Conservation Biology

Contributed Paper

The Capacity of Australia's Protected-Area System to Represent Threatened Species

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Abstract: *The acquisition or designation of new protected areas is usually based on criteria for representation of different ecosystems or land-cover classes, and it is unclear how well-threatened species are conserved within protected-area networks. Here, we assessed how Australia's terrestrial protected-area system (89 million ha, 11.6% of the continent) overlaps with the geographic distributions of threatened species and compared this overlap against a model that randomly placed protected areas across the continent and a spatially efficient model that placed protected areas across the continent to maximize threatened species' representation within the protected-area estate. We defined the minimum area needed to conserve each species on the basis of the species' range size. We found that although the current configuration of protected areas met targets for representation of a given percentage of species' ranges better than a random selection of areas, 166 (12.6%) threatened species occurred entirely outside protected areas and target levels of protection were met for only 259 (19.6%) species. Critically endangered species were among those with the least protection; 12 (21.1%) species occurred entirely outside protected areas. Reptiles and plants were the most poorly represented taxonomic groups, and amphibians the best represented. Spatial prioritization analyses revealed that an efficient protected-area system of the same size as the current protected-area system (11.6% of the area of Australia) could meet representation targets for 1272 (93.3%) threatened species. Moreover, the results of these prioritization analyses showed that by protecting 17.8% of Australia, all threatened species could reach target levels of representation, assuming all current protected areas are retained. Although this amount of area theoretically could be protected, existing land uses and the finite resources available for conservation mean land acquisition may not be possible or even effective for the recovery of threatened species. The optimal use of resources must balance acquisition of new protected areas, where processes that threaten native species are mitigated by the change in ownership or on-ground management jurisdiction, and management of threatened species inside and outside the existing protected-area system.*

Keywords: adequacy, Australia, protected areas, range size, representation, spatial prioritization, threatened species

La Capacidad del Sistema de Áreas Protegidas de Australia para Representar Especies Amenazadas

Resumen: *La adquisición o designación de áreas protegidas nueves generalmente se basa en criterios para la representación de diferentes ecosistemas o clases de cobertura de suelo, y no es claro que tan bien son conservadas las especies amenazadas en el interior de las redes de áreas protegidas. Aquí evaluamos como se traslapa el sistema de áreas protegidas terrestres de Australia (89 millones ha, 11.6% del continente) con*

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Paper submitted February 16, 2010; revised manuscript accepted June 11, 2010.

DOI: 10.1111/j.1523-1739.2010.01587.x

las distribuciones geográficas de especies amenazadas y comparamos ese traslape con un modelo que ubicó áreas protegidas aleatoriamente en el continente y con un modelo espacialmente eficiente que ubicó áreas protegidas en el continente para maximizar la representación de especies amenazadas dentro de las áreas protegidas. Definimos el área mínima necesaria para conservar cada especie con base en el tamaño del área de distribución de la especie. Encontramos que, aunque la configuración actual de las áreas protegidas cumplía mejor con los objetivos de representación de un porcentaje determinado de rangos de distribución de especies que la selección aleatoria de áreas, 166 (12.6%) de las especies amenazadas ocurrieron completamente fuera de las áreas protegidas y los niveles de protección proyectados solo se cumplieron para 259 (19.6%) especies. Especies críticamente amenazadas se encontraron entre las especies con la menor protección; 12 (21.1%) especies ocurrieron completamente fuera de áreas protegidas. Los reptiles y plantas fueron los grupos taxonómicos más pobremente representados, y los anfibios los mejor representados. Los análisis de priorización espacial revelaron que un sistema eficiente de áreas protegidas del mismo tamaños que el sistema actual de áreas protegidas (11.6% del área de Australia) podría alcanzar objetivos de representación para 1272 (93.3%) de especies amenazadas. Más aun, los resultados de esta priorización mostraron que mediante la protección de 17.8% de Australia, todas las especies amenazadas podrían alcanzar niveles deseables de representación, asumiendo que todas las áreas protegidas son retenidas. Aunque esta cantidad de área pudiera ser protegida teóricamente, los usos de suelo actuales y los limitados recursos disponibles para la conservación significan que la adquisición de tierras no será posible ni efectiva para la recuperación de especies amenazadas. El uso óptimo de recursos debe balancear la adquisición de áreas protegidas nuevas, los procesos que amenazan a las especies nativas son mitigados por el cambio en la propiedad o en la jurisdicción de manejo, y el manejo de especies amenazadas dentro y fuera del sistema de áreas protegidas existente.

