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The contribution of policy, law, management, research, and advocacy failings to the recent extinctions of three Australian vertebrate species

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Abstract

Extinctions typically have ecological drivers, such as habitat loss. However, extinction events are also influenced by policy and management settings that may be antithetical to biodiversity conservation, inadequate to prevent extinction, insufficiently resourced, or poorly implemented. Three endemic Australian vertebrate species – the Christmas Island pipistrelle (*Pipistrellus murrayi*), Bramble Cay melomys (*Melomys rubicola*), and Christmas Island forest skink (*Emoia nativitatis*) – became extinct from 2009 to 2014. All 3 extinctions were predictable and probably preventable. We sought to identify the policy, management, research, and other shortcomings that contributed their extinctions or failed to prevent them. Factors that contributed to these extinctions included a lack within national environmental legislation and policy of explicit commitment to the prevention of avoidable extinctions, lack of explicit accountability, inadequate resources for conservation (particularly for species not considered charismatic or not of high taxonomic distinctiveness), inadequate biosecurity, a slow and inadequate process for listing species as threatened, recovery planning that failed to consider the need for emergency response, inability of researchers to identify major threatening factors, lack of public engagement and involvement in conservation decisions, and limited advocacy. From these 3 cases, we recommend environmental policy explicitly seek to prevent extinction of any species and provide a clear chain of accountability and an explicit requirement for public inquiry following any extinction; implementation of a timely and comprehensive process for listing species as threatened and for recovery planning; reservation alone not be assumed sufficient to maintain species; enhancement of biosecurity measures; allocation of sufficient resources to undertake actions necessary to prevent extinction; monitoring be considered a pivotal component of the conservation response;

research provide timely identification of factors responsible for decline and of the risk of extinction; effective dissemination of research results; and advocacy by an informed public for the recovery of threatened species; and public involvement in governance of the recovery process. These recommendations should be applicable broadly to reduce the likelihood and incidence of extinctions.

Introduction

The current rate of extinction is 100-1000 times the normal background rate, largely because of the increasing extent of environmental changes wrought or influenced by humanity (Pimm et al. 1995; Ceballos et al. 2015). Many recent analyses have reviewed the proportion of extinctions across taxonomic groups to seek general relationships between extinction and life history and ecological factors. Typically, such studies identify habitat loss, introduced species, changed fire regimes, and disease as major drivers of extinction (Cardillo et al. 2008; Davidson et al. 2009). Although such general patterns are informative, it is also instructive to consider the path to extinctions on a case-by-case basis. Furthermore, the incidence, intensity, and impact of proximate threat factors, such as habitat loss, may be substantially influenced by policy and management settings that are antithetical to biodiversity conservation, inadequate to prevent extinctions, or insufficiently implemented. With rare exceptions – such as the impacts of natural catastrophes (e.g., volcanic eruption) on highly localized species – human action or inaction has been a contributing factor in most recent extinctions (Pimm 1996).

Although there have been some reviews of policy instruments and conservation management investments that have successfully reduced biodiversity loss (Brooks et al. 2009; Butchart et al. 2010), far less attention has been directed to the set of policy, legislation, and management factors that have contributed to or been insufficient to prevent extinctions (Black et al. 2011). Conservation failures are often unreported (Redford & Taber 2000), despite the potential for review of such cases to expose weaknesses in management systems that, if not remedied, could subvert recovery efforts for other threatened species (Pimm 1996). In contrast, in medicine and many other fields, reporting on failure has long been a crucial component for system improvement (Reason 2000).

We used a coronial-investigations approach to review 3 recent extinctions. Retrospective and systematic analysis by a coroner (a specially appointed judicial official) is a mandatory response in many countries to human fatalities that may initially be unexplained, and such analyses are also widely used to identify and remedy failings in governance standards where shortcomings may have serious consequences. We followed the typical steps in coronial review. First, we detailed the circumstances of the deceased (i.e., the extinct species) and the characteristics of the death (i.e., extinction) and then sought to identify causal or contributory factors. Finally, we devised recommendations to reduce the likelihood of similar future failures. Coronial reviews may be particularly effective when dealing with multiple and related cases of deaths, from which systemic failings may be most clearly and usefully identified. Our assessment does not pretend to constitute an official legal review. Our primary interest was not to apportion blame in these cases; rather, we sought to identify tractable remedies such that future extinctions may be less likely.

