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# Progress in improving the protection of species and habitats in Australia

Lissa M. Barr [a], James E.M. Watson [b,c], Hugh P. Possingham [a,d], Takuya Iwamura [e], Richard A. Fuller [a,*]

[a] Centre for Biodiversity and Conservation Science, School of Biological Sciences, University of Queensland, Brisbane, Qld 4072, Australia
[b] Centre for Biodiversity and Conservation Science, School of Geography, Planning and Environmental Management, University of Queensland, Brisbane, Qld 4072, Australia
[c] Global Conservation Program, Wildlife Conservation Society, New York, USA
[d] Imperial College London, Department of Life Sciences, Silwood Park, Ascot, SL5 7PY, Berkshire, England, UK
[e] Department of Zoology, Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel

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ABSTRACT

Historically, protected areas were often designated using criteria other than biodiversity conservation as the primary objective. With the emergence of the science of systematic conservation planning, the designation of new protected areas is increasingly made with explicit conservation objectives in mind. However, assessments of the performance of protected area systems typically include all protected areas, regardless of when they were designated, potentially obscuring recent improvements in conservation planning decisions. Thus, it is often unclear to what extent systematic conservation planning principles have influenced the placement of new protected areas. Here, we compare recently designated protected areas in Australia with the protected area system that existed prior to the introduction of systematic conservation planning guidelines in 2000. We ask whether there is a difference between past and recent protection in terms of (i) the size and spatial distribution of protected areas, (ii) the characteristics of broad regions in which protection is concentrated, and (iii) the extent to which protected areas represent ecosystems and threatened species in comparison with selecting protected areas at random. We find that the protected area system was historically biased toward areas with steep slopes and low human populations. In contrast, recent protection is more likely to be allocated to regions with high human population and high numbers of threatened species; we show that this effect is not simply a result of biases in the places now available for conservation. Despite this successful realignment of practice, we find that the increase in protected area coverage in poorly protected regions has occurred more slowly than expected if protected area selections were fully guided by systematic conservation planning principles. Our results demonstrate rapid progress in improving Australia's protected area system in the last decade, and highlight the importance of separating recent from historical additions to the protected area system when measuring the performance of conservation decision-making.



## 1. Introduction

Protected areas are one of the most important tools for mitigating the decline of biodiversity (Bruner et al., 2001; Mulongoy and Chape, 2004; Watson et al., 2014). However, the placement of many protected areas has historically been biased toward areas not required for anthropogenic land uses such as logging, agriculture and human infrastructure (Pressey, 1994; Sellars, 1997), resulting in underprotection for many ecosystems (Fuller et al., 2010; Hoekstra et al., 2005; Pressey et al., 2002) and species (Brooks et al., 2004; Rodrigues et al., 2004).

Increasing the representation of all under-protected species and habitats is an important objective in protected area designation (Moilanen et al., 2009; Possingham et al., 2006; Watson et al., 2011). This is illustrated by its incorporation into many international strategies for reducing biodiversity loss (Mulongoy and Chape, 2004; Secretariat of the Convention on Biological Diversity, 2006), and its enshrinement in law in some countries such as Australia (Commonwealth of Australia, 1992). Systematic conservation planning is formulated to assist decision making for protecting biodiversity based on quantitative data such as distribution of species, conservation costs and landscape characteristics (Pressey and Bottrill, 2008). Consequently, one might expect recent additions to the protected area system to be less biased with respect to human land use requirements than protected areas designated before biodiversity protection was ensconced in policy. Despite this, previous evaluations of the performance of protected area systems and analyses of the biases inherent in their location tended not to distinguish historical designations from recent additions (*e.g.* Brooks et al., 2004; Coad et al., 2008; Jenkins and Joppa, 2009). Therefore it is unclear what progress has been made in translating the principles of systematic conservation planning into practice because any evaluation of protected area coverage is overwhelmingly influenced by historical decisions.

Australia is an ideal place to examine the impact of systematic conservation planning in practice. Early protected area designations in

* Corresponding author.
*E-mail address:* r.fuller@uq.edu.au (R.A. Fuller).

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Australia were concentrated in areas of high esthetic value or low primary resource value (Mendel and Kirkpatrick, 2002). For example, protected area designation in 1950s and 1960s New South Wales was only given strong consideration if no other form of land use had been identified for an area (Pressey and Tully, 1994). Despite the protection of some globally important sites, such as the Great Barrier Reef and Kakadu National Park by the 1980s, the reserve system nationally was not protecting a representative sample of Australia's biodiversity (Pressey and Taffs, 2001; Watson et al., 2010). In response to this, in 2000 the Australian Government adopted a series of systematic conservation planning principles to guide further expansion of its National Reserve System (NRS). The key changes were to require that potential new protected areas are evaluated to assess the extent to which they would (i) increase comprehensiveness at a continental scale, (ii) add to the reservation of the full range of ecosystems, (iii) enable better representation of ecosystems across their geographic or environmental range, and (iv) increase the security of one or more ecosystems and associated species (Commonwealth of Australia, 1999). Over time the objectives of the NRS evolved to prioritise increasing protection in bioregions (large geographically distinct areas of land with common ecological characteristics) that have less than 10% protection (Commonwealth of Australia, 2009a; Department of Environment and Heritage, 2005) and specifically to protect threatened species (Department of Environment Water Heritage and the Arts, 2009). As such, we might expect the locations of recently designated protected areas to reflect these objectives. Here, we test whether this transfer of science into policy has delivered an improved terrestrial protected area system in Australia.