Palabras Clave: adecuación, Australia, áreas protegidas, especies amenazadas, priorización espacial, representación, tamaño de área de distribución

Introduction

Protected areas form a major component of global efforts to conserve biological diversity, particularly for conserving populations of threatened species (Brooks et al. 2004; Possingham et al. 2006; Gaston et al. 2008). The number and size of protected areas has grown markedly in the past 20 years (Jenkins & Joppa 2009). Yet, surprisingly little is known about the extent to which protected-area systems fulfill one of their major goals—the conservation of threatened species (Gaston et al. 2008; Brooks et al. 2009). Spatial overlap between protected areas and the geographic distributions of threatened species at the global level has been assessed (e.g., Brooks et al. 2004; Rodrigues et al. 2004*a*, 2004*b*), but global assessments are too coarse to inform national policy (Smith et al. 2009). Few studies have examined how well protected-area networks protect threatened species at a national level, those that have focused mainly on small island systems or a subset of taxa (Gaston et al. 2008; Wiersma & Nudds 2009, but see Tognelli et al. 2008). To our knowledge, no one has assessed how well extant protected-area networks represent the ranges of threatened species compared with either a null model that positions protected areas at random across a continent or with an efficient model that places protected areas across a continent to maximize the achievement of predefined species' representation targets at the least cost.

We assessed the extent to which Australia's protected-area system encompasses the spatial ranges of the country's most threatened species. The continent of Australia is a good case study for a number of reasons. First, Australia's biological diversity (in terms of both its total number of species and the number of species endemic to the continent) is globally important, but much of its landmass has been transformed by human activities (Lindenmayer 2007). Most obvious is the extensive conversion of natural vegetation in southern Australia to agriculture, forestry, and urban area (Lindenmayer et al. 2008). Even where native vegetation remains, the functioning of ecosystems has been altered by invasive nonnative species and land management (Woinarksi et al. 2007; Watson et al. 2008*a*, 2008*b*). Close to half of all known extinctions of mammals in the last 200 years have occurred in Australia (Short & Smith 1994; Johnson 2006), and three bird species, four frog species, and 61 species of flowering plant have become extinct since European settlement in 1788 (Australia Bureau of Statistics 2006). Australia's biodiversity is also characterized by a high number of native species with declining ranges and abundance. Nearly 13% of all Australia's known terrestrial vertebrate species are listed under Australia's Environment Protection and Biodiversity Conservation Act (EPBC Act) as critically endangered, endangered, or vulnerable (Department of the Environment, Water, Heritage and the Arts 2009*a*, 2009*b*; Kingsford et al. 2009).

Second, the Australian government has actively sought to increase the size of the terrestrial protected-area network (known as the National Reserve System [NRS]) to reverse these trends of species decline and extinction

(Commonwealth of Australia 2009*a*, 2009*b*). Since 1995 the Australian government has applied systematic planning criteria to guide expansion of the NRS. Eighty-five biogeographical regions (hereafter bioregions) have been defined on the basis of similarities in geology, landform, climate, and ecology. The planning criteria prioritize bioregions with low levels of representation in the current NRS and in which levels of threat to native species are high, as gauged by past land-use change, known extinctions, and abundance of invasive non-native plants (Commonwealth of Australia 2005). Since implementation of this framework in 2000, the NRS increased in size from 65 to 89 million ha (Watson et al. 2009). The NRS is now a network of approximately 9000 protected areas, which includes national parks, nature reserves, private conservation reserves, indigenous protected areas, and other reserve types that cover 11.6% of the continent (Sattler & Taylor 2008).