The ambit of possible contributing factors to the extinctions we considered is deliberately broad. It includes legislation, policy, management, resources, research, and other factors. Although the death of the last individual is a single unequivocal defining feature of extinction, the process leading to that extinction may involve a chain of events that contribute successively and interactively to the decline and the ineffectiveness of remedial measures. Although factors in the terminal phase of extinction are often highlighted as the pivotal shortcomings that allowed an extinction to occur, such failings may be simply the last, and not necessarily the most critical, of the contributing factors (Caughley 1994).

The examples we considered are all Australian and hence share some policy and management features. Australia has a high rate of extinctions for some taxonomic groups (Woinarski et al. 2015). However, although some governance arrangements are unique to the Australian context, many of the factors identified as contributing to these extinction cases will apply internationally, as do our recommendations.

Case studies

The extinctions we reviewed involve endemic Australian vertebrate species that became extinct from 2009 to 2014: the Christmas Island pipistrelle (*Pipistrellus murrayi*), Bramble Cay melomys (*Melomys rubicola*), and Christmas Island forest skink (*Emoia nativitatis*). The 3 species are all island species. All are in speciose genera:
there are >30 species 1 *Pipistrellus* (Wilson & Reeder 2005), >20 in *Melomys* (Wilson & Reeder 2005), and >70 in *Emoia* (Brown 1991). In some prioritization approaches, species with such low levels of taxonomic distinctiveness are accordingly allocated few or no resources for conservation (Joseph et al. 2009). These 3 species also would have scored low

on any prioritization that weighted charisma, utility, cultural significance, or ecological role (Walker 1992; Commonwealth of Australia 2015).

The Christmas Island pipistrelle (hereafter pipistrelle) was a small insectivorous bat restricted to the 135-km^2 Christmas Island, an Australian territory in the Indian Ocean. This island is almost entirely owned by the Australian Government, and 63% of its extent is national park. Phosphate mining (ongoing since the island's settlement in the 1880s) has caused habitat loss over about 25% of the island. Although considered common up to the mid-1980s (Tidemann 1985), the pipistrelle declined at a rapid and remarkably consistent rate from the mid-1990s, when next sampled (Lumsden & Cherry 1997), until its extinction on 26 August 2009, when the last record of the species was reported from an intensive monitoring program that could readily detect it if present (Lumsden 2009). The primary ecological cause of its extinction was not resolved, but it was most likely one or more introduced predators (Lumsden et al. 2007). Three papers consider some policy and management factors that may have contributed to this extinction (Lunney et al. 2011; Martin et al. 2012; Ng et al. 2014), including the perceived late response of the Australian Government's Environment Department and its unpreparedness to act decisively following a recommendation to establish a captive breeding program.

The pattern of decline was less clearly described for the Christmas Island forest skink (hereafter forest skink). Monitoring was only occasional and unsystematic, but this sampling indicated that its formerly abundant population (Cogger et al. 1983; Cogger & Sadlier 1999) declined precipitously (along with other native reptiles) after the late 1980s (Cogger & Sadlier 1999; James 2004; Schulz & Barker 2008; Smith et al. 2012). Extinction almost certainly occurred on 31 May 2014, when the last of three captive-held individuals died

(Woinarski et al. 2014b). As with the pipistrelle, the primary ecological cause of its extinction was not resolved, but most likely it also was one or more introduced predator species (Schulz & Barker 2008; Smith et al. 2012). Although its extinction has been reported (Woinarski et al. 2014b), no one has assessed the policy or management shortcomings that may have contributed to that extinction.

The Bramble Cay melomys (hereafter melomys) was a small rodent restricted to a 5-ha uninhabited island in Torres Strait (in the Australian state of Queensland). Occasional sampling and anecdotal records indicated an ongoing decline after the late 1970s, when the population was estimated at "several hundred individuals" (Limpus et al. 1983). By 1998 the estimated population was about 90 individuals (Dennis & Storch 1998), and by 2004 only 12 individuals were recorded in comparable sampling (Dennis 2012). It was only briefly and occasionally sampled subsequently; the final anecdotal record was made in 2009. A thorough survey in 2014 found no individuals, demonstrating that the species was no longer extant (Gynther et al. 2016). The primary ecological cause of its extinction was not resolved, but it was most likely due to one or more storm surges leading to brief inundation of its low-lying island home (Gynther et al. 2016). Although the possible connection of this extinction to the effects of climate change has been noted (Watson 2016), there has been only limited previous consideration of the policy or management shortcomings that may have contributed to this extinction (Watson 2016; Woinarski et al. 2016).