Since the current process for admitting new sites to Australia's NRS explicitly seeks to achieve ecosystem and threatened species representation, we reason that variables influencing the selection of new protected areas will differ from those operating before the guidelines were introduced. For example, protected areas designated since 2000 (when the NRS guidelines were introduced) might favor bioregions with little protection and areas with high numbers of threatened species, because these are explicit objectives of the new planning process. On the other hand, bioregions in which historical protection is concentrated (before 2000) might show traditional historic biases such as high elevations and steep slopes (Pressey et al., 2000; Scott et al., 2001; Joppa and Pfaff, 2009), be cheaper and less populated (Pressey, 1994), and less affected by clearing (Hoekstra et al., 2005; Pressey and Taffs, 2001).

Here, we compare recently designated protected areas in Australia with the protected area system existing prior to the introduction of systematic conservation planning principles into national legislation. We ask whether there is a difference between past and current protection in terms of (i) the size and spatial distribution of protected areas, (ii) the characteristics of bioregions in which protection is concentrated, and (iii) the extent to which protected areas represent ecosystems and threatened species in comparison with selecting reserves at random.

## 2. Methods

### 2.1. Protected area data

All officially designated protected areas are considered part of the National Reserve System (Department of Environment and Heritage, 2005). Priority areas for new protected areas are identified by the Australian government, which follow the systematic conservation principles outlined in the National Reserve System guidelines (Commonwealth of Australia, 1999). The acquisition of protected areas within these priority areas is implemented by the six states and two territories of Australia.

To compare the growth in protected areas under systematic conservation planning guidelines we compared the protected area system as it stood in 2000 with the new additions between 2000 and 2008. These years were chosen because the National Reserve System guidelines were introduced in 2000, and the following decade was a period of rapid expansion of the protected area system. Both protected area systems were obtained from the Collaborative Australia Protected Area Database, in which the source resolution is 1:250,000 and the minimum mapped area is 6.25 ha (CAPAD, 2000, 2008). From this we calculated the total area of the national protected area system in 2000 and 2008 as well as the total number and average size of protected areas in these years.

We compared protected area coverage across (i) major vegetation types and (ii) bioregions. We used the 23 major vegetation groups identified in the National Vegetation Information System (NVIS), based on structure, growth form and floristic composition of the dominant stratum of each vegetation type, with the scale of source maps typically 1:250,000, rasterized to a 100 m raster; (Department of Environment and Water Resources, 2007). For the regional analysis we used bioregions identified in Australia by the Interim Biogeographic Regionalisation (IBRA version 6.1). There are 85 bioregions in Australia, each comprising large contiguous areas of land that share pattern and composition with respect to climate, substrate, landform, vegetation and fauna. This is a vector dataset, derived from source maps typically produced at a scale of 1:250,000 (Commonwealth of Australia, 2009a). Major vegetation types and bioregions were overlaid with protected area coverage in 2000 and 2008 and the increase in protection was assessed for each in relation to their coverage in 2000.

### 2.2. Assessing bias in the location of protected areas

We used the 85 IBRA bioregions (version 6.1) as the spatial units for assessing environmental biases in past and recent protected area designations. Bioregions were chosen because in Australia these are used for decisions about protected area priorities and to report the status of ecosystems and their protection (Commonwealth of Australia, 2009a; Department of Environment Water Heritage and the Arts, 2009).

We chose five predictor variables within each bioregion to reflect some of the well-known historical biases in protected area placement: human population size, land cost, topographic heterogeneity (standard deviation of elevation), slope and proportion of habitat cleared. Human population size for each bioregion was obtained from the 2006 Australian census (Australian Bureau of Statistics, 2006). Land cost was the price per $km^2$ of acquiring all remnant vegetation in the bioregion. This was based on unimproved land value in 2006 sourced from state land valuation offices in Australia (see Carwardine et al., 2008 for further information). Topographic heterogeneity and slope data were obtained from the Global Map Elevation project (Australia), with source maps typically at a scale 1:250,000, rasterized to a 9 s (~250 m) raster (Geosciences Australia, 2006). All the regional data layers were combined into a single raster dataset by using mosaic function of ArcGIS 10, after appropriately eliminating the sea surface. Topographic heterogeneity was calculated by using the standard deviation of elevation among all pixels occurring within each bioregion. The degree of slope (0–90) was calculated using the function slope in ArcGIS 10. The average slope (0–90°) of a bioregion was used as the measure of slope steepness. The proportion of natural vegetation cleared since 1750 within each bioregion was obtained from the NVIS database (NVIS, 2001).

We derived three variables reflecting the stated objectives of the NRS within each bioregion, (i) initial protection, which was the percentage of each bioregion that was protected in 2000, (ii) whether the 10% protection target was achieved, which was whether 10% or more of the bioregion's area was protected in 2000, and (iii) threatened species richness, which was how many threatened species had a distribution that overlapped each bioregion. Maps of the geographic distributions of threatened species listed under the Environmental Protection and Biodiversity Conservation Act were obtained from the Species of National Environmental Significance database in polygon format (Commonwealth of Australia, 2008). A wide range of methods including direct plotting of records, habitat-based surrogates, digitising existing