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LETTERS

Replacing underperforming protected areas achieves better conservation outcomes

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Protected areas vary enormously in their contribution to conserving biodiversity, and the inefficiency of protected area systems is widely acknowledged[1–3]. However, conservation plans focus overwhelmingly on adding new sites to current protected area estates[4]. Here we show that the conservation performance of a protected area system can be radically improved, without extra expenditure, by replacing a small number of protected areas with new ones that achieve more for conservation. Replacing the least cost-effective 1% of Australia's 6,990 strictly protected areas could increase the number of vegetation types that have 15% or more of their original extent protected from 18 to 54, of a maximum possible of 58. Moreover, it increases markedly the area that can be protected, with no increase in overall spending. This new paradigm for protected area system expansion could yield huge improvements to global conservation at a time when competition for land is increasingly intense.

Protected areas are one of the most important tools in modern conservation, with over 100,000 sites covering about 12% of the area of countries and their territorial waters worldwide[5]. Historically, the placement of protected areas has been driven more by a lack of potential for economic development in an area than its contribution to conservation goals[6]. Consequently, many species and habitats remain inadequately protected and vulnerable to threatening processes. For example, only 0.01% of the global extent of coral reefs occurs within effective protected areas[7], the distributions of 20% of the world's threatened bird species do not overlap at all with protected areas[1], and 83% of threatened plants in New Caledonia are found only outside protected areas[8].

Schemes for improving the performance of protected area systems typically begin by determining whether biodiversity features (for example, ecosystems, species) are adequately represented in the existing system, and then go on to identify further areas to fill the gaps[1,3,9–11]. This approach means that resources will continue to be expended on managing poor quality sites within the existing protected area system, and large amounts of financial capital will remain tied up. Clearly, achieving a given level of biodiversity protection by adding to an inefficient system is ultimately much more expensive than one efficiently planned from the outset by comparing the costs and benefits of candidate protected areas[12,13].

A more radical approach to expanding protected area systems would be to reverse the protection status of the least cost-effective sites and use the resulting capital to establish and manage new protected areas. Whether this is worth doing depends on the magnitude of the potential gains for conservation. Here we measure the improvement in protected area system performance that could be delivered by replacing a small number of sites that contribute the least for conservation given the capital they absorb. We illustrate this approach for Australia, a country that spans ecosystems from tropical lowland rainforest to subalpine meadows, arid scrub and desert. It has among the world's most systematically designed protected area systems[14], and therefore one would expect the benefits of protected area replacement to be small relative to many other regions around the world.

The protected area estate in Australia comprised 6,990 sites covering 629,352 km^2 (~8% of Australia's landmass) managed under the International Union for Conservation of Nature (IUCN) management categories I–IV in 2006[15]. The distributions of 60 vegetation types in 1750 (before widespread clearance by Europeans) and in 2000 are mapped by the National Vegetation Information System (Version 3.0; available at http://www.environment.gov.au). We used a conservation target of 15% of the pre-clearance extent of each vegetation type to measure the performance of the system, although this could be substituted by, or augmented with, any desired performance metric including those reflecting cultural values, human recreation or other needs.

We superimposed the 6,990 protected areas onto 62,630 subcatchments (mean area = 123 km^2) mapped across Australia[16], resulting in 64,991 distinct planning units for which we had cost and vegetation mapping information. We estimated the value of all land covered by native vegetation within each planning unit using data on average unimproved land values at the scale of local government areas. These values represented the purchase price or the funds realized when degazetting (removing protection and selling) the land occupied by all areas of native vegetation in each planning unit. We also applied a fixed area-based transaction cost levied when either acquiring or degazetting land (Supplementary Information). Our cost estimates assume that land has not had value added by virtue of being in or near a protected area. This has a conservative effect on our analysis, as there are examples of protected areas positively affecting the value of adjacent land[17].