Identification of Contributing Factors

Legislation and Policy Settings

Deficiencies in Australian (commonwealth, state, and territory) environmental legislation and policy probably allowed each of these three extinctions to occur. Australia's overarching

environmental legislation, the Environment Protection and Biodiversity Conservation Act of 1999, and principal conservation policy, Australia's Biodiversity Conservation Strategy 2010-2030 (Natural Resource Management Ministerial Council 2010) and its predecessors, provide no commitment to attempting to prevent avoidable extinctions. Hence, extinction is not explicitly recognised as undesirable or indicative of policy failure. There is no provision in Australian legislation that makes it an offense to cause, contribute significantly to, or fail to take reasonable actions to prevent an extinction. Because there was no explicit policy or law that stipulated the objective of averting extinction, any agencies or individuals who contributed to these extinctions or failed to take reasonable steps to prevent them operated with impunity.

Under Australian legislation, the environment minister has responsibility for the maintenance of biodiversity values deemed "matters of national environmental significance" (which includes listed threatened species). However, there is no clear chain of accountability subsidiary to this. Furthermore, the minister's frame of responsibility lies mostly with oversight of the assessment process for developments that may have acute impacts on threatened species rather than with dealing effectively with the complex mix of more diffuse and chronic threats that most likely were drivers of these extinctions. Even in recovery plans for threatened species, the allocation of responsibility for specific actions is typically opaque or vague, and plans provide no clear accountability for the implementation of actions or for failures in such implementation (Auditor-General 2007).

Until recently, there has been no national obligation to report on extinctions that have occurred or been prevented. The Convention on Biological Diversity's Aichi target 12 and the targets in the United Nation's 2015 Sustainable Development goal 15 now require such

reporting. However, even this reporting may be evadable because the Australian government's listing of threatened species still treats these 3 extinct species as extant (as of August 2016).

There has been no formal inquiry into any of these extinctions; hence, there has been no public process to identify and remedy inadequacies in existing protection mechanisms or to learn from mistakes that may have been made.

As evident in these examples, a locally abundant species may decline rapidly to extinction. To allow for the implementation of effective management responses, it is imperative that the extinction-risk be recognised in a timely manner. At least until very recently, under Australian legislation, there has been no strategic and comprehensive process to assess the conservation status of species. Nomination of individual species for consideration as threatened is largely ad hoc, although with significant biases toward charismatic vertebrates (Walsh et al. 2012). Following nomination of a species for conservation assessment, the process of listing may take several years, and that period is partly dictated by rigorous statutory requirements. Due to insufficient resources, not all nominated species are necessarily evaluated, and many species that probably merit listing as threatened are not nominated and hence are not given legislative protection.

Listing as threatened under Australian legislation was relatively timely for the melomys (listed as endangered in 2000) and pipistrelle (listed as endangered in 2001 and uplisted to critically endangered in 2006). However, listing came far too late for the forest skink; its official recognition as threatened (as critically endangered) occurred in January 2014, only 4 months before its extinction. The long interval (about 15 years) between the demonstration of

very significant decline (Cogger & Sadlier 1999; James 2004; Schulz & Barker 2008) and its listing as threatened meant that the species was not afforded, until far too late, any particular priority for research or conservation management. The delay in listing was partly attributable to the lack in Australian government conservation practice of strategic and comprehensive assessments of species' conservation status. However, there was also a particular obstacle for listing the forest skink as threatened. The expert with most knowledge of its decline was an employee of the environment department. This person sought in 2006 to nominate it for listing as threatened but was instructed by a superior in the agency not to submit such a nomination (James 2014). Had this obstruction not occurred, the extinction of this species may have been averted.