Despite the substantial growth of Australia's protected-area system, little is known of the extent to which this network fulfills its major goals of protecting highly threatened species (Commonwealth of Australia 2009*a*, 2009*b*). We assessed how the percentage of species' ranges included within the NRS varies among taxonomic groups and among species with different geographic range sizes. We then compared Australia's NRS with a null model and an efficient model based on targets defined by threatened species' range size and determined how much more area would be required to adequately protect all threatened species.

Methods

At the time of this study, 1700 species had been listed under the EPBC Act, 110 as extinct and 1590 as critically endangered, endangered, or vulnerable (Commonwealth of Australia 2009*b*). The definitions of these categories as they are applied in Australia differ slightly from those of the International Union for Conservation of Nature (IUCN). Hereafter, we refer to all extant species listed by the EPBC Act as threatened species. Current ranges of extant terrestrial and freshwater threatened species have been mapped and the maps are available from the Species of National Environmental Significance database. Table 1 provides a breakdown of these species by major taxonomic group (Commonwealth of Australia 2008). These maps were developed in a two-step process. First, through the use of a national database of observational records, each species' "extent of occurrence" was defined (sensu Gaston & Fuller 2009). Second, with species-specific habitat characteristics (e.g., vegetation, soil, geology, elevation, and slope) from the literature, these maps were refined to reflect area of occupancy (Jetz et al. 2008). We excluded 270 species that inhabit marine or freshwater environments and species for which range estimates are uncertain. The final database contained the geographic ranges of 1320 threatened species.

Despite a large literature, there is much debate about the levels of protection required to ensure the long-term persistence of threatened species (Svancara et al. 2005; Pressey et al. 2007; Carwardine et al. 2009). For

Table 1. Mean and median percentage of the geographic ranges of threatened species included in Australian protected areas (National Reserve System [NRS]), number of species with ranges not included in protected areas (gap species), and number of species for which the adequacy target* of geographic range included in protected areas (see text) was met by taxonomic group, threat category, and range–size class.

	Number of species	*Average range size (km^2)*	*Average range included in NRS (%)*	*Median range included in NRS (%)*	*Number species for which adequacy targets are met (%)*	*Number of gap species (%)*
Taxon						
all	1320	11,227	33.6	19.4	259 (19.6)	166 (12.6)
amphibians	24	11,089	46.4	33.3	12 (50)	0
birds	55	104,025	26.7	17.8	27 (49.1)	4 (7.3)
nammals	55	78,954	44.9	36.6	37 (67.7)	4 (7.3)
reptiles	23	35,918	29.3	13.3	6 (26.1)	4 (17.4)
plants	1163	3,150	33.2	18.7	177 (15.2)	154 (13.3)
Threat category						
critically endangered	57	823	41.5	32.5	13 (22.8)	12 (21.1)
endangered	540	6,474	31.1	15.0	85 (15.7)	75 (13.9)
vulnerable	723	15,598	35.0	22.5	161 (22.2)	79 (10.9)
Range size (km^2)						
<10	163	4	47.4	44.8	36 (22.1)	49 (30.1)
10–100	355	46	38.9	24.7	42 (11.8)	65 (18.3)
100–1,000	397	367	33.8	24.1	18 (4.5)	41 (10.3)
1,000–10,000	257	3,439	27.5	17.6	77 (29.9)	11 (4.2)
>10,000	148	93,061	15.60	11.20	86 (58.1)	0

*For species with a geographic range size of <10,000 km^2, the adequacy target is either 1,000 km^2 or 100% coverage of the range of the species, whichever value is smaller. For species with a geographic range size of >10,000km^2, the adequacy target is set at 10% coverage.

