R., Johnson, C.N., Johnston, E.L., Laurence, W.F., Lindenmayer, D., McCarthy, M.A., Nimmo, D.G., 2013. Continental-scale governance failure will Hasten Loss of Australia's Biodiversity. Conserv. Biol. 27, 1133–1135.
Rohlf, D.J., 1991. Six biological reasons why the Endangered Species Act does not work – and what to do about it. Conserv. Biol. 5, 273–282.
Runge, M.C., 2011. An introduction to adaptive management for threatened and endangered species. J. Fish Wildlife Manage. 2, 220–233.
Short, J., Smith, A., 1994. Mammal decline and recovery in Australia. J. Mammal., 288–297.
Simberloff, D., 1998. Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biol. Conserv. 83, 247–257.
State of the Environment Committee, 2011. State of the Environment. Independent report to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities. DSEWPaC, Canberra.
Steffen, W., Burbidge, A.A., Hughes, L., Kitching, R., Lindenmayer, D., Musgrave, W., Smith, M.S., Werner, P.A., 2009. Australia's Biodiversity and Climate Change. CSIRO Publishing.
Stokstad, E., 2005. What's wrong with the Endangered Species Act? Science 309, 2150–2152.
Suckling, K.F., Taylor, M., 2005. Critical Habitat and Recovery. In: Goble, D.D., Scott, J.M., Davis, F.W. (Eds.), The Endangered Species Act at Thirty: Renewing the Conservation Promise. Island Press, pp. 75.
Szabo, J.K., Briggs, S.V., Lonie, R., Bell, L., Maloney, R., Joseph, L.N., Hunter, I., Possingham, H.P., 2009. The feasibility of applying a cost-effective approach for assigning priorities for threatened species recovery with a case study from New South Wales, Australia. Pacific Conserv. Biol. 15, 238.
Szabo, J.K., Butchart, S.H.M., Possingham, H.P., Garnett, S.T., 2012. Adapting global biodiversity indicators to the national scale: a Red List Index for Australian birds. Biol. Conserv. 148, 61–68.
Taylor, M.F., Sattler, P.S., Evans, M., Fuller, R.A., Watson, J.E.M., Possingham, H.P., 2011. What works for threatened species recovery? An empirical evaluation for Australia. Biodivers. Conserv. 20, 767–777.
Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D., Schlesinger, W.H., Simberloff, D., Swackhamer, D., 2001. Forecasting agriculturally driven global environmental change. Science 292, 281–284.
Tisdell, C., Nantha, H.S., Wilson, C., 2007. Endangerment and likeability of wildlife species: how important are they for payments proposed for conservation? Ecol. Econ. 60, 627–633.
Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I., Thies, C., 2005. Landscape perspectives on agricultural intensification and biodiversity-ecosystem service management. Ecol. Lett. 8, 857–874.
USFWS, 2013. Listing and Critical Habitat|Critical Habitat|Frequently Asked Questions. Endangered Species. United States Fish and Wildlife Service. <http://www.fws.gov/endangered/what-we-do/critical-habitats-faq.html>.

Waldron, A., Mooers, A.O., Miller, D.C., Nibbelink, N., Redding, D., Kuhn, T.S., Roberts, J.T., Gittleman, J.L., 2013. Targeting global conservation funding to limit immediate biodiversity declines. Proc. Natl. Acad. Sci. 110, 12144–12148.

Walsh, J.C., Watson, J.E.M., Bottrill, M.C., Joseph, L.N., Possingham, H.P., 2012. Trends and biases in the listing and recovery planning for threatened species: an Australian case study. Oryx 1, 1–10.

Walters, C.J., 1986. Adaptive Management of Renewable Resources. Blackburn Press, Caldwell, USA.

Watson, J.E., Bottrill, M.C., Walsh, J.C., Joseph, L.N., Possingham, H.P., 2010. Evaluating Threatened Species Recovery Planning in Australia. Prepared on Behalf of the Department of the Environment, Water, Heritage and the Arts by the Spatial Ecology Laboratory, University of Queensland, Brisbane.

Watson, J.E.M., Fuller, R.A., Watson, A.W., Mackey, B.G., Wilson, K.A., Grantham, H.S., Turner, M., Klein, C.J., Carwardine, J., Joseph, L.N., 2009. Wilderness and future conservation priorities in Australia. Divers. Distrib. 15, 1028–1036.

Watson, J.E.M., Iwamura, T., Butt, N., 2013. Mapping vulnerability and conservation adaptation strategies under climate change. Nature Clim. Change.

Watson, J.E.M., Evans, M.C., Carwardine, J., Fuller, R.A., Joseph, L.N., Segan, D.B., Taylor, M.F.J., Fensham, R.J., Possingham, H.P., 2011. The capacity of Australia's protected-area system to represent threatened species. Conserv. Biol. 25, 324–332.

Wilhelm-Rechmann, A., Cowling, R.M., 2011. Framing biodiversity conservation for decision makers: insights from four South African municipalities. Conserv. Lett. 4, 73–80.

Woinarski, J., Burbidge, A., Harrison, P., 2014. The Action Plan for Australian Mammals 2012. CSIRO Publishing.

Woinarski, J., Cogger, H., 2013. Australian endangered species: Christmas Island Forest Skink. The Conversation.

Woinarski, J., Mackey, B., Nix, H., Traill, B., 2007. The Nature of Northern Australia: Its Natural Values, Ecological Processing and Future Prospects. ANU E Press.

Woinarski, J.C.Z., Legge, S., Fitzsimons, J.A., Traill, B.J., Burbidge, A.A., Fisher, A., Firth, R.S.C., Gordon, I.J., Griffiths, A.D., Johnson, C.N., McKenzie, N.L., Palmer, C., Radford, I., Rankmore, B., Ritchie, E.G., Ward, S., Ziembicki, M., 2011. The disappearing mammal fauna of northern Australia: context, cause, and response. Conserv. Lett. 4, 192–201.