Under Australian law, the strategic conservation management response for most (but not all) listed threatened species is provided in recovery plans, which are approved by the Environment Minister. Recovery plans may often provide a useful blueprint for conservation management, but there is no legislative requirement for these plans to be implemented. Recovery plans were developed in a reasonably timely manner for the pipistrelle (Schulz & Lumsden 2004) and rather later in the extinction timeframe for the melomys (Latch 2008). No plan was developed for the forest skink, given the short period between its formal recognition as threatened and its extinction.

The recovery plans for the pipistrelle and melomys provided some framework for research and management. However, recovery planning is likely to be most effective when it is targeted at ameliorating the primary threats driving decline (Troyer & Gerber 2015). For the pipistrelle, the primary factor or factors causing decline remained unknown, rendering its recovery plan a blunt management instrument.

Furthermore, the recovery plans for the pipistrelle and melomys omitted any consideration of the emergency response of captive breeding. The authors assumed the actions proposed would achieve recovery and failed to include any response should the trend of severe decline continue. This misplaced optimism and the omission of an emergency response were attributable to the plans' authors and to the independent Threatened Species Scientific Committee that endorsed the plans and recommended their acceptance to the Environment Minister.

The omission of captive breeding within the recovery plan was particularly nonsensical for the melomys. With a very small (and rapidly declining) population, and restriction to a single very small and unstable location, the actions most likely to prevent extinction would have involved the establishment of an insurance captive breeding population or translocation to a more secure site. However, in this case the Queensland environment department (or one or two key personnel within it) was unsympathetic to captive breeding generally and refused to countenance any recovery plan (for this or other species) that included such actions. Although recovery planning is the ultimate responsibility of the Australian government, such plans are typically developed collaboratively with state government agencies. Ultimately, the Australian environment department ceded to the opinions of officers in the Queensland agency, allowing the omission of captive breeding from the recovery plan. Without this component, it was a recovery plan doomed to fail.

Consideration of captive breeding was also a pivotal issue for the pipistrelle. In this case, the researchers compiling the 2004 recovery plan did not consider any need for captive breeding. As the population subsequently continued to decline rapidly toward extinction, in the absence of any effective mediation of threats, the need for captive breeding was belatedly recognised.

The subsequent (initially in 2008 and formalized in January 2009) appeal by researchers and conservation groups to establish a captive breeding population (Lumsden & Schulz 2009) may or may not have come too late. Regardless, the government's response failed to recognise the urgency. Its belated approval came six months later, by which time there was probably only a single individual remaining, and that individual eluded capture.

For the forest skink, the ongoing declines prompted some attempt in 2009 by the environment department to collect individuals for captive breeding, but the species could no longer be reliably located, and only three individuals (all females) could be captured.

Reservation, Threat Management, Provision of Resources, and Implementation of Conservation

The conservation of many threatened species is influenced by policies and practices that reduce the likelihood of the introduction of new threats or provide effective control of existing threats. Habitat loss is a major driver of extinctions worldwide (Ceballos et al. 2015). On Christmas Island, habitat loss due to mining was unregulated until at least the 1970s; some subsequent constraint was applied because of environmental impact procedures that included consideration of potential consequences to threatened species. The cumulative impacts of >100 years of habitat loss to mining would have reduced the population size and viability of the pipistrelle and skink. This may have contributed to their extinctions, but it is unlikely that it was a pivotal cause.

The establishment of conservation reserves provides a variably effective mechanism for control of some threats (Brooks et al. 2004). A substantial conservation reserve was established on Christmas Island prior to the decline of the pipistrelle and forest skink. That

reserve encompassed most of their distribution and served to provide some protection against habitat loss, but it proved entirely ineffective against the threats that caused their extinction. Those factors apparently operated with comparable magnitude in reserved and unreserved parts of the island.

In contrast, the melomys occurred on one island that had no reservation, but it is highly unlikely that any reserve would have altered the likelihood and course of its extinction.

Australia has a very poor biosecurity record; numerous regulated and unregulated introductions of plants, animals, and diseases have been highly detrimental to native species. This shortcoming persists, and its effect is particularly pronounced on Australia's islands (Woinarski et al. 2014a). For Christmas Island, there has been a long history of inadequate biosecurity policy and practice (Beeton et al. 2010); thus, many weed and pest species were introduced and subsequent control was inadequately funded, ineffective, or absent. These introductions, which reflected biosecurity failure, were almost certainly critical factors in the extinction of the pipistrelle and forest skink. There were similarly inadequate biosecurity provisions for Bramble Cay. However, by chance or due to Bramble Cay's very low level of visitation, no significant biosecurity threats to the melomys were introduced.