conservation plans that are to be implemented over large areas and that account for the needs of a large suite of species, the most widely applied method is to develop targets for representation of species' ranges that change as a function of geographic range size (Rodrigues et al. 2004*a*, 2004*b*; Carwardine et al. 2008). Building on methods developed by Rodrigues et al. (2004*b*) and Kark et al. (2009) for species with a geographic range of $<10{,}000$ km^2, we set a target for inclusion within protected areas of either 1000 km^2 or 100% of the range of the species, whichever value was smaller. For all species with a geographic range of $>10{,}000$ km^2, the target was at least 10% of the range included in protected areas. We chose a target of 10% because even for species with the most extensive ranges, it is reasonable to expect that 10% of their ranges could be captured in a continent-wide protected-area system. We used current geographic range maps in all analyses because we were interested in the extent to which the protected-area network captured the current ranges of highly threatened species.

We first determined the degree of coverage by the current NRS of the spatial extents of threatened species across Australia. We intersected species distribution maps with the most recent spatial data available for the Australian NRS (Department of the Environment, Water, Heritage and the Arts 2009; these data include IUCN management categories I–VI). We calculated the number of gap species (species occurring entirely outside protected areas), number of adequately protected species (species protected at our target levels of inclusion in protected areas), and overall percentage of each species' range protected by the current protected-area system. We also undertook a sensitivity analysis by changing the lower bounds of the target (i.e., the target for species with wide ranges [10,000 km^2]) to examine whether setting targets higher or lower would substantially affect the overall results.

To compare the current reserve system with random and optimal solutions, we created planning units within 100-km^2 grids intersected with protected areas and the 85 bioregions such that each planning unit belonged to a single bioregion and protected area. This generated 114,954 unevenly sized planning units with an average size of 66.8 km^2 and maximum (and mode) size of 100 km^2, which is similar to the average size (99.8 km^2) of the current protected-area system. From this we generated 60 randomly selected reserve systems that covered 11.6% of the country, which provided a benchmark (null model) against which to assess the current protected-area system. We calculated the percentage of each species' range protected by each randomly selected reserve system and from this percentage determined the number of gap species and number of adequately protected species on the basis of the range-based targets outlined above.

We conducted spatial prioritization analyses to explore theoretical solutions for protecting a greater number of the 1320 threatened species we considered in this analyses. We used the software Marxan (Ball et al. 2009), which has been used to identify areas for conservation in Australia and throughout the world (e.g., Fernandes et al. 2005; Carwardine et al. 2008; Smith et al. 2008). Marxan uses a simulated annealing algorithm to select multiple alternative sets of areas that meet a priori species or ecosystem targets while minimizing costs (Ball et al. 2009). For these sets of analyses, we assumed all species were of equal importance and ignored ownership, jurisdictional boundaries, and the cost of land. Using the planning units described above, we determined the most efficient use of 11.6% of Australia's land area in capturing threatened species' ranges. We first allowed all planning units to be available for selection to meet targets (including the area within current protected areas), but constrained the total area to 11.6% of Australia's land surface. Next, we determined the amount of land required to meet the adequacy targets on the basis of range size (i.e., for species with a geographic range of $<10{,}000$ km^2, the adequacy target was either 1000 km^2 or 100% and for all species with a geographic range of $>10{,}000$ km^2, the adequacy target was 10%) while allowing area within current protected areas to be either included or excluded, depending on each planning unit's contribution to the species targets. We then repeated the analysis but ensured that all current protected areas were forced to be included in the final system selected. We calculated the number of gap species and adequately protected species and the average coverage of species ranges by protected areas in the most efficient solutions generated by Marxan.