The cost effectiveness of each planning unit, E_j, is derived from its contribution to conserving vegetation types within Australia (the benefit), B_j, relative to the cost of protecting that planning unit, C_j: $E_j = \frac{B_j}{C_j}$. Here, $B_j = \sum_{i=1}^{m} A_{ij}/r_i$, where m is the total number of vegetation types, A_{ij} is the area covered by vegetation type i in planning unit j and r_i is the proportion of each vegetation type i remaining in Australia from pre-clearance levels. The cost, C_j, is the estimated land value for each planning unit. We calculated E_j for each planning unit, and sequentially removed the least cost-effective protected areas, replacing them progressively with the most cost-effective new sites until the funds yielded by degazettement were exhausted. Our measure of cost effectiveness prioritizes planning units containing vegetation types that have been heavily cleared.

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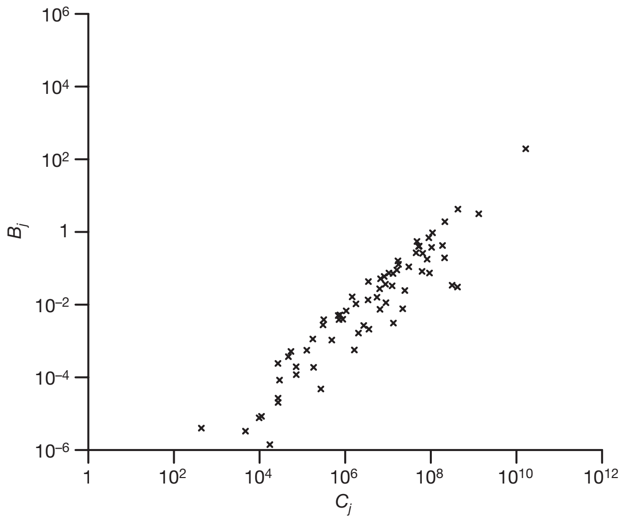

Figure 1 | Cost effectiveness in Australia's protected areas. The contribution of Australian protected areas to conserving vegetation types relative to their rarity (B_j) is positively related to the estimated cost of acquisition and management of the sites (C_j). However, there is a great deal of scatter in the cost effectiveness among the 6,990 protected areas; here the least cost-effective 1% of sites (70 protected areas) are denoted by crosses.

Being a static measure that is calculated once for each planning unit at the start of the analysis, it continues to prioritize threatened vegetation types without specifying a threshold for adequate protection, and it does not incorporate complementarity[18]. It is thus conservative for this application, because a dynamic prioritization algorithm would be even more efficient[19]. Furthermore, our static cost-effectiveness metric is transparent, simple to interpret and easy to implement.

The relationship between the estimated value of the land occupied by a protected area (C_j) and its contribution to protecting heavily cleared vegetation types (B_j) was strongly positive (standardized major axis regression: $\beta = 0.85$; $r^2 = 0.34$; $P < 0.001$), driven by the fact that both cost and benefit increase with the size of the protected area (Fig. 1). However, there is substantial variation in cost effectiveness among current protected areas. The least cost-effective protected areas span a wide range of land values and benefit values, and it is worth noting that many of the most expensive sites are still cost effective (Fig. 1).

Replacing the least cost-effective protected areas with the most cost-effective new sites produces a very rapid increase in system performance (Fig. 2). By replacing only the lowest ranked 1% of protected areas we can increase the number of vegetation types for which 15% of their pre-clearance extent is conserved in Australia from 18 to 54, of a maximum possible of 58. Two of the original 60 vegetation types (brigalow *Acacia harpophylla* forests and woodlands; mallee with a tussock grass understorey) have less than 15% of their original extent remaining and thus the reservation target cannot be met. Moreover, by reconfiguring the protected area system we can increase the total area under protection by a factor of ten. We repeated the analysis assuming that only 80% of the estimated value of a land parcel is realized when sold, and 120% of its value is required for purchase. The results were nearly as marked, with vegetation types protected to 15% again rising from 18 to 54, and the total area under protection increasing by a factor of 9.8 (Supplementary Information). A dynamic version of this analysis that aims to equalize protection levels across vegetation types produces slightly stronger results, with vegetation types protected to 15% rising from 18 to 55, and the total area under protection increasing by a factor of ten (Supplementary Information). We emphasize that all these performance gains are budget neutral, achieved using only the funds realized from degazettement.