There is no evidence that global environmental change was a factor in the extinction of the pipistrelle or forest skink. In contrast, rising sea levels may have contributed to one or more episodes of inundation of all or parts of the low-lying Bramble Cay (highest point 3 m asl). Sea level rose by 0.6 cm/year in the Torres Strait region from 1993 to 2010 (Suppiah et al. 2010), and in north Australian waters extreme sea-level events (>2.5 m storm surges associated mostly with cyclone activity) have increased from an incidence of 1in 100 years

before 1950 to 1 in 40 years after 1950 (Church et al. 2006). Such storm surges and inundation events would have killed individual melomys and destroyed most of the vegetation on which it depended. This may be the first species to have become extinct due to rising sea levels associated with human-caused global climate change (Gynther et al. 2016; Watson 2016).

Australian legislation and policy provide no assurance of (adequate) funding with which to implement recovery plans or undertake other conservation actions. There has been no public reporting of the resources allocated to conservation management of these three species. It is likely there was no funding allocated to conservation management of the melomys over the course of its decline and extinction, other than for the compilation of a recovery plan. This lack of investment was not entirely due to disinterest. An application in 2013 for funding from the Australian government's major environmental grants programs ("Caring for Our Country"/"Biodiversity Fund") to conduct the first substantial research and conservation project for the melomys was rejected. Consequently, this study was not conducted (L. Leung, personal communication).

Likewise, the Australian government's primary environmental grant program (Caring for Our Country) rejected an application in 2008 for funding to undertake more substantial, focused research to identify the primary threat to the pipistrelle and evaluate options for its amelioration (L. Lumsden, personal communication). However, some such research was conducted by the government agency Parks Australia on the pipistrelle and, less so, on the forest skink. Much of this funding was serendipitously provided as a de facto offset associated with habitat loss for the construction of a refugee detention center on Christmas Island (James & Retallick 2007).

The rejection of specific funding applications for proposed studies pivotal to the conservation of the pipistrelle and melomys and the more general limited resources allocated for the conservation of these three species probably contributed substantially to these extinctions. This underfunding is characteristic of the severe shortfall in support in general by the Australian government relative to conservation need (Waldron et al. 2013); indeed, investments in and commitments to biodiversity conservation by Australian governments (Commonwealth and state) may be waning (Ritchie et al. 2013).

Almost ipso facto, extinction is a consequence and indicator of management failure. Due to its precarious distribution, the risk of extinction for the melomys has long been recognised (Limpus et al. 1983; Latch 2008), but awareness of such risk by the relevant managers prompted no heightened investment in research or conservation. For the melomys, we found no record of any activity devoted to its conservation. The recovery plan, whatever its shortcomings, was not implemented (Woinarski et al. 2016).

For Christmas Island environments generally, there was substantial management activity directed to some putative threats , principally environmental meltdown caused by the introduced yellow crazy ant (*Anoplolepis gracilipes*) (O'Dowd et al. 2003). However, it is doubtful that the management of crazy ants had any benefits for the pipistrelle and forest skink, given that the rate of decline for these two soon-extinct species was largely invariant over the period of such control (James & Retallick 2007) and that their decline probably occurred consistently in those parts of the island with and without crazy ants. For the pipistrelle, many research, monitoring, and management actions stipulated in the recovery plan were at least superficially implemented – although the extent and effectiveness of such

implementation were never publicly reported (James & Retallick 2007). However, the primary threats to the pipistrelle and forest skink were not identified and hence were never subject to targeted control. It is possible that the primary threats (most likely predation by the introduced giant centipede [*Scolopendra subspinipes*] and wolf snake [*Lycodon capucinus*] [Rumpff 1992]) would have been difficult to control across the entire island, but the identification of such causal factors could have allowed specific ameliorative actions at some key sites.