Results

Representation of Threatened Species in Current System

Of the 1320 threatened species we included in our analysis, 166 (12.6%) did not occur in any protected area (Table 1). These gap species occurred throughout Australia and were not confined to a few regions or vegetation types (Fig. 1). All taxonomic groups except amphibians contained gap species, although mean and median percentages of species' ranges in protected areas varied widely among taxonomic groups (Table 1). Mean percentage of threatened species' ranges included in protected areas was 33%, and the median was 19.4% (Table 1). The disparities between median and mean levels of protection are due to a relatively large proportion of threatened species having small portions of their range captured within the NRS. The greatest percentage of species with no protection were in the critically endangered category (n = 12, 21.1%); proportionally fewer endangered (n = 75, 13.9%) and

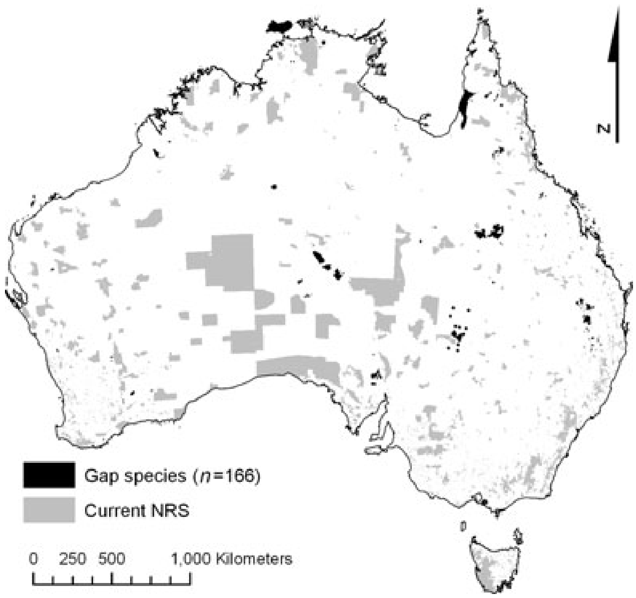

Figure 1. Geographic distributions of the 166 species with ranges that are not represented in Australia's protected-area system (i.e., gap species) overlaid on the National Reserve System (NRS) in 2006 (DEHWA 2009).

vulnerable species (n = 79, 10.9%) were unprotected (Table 1). Conversely, more of the geographic ranges of critically endangered species were included in protected areas (mean = 41.5%, median = 32.5%) than endangered (mean = 31.1%, median = 15.0%), and vulnerable (mean = 35.0%, median = 22.5%; Table 1) species. This is logical because critically endangered species tended to have smaller ranges that are likely to be either fully included or not included in protected areas rather than partially included. Amphibians (mean = 46.4%, median = 33.3%) and mammals (mean = 44.9%, median = 36.6%) had by far the highest levels of mean and median range inclusion in protected areas. Conversely, reptiles (mean = 29.3%, median = 13.3%) and plants (mean = 33.2%, median = 18.7%) had relatively little of their ranges within protected areas (Table 1); median coverage for reptiles only just exceeded the proportion of protected land across Australia.

The current system of protected areas achieved target levels of geographic range protection for 259 (19.6%) species (Table 1); levels of protection varied among taxonomic groups. Relatively high percentages of birds (n = 27, 49.1%), amphibians (n = 12, 50%), and mammals (n = 37, 67.7%) were protected at target levels relative to reptiles (n = 6, 26.1%) and plants (n = 177, 15.2%). When level of vulnerability was considered, the category of species with the highest percentage of species protected at target levels was critically endangered (n = 13, 22.8%), followed by endangered species (n = 85, 15.7%) and vulnerable species (n = 161, 22.2%) (Table 1). A sensitivity analyses around the lower target of 10% of geographic range included in protected areas showed that the number of species represented decreased as the target increased. For example, if the minimum target was set to 20% of a species range, the current protected-area system represented 207 species (15.7%), whereas if the minimum target was set to 30%, the current protected-area system represented 191 species (14.5%).