Enormous efficiency gains could be achieved by modest and careful adjustments to a protected area system. Although we do not advocate wholesale reassembly of protected area systems that have been built up over decades, our results show that a more flexible approach to the expansion of protected area systems could ultimately protect much more biodiversity. With increasing pressure on environmental budgets, demonstrating value for money is more urgent than ever, and protected area replacement produces demonstrable gains in representing biodiversity.

There are many possible cost-effectiveness metrics that could be used to construct this kind of analysis, reflecting the full range of reasons why protected areas have been designated and are valued by society. Whatever metrics are used, wide variation among protected areas in their cost and contribution to system performance will inevitably result in large gains to performance by some judicious changes. For example, a cost-effectiveness metric based on human amenity value using the number of people living within 50 km of protected areas yields equally strong efficiency gains (Supplementary Information). However, as more objectives are added, the performance of the protected area system in relation to any individual objective will inevitably decline.

The idea of degazettement usually has negative connotations, and it is highly controversial among conservation scientists and practitioners[20–22]. Yet designing processes to deal with protected area replacement is essentially no different to solving other complex environmental management questions where costs and benefits are spread unequally across society and among generations[23]. Formalizing the process using biological criteria might even improve accountability, particularly if replacement with a higher quality site is formally mandated. For example, instead of such decisions being framed as giving up on protection, the focus could be on allowing fair economic use of downlisted sites while insisting on protection for new, more cost-effective sites. The reality is that excision of commercially valuable parts of protected areas, and degazettement or downgrading of entire sites, are becoming increasingly common in many

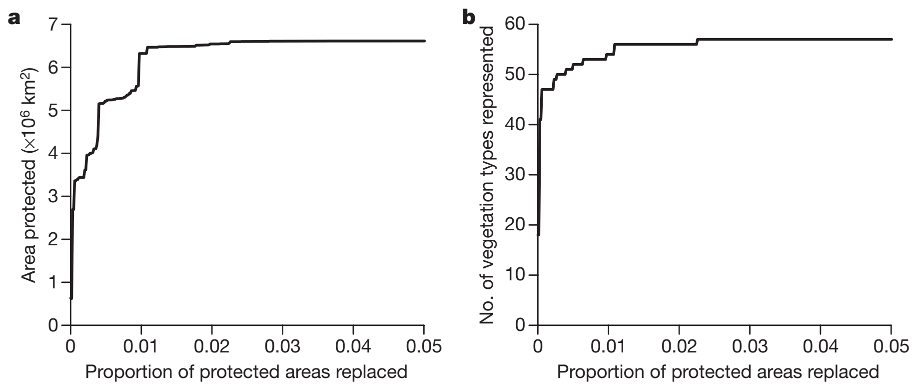

Figure 2 | Conservation outcomes delivered by protected area replacement. a, Change in total area under protection. **b**, The number of vegetation types for which at least 15% of their pre-clearing extent are represented, as existing protected areas are progressively replaced with more efficient sites.

countries, often with no form of mitigation[24–26]. This is especially likely where the opportunity costs of protected areas are greater than the revenue they generate, and is currently a particularly acute problem in east Africa[27].

Relaxing the protection status of any existing protected area will probably prove politically difficult. As an alternative to protected area replacement, investment in the ongoing management of a protected area could be scaled up or down according to its cost effectiveness. This does not necessarily mean abandoning sites with low conservation value. Providing management costs are low it might be worth continuing to manage such a site. In some cases, and particularly where a site is near an urban area, alternative commercial sources of funds for management could be sought, for example, revenue from tourism or recreational users. This would enable biodiversity-conservation-specific funds to be directed towards areas with the greatest biological value.

Growth in global spending on protected areas has stagnated in recent decades[28], and the rate of gazetting new protected areas is slowing as countries begin to meet their obligations under the Convention on Biological Diversity. If the rate of new investment in protected areas continues to decline, ensuring that the best places are retained in the face of rampant land clearance will be more important than ever. Protected areas form a large part of our conservation legacy to future generations, and handing down a healthy and well-reasoned set of sites is, in our view, the best way of justifying this investment.

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Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

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