Research, Monitoring, and Public Reporting

Australia has no integrated monitoring for biodiversity generally, and few threatened species are monitored adequately (Lindenmayer & Gibbons 2012). For the melomys, there was occasional unsystematic sampling over the course of its decline, but results were not publicly reported, and the monitoring program (to the extent that there was any such program) had no threshold values that were set to trigger remedial intervention.

A substantial and sensitive monitoring program was established for the pipistrelle, based on an initial survey in 1994 (Lumsden & Cherry 1997), and monitoring effort and precision increased over the course of the species' decline (James & Retallick 2007). This monitoring program provided a remarkable record of the species' decline to extinction and a firm evidence base for warnings of looming extinction (Lumsden et al. 1999; James & Retallick 2007; Lunney et al. 2011). However, with the exception of some research and monitoring outcomes presented in the newsletter of the Australasian Bat Society, the results of this monitoring were documented only in internal reports to the environment department that were not publicly accessible. The monitoring program had no inbuilt triggers for remedial responses, although the environment department gave indications of increasing concern

(including the establishment of an expert reference group in 2009) as the monitoring results projected an increasingly short remaining time to extinction.

There was no monitoring program established specifically for the forest skink, but brief surveys aimed at establishing the status of Christmas Island reptiles generally were undertaken in 1998 (Cogger & Sadlier 1999) and occasionally from 2004 to 2008 (James 2004; Schulz & Barker 2008). As for the pipistrelle, there was no public reporting of monitoring results nor were trigger points established for remedial actions.

For the two extinct Christmas Island species, researchers were unable to identify the primary threatening factor or factors. This failing does not necessarily imply research incompetence because the resources allocated to researchers were very limited; there was a very complex medley of potential (and probably interacting) threats that may have long defied elucidation through research; and the rate of decline for these 2 species was so rapid that there was very limited time and scope (and numbers of remaining individuals) to undertake research that could have clearly identified the relative impacts of candidate threats.

Researchers produced no peer-reviewed articles in publicly accessible journals that focused on the ecology, conservation status, or management requirements for any of these three species over the period of their decline. One paper was published on the decline of Christmas Island reptiles in general (Smith et al. 2012), although this paper appeared after it was too late to rescue the forest skink. The Australian environment department included some relevant research results on a website that compiled information on all listed threatened species (the Species Profile and Threats Database: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl).

Advocacy

The 3 species we considered occurred in areas that were remote from major human population centres. Hence, they were largely unfamiliar to a potentially supportive public. In part due to the lack of publicly available information on their increasingly imperilled status, there was almost no public awareness or advocacy for the conservation of the forest skink or melomys. The public generally had no active involvement in research or management of these two species or oversight through recovery teams or other governance mechanism (Martin et al. 2012).

There was somewhat more public concern expressed for the fate of the pipistrelle. This may have arisen serendipitously because individuals from the Australasian Bat Society were involved in some of the research undertaken. The principal researcher who initially documented the pipistrelle's decline (Lindy Lumsden) subsequently championed the conservation of the species, particularly through the Australasian Bat Society, which advocated strongly for more action to prevent extinction.

Recommendations

From our review and interpretation of the shortcomings in policy, legal, management, research, and other factors that contributed to these extinctions, we devised recommendations that seek to reduce the likelihood of future extinction (Table 1). The factors associated with these recommendations contributed variably to these three extinctions (Table 2). Although these recommendations are informed particularly by these three cases and the Australian context generally they are likely to be applicable to efforts to prevent extinction in most parts of the world.

Discussion

These are sorry tales. All 3 extinctions were predictable and most likely could have been prevented. Our assessment indicates no single factor caused extinction for these species; rather, different mixes of factors contributed to each one. For example, for the 2 Christmas Island species, it was difficult to weight the relative contributions of decades of inadequate biosecurity that led to the introduction of many predators that caused apparently intractable and inexorable population declines against the failure of managers to take timely actions to establish captive-breeding programs. Both, and other, factors were implicated. In these cases, extinction resulted from a chain of factors that operated or did not operate. The redressing of any one of the critical factors may have prevented extinction. Although it is tempting to caricature these extinction events as monitoring to extinction (pipistrelle), a conservation bureaucratic process working more slowly than an extinction process (all three species), extinction by neglect (melomys), or extinction by departmental obstruction (forest skink), such simplification obscures the medley of factors involved and the diverse options that may have prevented these extinctions.