Relation of Species' Range Size with Protected-Area Coverage

The proportion of species' ranges included in protected areas declined as range size of species increased (Table 1). Large percentages of species with relatively small geographic ranges were either protected at target levels or were unprotected (Table 1). In general, as range size increased the number of gap species decreased, but so did the number of species that were adequately represented (Table 1). Eleven (4.2%) species with geographic ranges >1000 km^2 were not protected by the NRS (Table 1). Because the adequacy thresholds were proportionally low (10%) for species with ranges >10,000 km^2, a large percentage of adequately protected species were in this range–size category.

Comparison of Current Protected-Area System with Random and Efficient Models

The random model protected an average of 16.9% and median of 11.9% of threatened species' geographic ranges, which is substantially lower than coverage in the current protected-area network. The random model yielded an average of 292 (22.1%) gap species and 150 (11.4%) species protected at target levels, which indicates the current NRS is outperforming the null expectation of threatened species coverage (Fig. 2).

When we set the amount of Australia's land available for reservation at 11.6% (i.e., equal to the size of the current protected-area system), Marxan produced a reserve system that captured at least part of all 1320 threatened species' geographic ranges and an average of 99% of the representation target for each species covered within the NRS, which is more than double the average proportion of representation of the current NRS (44%, Fig. 2). Moreover, 1054 (79.8%) species' adequacy targets were met completely in the Marxan output, whereas the current NRS meets adequacy targets of only 259 (19.6%) species.

When we ignored the current reserve system's contribution to species conservation and assumed all land in Australia was available for inclusion in protected areas, approximately 11.9% of the land was needed to adequately protect all threatened species. This efficient solution included 16.7% of the current NRS. When we included the current reserve system in the analyses, we found that 6.2% more of the area of Australia was needed to capture the adequacy targets for all threatened species,

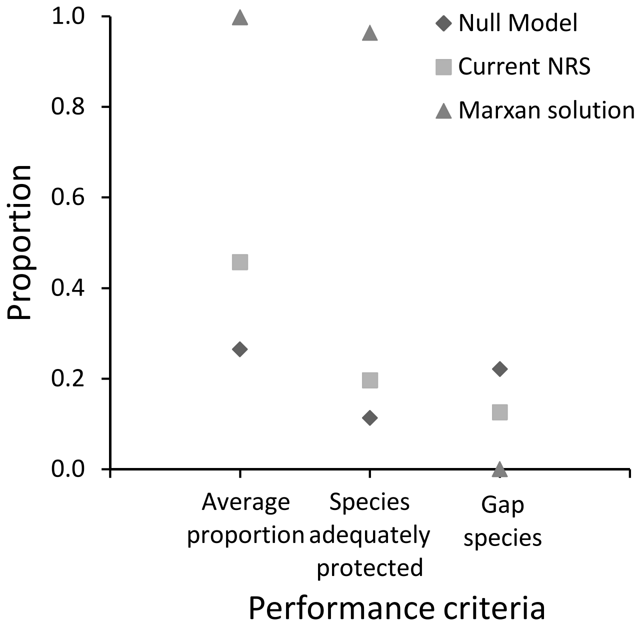

Figure 2. A comparison of the three criteria (overall average of how much the adequacy target, derived from a species' range size, was met for each species [average proportion]; proportion of species for which ranges fully met the range-based adequacy targets [adequately protected]; and proportion of gap species [species that occur entirely outside protected areas]) used to assess the coverage of species' geographic ranges in the Australian protected-area system relative to coverage under the current National Reserve Sysem (NRS), a null model that randomly placed protected areas across the continent, and a spatially efficient model produced with the spatial prioritization tool Marxan.

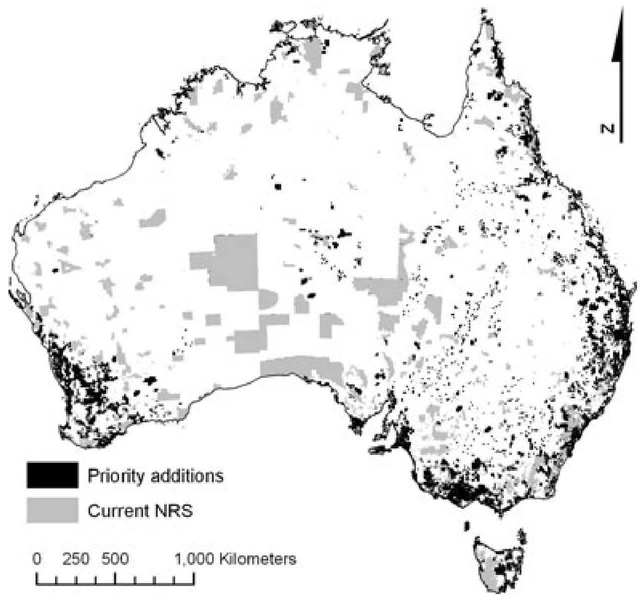

Figure 3. Areas that include the ranges of threatened species that do not meet the adequacy targets for representation in the current system. With Marxan this analysis starts with the existing reserve system and adds new sites that contribute most to meeting range representation targets.

resulting in a protected-area system that covers 17.8% of the Australian continent (Fig. 3).

Discussion

Australia's protected-area system still falls short of achieving one of its fundamental aims to adequately protect threatened species (Commonwealth of Australia 2009*a*, 2009*b*). Although the average percentage of species' ranges included in the protected-area system appeared relatively high (33.6%; Table 1), only a small number of species, usually those with small geographic ranges, were represented well by the NRS. Many species had limited or no representation (Table 1). For example, 166 (12.6%) threatened species were not present in the protected-area network, and 1061 (80.4%) species were not adequately protected when conservative targets based on range size were set. It is of particular concern that those species listed as critically endangered are among those most underrepresented by the protected-area network; one-fifth (12 species) of critically endangered species do not occur at all in protected areas and 154 species listed as vulnerable and endangered are completely unprotected (Table 1).

Commission errors, in which a species is considered present in a protected area but in reality is absent, are likely to be more common than omission errors in the Species of National Environmental Significance database because many factors other than major land-cover associations limit the distributions of species within their extent of occurrence (Rondinini et al. 2006; Gaston & Fuller 2009). This is likely to have two effects on our results. First, we likely underestimated the number of species that are inadequately protected by Australia's protected-area system. Targeted intensive fieldwork would be required to estimate the magnitude of this effect because it would be necessary to document false–positive records (i.e., commission errors) in specific protected areas. Second, we likely underestimated the amount of additional land needed to improve representation of gap species by the protected-area system. This may have occurred because coarse area-of-occupancy maps overestimate the extent to which species' ranges overlap and thus the ability of any given protected area to simultaneously represent multiple species (Rondinini et al. 2005).

The NRS protected more species than the random solution; there were fewer gap species and adequacy targets were met for more species (Fig. 2). The fact that the current NRS performed better at representing the ranges of threatened species relative to the random system suggests either that some protected areas are being systematically selected because they contain threatened species or that threatened species have been extirpated from surrounding unprotected landscapes and now persist largely or only in protected areas.

There was considerable taxonomic variation in representation; plants and reptiles were represented poorly within the NRS and amphibians and mammals were represented well. The percentage of mammals ($n = 4$, 7.3%), birds ($n = 4$, 7.3%), and amphibians ($n = 0$) classified as gap species was much lower than Rodrigues et al.'s (2004*b*) global analyses (mammals = 14%, birds = 19.8%, and amphibians = 26.6%). This suggests that the Australian protected-area system better represents threatened species than the global average, although it is also possible that the range sizes of Australian taxa differ from the global average, which affects the ability of a reserve system to capture species' distributions.