Our review suggests there is much scope for significantly improving legislation, policy, and resourcing. One of the most important of these improvements has been recently proffered in Australia and globally – to make the prevention of avoidable extinction a far more explicit commitment. Belatedly, in 2015 the Australian government released its first threatened species strategy that explicitly commits to attempting to prevent extinctions. In part, this advance mirrors the global process: the initial relatively weak Millennium Development goal 7B for biodiversity ("reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss" [http://www.un.org/millenniumgoals/environ.shtml]) was advanced by the far more explicit and resolute Aichi target 12 of the Convention on Biological Diversity ("By 2020 the extinction of known threatened species has been prevented and their conservation

status … has been improved and sustained." [https://www.cbd.int/sp/targets/]), which was itself augmented in 2015 by the United Nation's Sustainable Development goal 15.5 ("Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species" [https://sustainabledevelopment.un.org/?menu=1300]). While this commitment to attempting to prevent extinctions is a notable advance, the Australian policy settings still lack a clear chain of responsibility for such prevention.

One positive legacy of these extinction events is the lessons learned. The pipistrelle and forest skink extinctions have prompted the Australian environment department to undertake a (so far successful) captive-breeding program for 2 endemic Christmas Island lizard species (Andrew et al. 201x), both of which became extinct in the wild shortly after the forest skink (Smith et al. 2012).

A comprehensive reserve system is an important foundation for the conservation of biodiversity. The ranges and populations of pipistrelles and forest skinks were primarily in a large national park, but this provided inadequate protection from the processes that led to extinction. These cases add to many comparable recent examples elsewhere that demonstrate that the conservation value of reserves may be unrealised unless those reserves are adequately resourced and their informed management aims to deliver appropriate conservation goals (Woinarski et al. 2010; Pressey et al. 2015).

The cases presented here also exemplify another well-recognized global phenomenon– that the very distinctive biota present on many islands is particularly prone to extinctions, mostly due to the impacts of introduced species (Savidge 1987; Alcover et al. 1998; Blackburn et al.

2004). As evident in these cases, the control of some introduced species may be a formidable challenge and the consequences of some introductions may be the almost inexorable loss of island species. These cases provide another unfortunate demonstration of the urgent need for enhanced biosecurity for islands supporting distinctive biota (Rodda et al. 2002).

A disquieting element in our reviews is that the actions (or inactions) of single individuals in government environment departments may have contributed to the failure to prevent the extinction of two of these species (forest skink and melomys). This problem was also evident in the extinction of some Hawaiian bird species (Black et al. 2011). The fate of species should not hang so capriciously on the foibles of individuals, and environment and other involved departments need to find better and more robust modes of governance and accountability that are more alert to such far-reaching consequences of the attitudes of individuals who happen to hold particular positions at pivotal times in the fates of individual species.

In contrast, even though their efforts were unsuccessful, a small number of individual researchers and personnel in and outside the environment department advocated determinedly in an attempt to prevent the extinction of the pipistrelle and, to a small extent, the forest skink. There was no such champion for the melomys. The limited extent of public scrutiny, involvement, and advocacy in these cases was due mostly to the remoteness of the locations of these species; the near absence of publicly accessible information that could have led to some community concern; the environment department not establishing a recovery team for any of these species (such teams elsewhere include representation of the community and other stakeholders [Martin et al. 2012]); and the uncharismatic nature and lack of taxonomic distinctiveness of these species. Without public awareness of the plight of these species, they

were accorded low priority in resource allocation or other recovery processes, relative to more accessible, better known, and more charismatic species with substantial public support, and there was little external pressure for accountability by the responsible government department.

Given very limited budgets (Waldron et al. 2013), many government agencies and nongovernmental organizations have advocated and implemented triage approaches based on the concept that not all species are equally important to save and that priority should be allocated to the most evolutionarily distinctive species or those with important ecological roles or cultural significance (Vane-Wright et al. 1991; Walker 1992; Bottrill et al. 2008; Joseph et al. 2009). It is likely that the extinction of these three species may have been influenced by such prioritisation processes, given the limited resources allocated to their conservation, although no such prioritization has been agreed upon by the Australian people through legislation. Ostensibly inconsequential or otherwise low-priority species, such as those considered here, will increasingly be the casualties of inadequate conservation funding coupled with direction of that funding to high profile species. Triage may provide some useful context for conservation, but this approach should not come at the cost of relinquishing responsibility to prevent extinction of any threatened taxon (Jachowski & Kesler 2009; Parr et al. 2009; Cafaro & Primack 2014). The path out of this conservation dilemma is not through exclusion of taxa or submissive acceptance of the market but through expansion of the available resources to meet conservation needs.