Consistent with Gaston et al.'s (2008) results, the percentage of the geographic ranges of narrowly distributed species included within protected areas tended to be either high or low (Table 1). This pattern can occur for two reasons. At one extreme, protected areas could comprise refugia for species with ranges that have contracted due to habitat modification; thus, one would expect the distributions of many range-contracted species to be mainly or entirely confined to protected areas. At the other extreme is the simple statistical explanation: narrowly distributed species are likely to be either fully represented in reserves or excluded. In Australia a relatively high proportion of threatened birds, reptiles, and to a lesser extent mammals have ranges >10,000 km^2, whereas most plants and amphibians have ranges <1000 km^2 (Table 1). Therefore, the taxonomic groups with the smallest ranges (amphibians and plants) had relatively high representation in protected areas and few amphibians and many plants were categorized as gap species. In some instances endangered amphibians have been targeted specifically for protection at the time of their listing under the EPBC Act (Lemckert et al. 2009).

We measured the amount of geographical overlap between protected areas and threatened species' ranges, not the effectiveness of protected areas. The effectiveness of any protected area depends on local circumstances and the amount of investment in management (Brandon et al. 1998). Forty percent of the area of the NRS consists of multiple-use protected areas (IUCN management categories V and VI). Whereas wholesale destruction of vegetation is not occurring in any Australian protected area, many activities such as grazing of domestic animals and mining are permitted in IUCN V and VI reserves (Watson et al. 2008*a*, 2008*b*). Such activities threaten a large proportion of Australia's native species (Mackey et al. 2008). We also did not assess the effectiveness of the spatial configuration or size of protected areas. Many of Australia's protected areas may be too small or isolated to effectively conserve a population of a threatened species over the long term (Bruner et al. 2001; Watson et al. 2001).

We have shown that theoretically it would have been possible to meet minimal adequacy targets for representation of all threatened species' ranges within a protected-area network that is only slightly larger than the current NRS (11.9% compared with 11.6%) had that network been designed to meet threatened species adequacy targets from the outset. Nevertheless, this scenario is clearly not possible because it would mean degazetting the current protected-area network and starting over. We have shown that if we were to add to the existing protected-area system in a way that attempted to most efficiently cover ranges of threatened species to meet conservative adequacy targets based on range size, the area of Australia required for protection would need to be increased to 17.8% (Figs. 2 & 3). These analyses, however, did not account for tenure or the availability of sites for acquisition. It is likely that the most efficient solutions will not be possible to attain and an even greater overall area will be required.

Inclusion of a species' range in a protected area may not be the only, or even the most effective, means of maximizing the probability of persistence of many threatened species (e.g., Araujo et al. 2007; McAlpine et al. 2007; Joseph et al. 2009). For example, locally endemic species that are listed on the EPBC Act often occur in small, commercially unproductive areas that may not be threatened and thus may be of lower priority for protection. Simple management actions may effectively conserve other threatened species across a large portion of their geographic range at a fraction the cost of land acquisition. For example, a major threat to the Kangaroo Island population of the threatened Glossy Black-Cockatoo (*Calyptorhynchus lathami*), egg predation by brush-tailed possums (*Trichosurus vulpecula*), was mitigated by the extremely cost-effective placement of metal collars around trees in which the birds nest (Garnett et al. 1999). Moreover, acquisition of a protected area alone may not abate threats to species' persistence (Brooks et al. 2009). The major threat to artesian mound springs in arid lands (which contain high concentrations of endemic, threatened species) is overexploitation of groundwater. This threat can only be addressed through water conservation efforts of landholders throughout the area over the aquifer (Ponder & Walker 2003). The expansion of Australia's protected-area system to efficiently and adequately represent species' distributions will remain important for the persistence of native species in Australia. Nevertheless, strategic planning for recovery of individual species that involves conservation actions inside and outside protected areas will be necessary where land protection alone will not ensure species recovery or acquisition is not possible.

Acknowledgments

We thank A. Watson, J. Walsh, B. Mackey, L. Barr and P. Latch for comment and discussion. We also thank M. McCarthy, A. Rodrígues, E. Fleishman, E. Main, and two anonymous referees for suggestions that greatly improved this manuscript. This project was financially supported by the Commonwealth Environmental Research Facility program, the Australian Research Council and WWF-Australia.

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