Our recommendations (Table 1) are constructed to achieve a positive legacy from these three Australian extinctions. Recent global commitments (in the Aichi targets and sustainable

development goals) to prevent further extinctions are unlikely to be met unless a comparable framework is applied globally.

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Table 1. Recommendations to prevent species' extinctions drawn from the review of 3 extinctions.

1. As a fundamental objective, environmental legislation and policy explicitly seeks to prevent extinction of any species.
2. Policy and legislation provide a clear chain of accountability (including explicit allocation of personnel with responsibilities) for the prevention of extinction.
3. Policy and legislation provide an explicit requirement for retrospective public inquiry following any extinction, equivalent to a coroner's inquest.
4. The process for listing species as threatened is timely and comprehensive.
5. The process for recovery planning for threatened species is timely and effective and is designed to be responsive to assessment of management efficacy, unforeseen events, or marked decline in population trends.
6. Reservation alone should not be assumed to be sufficient to maintain some species.
7. Biosecurity and related policy is adequate and effective, such that it can prevent the introduction of novel threats likely to cause significant biodiversity decline.
8. Sufficient financial and other resources are allocated to undertake actions necessary to prevent extinction and provide for recovery.
9. Governments commit to implementation of recovery plans, and the management of threats affecting threatened species is undertaken in a timely, competent, effective, and adaptive manner.
10. Robust monitoring programs that evaluate population trends and responses to management are implemented for threatened species and include public reporting and explicit triggers for remedial management intervention.
11. Research provides timely identification of the risk of extinction.
12. Research on threatened species provides timely and clear identification of ecological factors responsible for decline and delineates the most appropriate and effective management response to these threats.
13. Research results relevant to conservation management are effectively disseminated.
14. The public is fully informed and involved in governance of the recovery process.
15. An informed public (including nongovernmental conservation groups) advocates for and is involved in the prevention of extinction and recovery.

Table 2. Summary of the extent to which proposed recommendations to prevent extinction were met and the consequences of shortcomings in the 3 case studies of extinction.

Standard	Pipistrelle	Melomys	Forest skink
Legal and policy commitment to prevent extinctions	not met; likely contributing factor	not met; likely a major contributing factor	not met; likely contributing factor
Explicit accountability	not met; likely contributing factor	not met; likely contributing factor	not met; likely contributing factor
Inquest following any extinction	not met, but not a contributing factor	not met, but not a contributing factor	not met, but not a contributing factor
Timely process for listing species as threatened	met	met	not met; likely contributing factor
Development of effective recovery plan	not met; inadequacies a major contributing factor	not met; inadequacies a major contributing factor	not met, absence of recovery plan a contributing factor
Reservation and habitat protection	met	not met, but not a contributing factor	met
Adequate controls to prevent introduction of new threats	not met; likely major contributing factor	not met, but not a contributing factor	not met; likely major contributing factor
Adequate resourcing	not met; likely major contributing factor	not met; likely major contributing factor	not met; likely major contributing factor
Effective control of threats	not met; likely major contributing factor	not met, but not a contributing factor	not met; likely major contributing factor
Effective monitoring, with remedial trigger points	not fully met; likely contributing factor	not met; likely contributing factor	not met; likely contributing factor
Timely prediction of extinction risk	met	met	not met; likely contributing factor
Effective identification of primary threats (and of appropriate management response)	not met; likely major contributing factor	not met; likely contributing factor	not met; likely major contributing factor
Effective dissemination of relevant conservation information	not fully met; likely contributing factor	not met; likely contributing factor	not met; likely contributing factor
Public involvement in governance	not met; likely major contributing factor	not met; likely major contributing factor	not met; likely major contributing factor
Community advocacy and involvement	not fully met; likely contributing factor	not met; likely major contributing factor	not met; likely major contributing factor