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Spatial conservation prioritization inclusive of wilderness quality: A case study of Australia's biodiversity

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ABSTRACT

There is considerable discussion about the relative importance of conserving high quality wilderness areas (i.e. large and intact landscapes) versus conserving areas with high biodiversity values. Places that are needed to achieve one aspect of biodiversity conservation are not necessarily optimal for another which can lead to conflict in assigning conservation priorities. However, both are important for biodiversity conservation, and carry social, economic, and ecological values. Investment in both (a) representation of elements of biodiversity (e.g. species, habitats) and (b) wilderness conservation is not only complementary but important for the long-term persistence of biodiversity. We develop two approaches to identify areas important for the conservation of biodiversity in terms of both wilderness quality and biodiversity representation, using Australia as a case study. We defined intact areas as sub-catchments with at least 70% or more vegetation that has not been subjected to extensive habitat loss and fragmentation as the result of land clearing. The first approach aims to achieve biodiversity representation goals in areas with intact native vegetation. The results of this approach would be extremely expensive to implement as they require a large portion of land. The second approach aims to achieve biodiversity representation goals anywhere across the landscape while placing a strong emphasis on identifying spatially compact intact areas. The results of this approach show the trade-offs between the economic costs of conservation and the size of conservation areas containing intact native vegetation. This manuscript provides a novel framework for identifying cost-effective biodiversity conservation priorities inclusive of wilderness quality.

1. Introduction

Biodiversity conservation aims to protect the variability among living things, including the diversity within species, between species, and of ecosystems (United Nations, 1992). The principles of protected area network establishment often include goals to comprehensively represent elements of biodiversity. However, protected areas that comprehensively protect representative elements of biodiversity may not be adequate for the long-term persistence of biodiversity (Possingham et al., 2006; Soulé and Sanjayan, 1998). For example, if size and condition are not considered in the identification of priority areas for biodiversity conservation, they may not be adequate to facilitate large-scale and long-term ecological processes (e.g. migrations and dispersal) and change (e.g. climate variability and fluxes) (Soule et al., 2004). Wilderness quality is one useful spatial surrogate for the long-term persistence of biodiversity and can be used to identify spatial conservation priorities. High quality wilderness areas, or large and intact areas, play an important role in sustaining ecological and evolutionary processes that maintain and generate biodiversity (Frankel and Soule, 1981; Geider et al., 2001; Solan et al., 2004; Thompson, 2005).

The wilderness quality of land can be measured as a continuum using various indicators but most commonly surrogates of human land use and infrastructure (Lesslie, 1991). As Indigenous hunter–gatherer societies occupied all continents except Antarctica for the last 14–50,000 years (Mulvaney and Kamminga, 1999), it is difficult to determine their ecological footprint. Therefore, the baseline wilderness quality is commonly taken as the land condition prior to European settlement as this coincides with the advent of modern industrialized land use activities including broad-scale land clearing and the large-scale impoundment and diversion of water (Fahrig, 1997; Glanznig, 1995). It follows that land with a relatively high wilderness quality has its native vegetation cover largely intact.

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There is considerable discussion about the relative importance of conserving areas with high wilderness quality versus conserving areas with high biodiversity values (Booth and Traill, 2008; Mittermeier et al., 1998; Redford et al., 2003; Sarkar, 1999). The places that are needed to achieve one aspect of biodiversity conservation are not necessarily optimal for another which can lead to conflict in assigning priorities for conservation investment (Mittermeier et al., 2003).

In a global study of important areas for wilderness conservation, Mittermeier et al. (2003) found that wilderness areas, covering 44% of the Earth's land area, are generally not species rich and concluded that the conservation of wilderness *per se* does not ensure the protection of biodiversity. Likewise, since areas of high biodiversity value typically coincide with areas of high human population density, the conservation of biodiversity may not ensure the protection of wilderness (Balmford et al., 2001). There are two reasons why the geographic distribution of wilderness areas may not coincide with places important for threatened species conservation or to meet biodiversity representation goals. First, where the major cause of the species or ecosystem's threatened status has been habitat loss and fragmentation then, by definition, the remnant populations will be located in areas with a low wilderness quality. Second, the definition of wilderness quality hinges primarily on the condition of the vegetation (Thackway et al., 2007) and includes no reference to useful surrogates of biodiversity value, such as endemism and level of extinction risk. It follows that in terms of spatial conservation prioritization, wilderness areas may or may not be a priority for meeting the goal of comprehensive biodiversity representation. Given limited resources available for conservation, should we invest in protecting areas of high wilderness quality or invest in protecting areas with high biodiversity values?

This question is an unnecessarily stark dichotomy, since both are important for the conservation of biodiversity, and carry social, economic, and ecological values (Callicott and Nelson, 1998; United Nations, 1992; World Conservation Union, 1994). High quality wilderness areas sustain critical ecological processes (e.g. water filtration, carbon sequestration, and nitrogen fixation) that constitute Earth's life support systems (e.g. provision of clean water and air, climatic stability) (Grumbine, 1990; Mittermeier et al., 2003). They also support local economies by providing renewable resources and by attracting tourism, and are important for cultural and religious values (Cronon, 1995). Biodiversity plays a critical role in sustaining ecological processes (Gilmore et al., 2007; Pressey et al., 2003), makes important economic contributions to agricultural and medicinal industries, and is significant for certain cultural traditions (United Nations, 1992). If no steps are taken to protect wilderness areas, these areas may eventually be subject to habitat loss and fragmentation, and accompanying loss of biodiversity. Therefore investment in both (a) representation of elements of biodiversity (e.g. species, habitats) and (b) wilderness conservation is not only complementary but important for the long-term persistence of biodiversity.

As a compromise, Mittermeier et al. (2003) suggests that we focus our conservation investments on species rich wilderness areas, such as those in parts of Amazonian Brazil, the Congo Basin, and Northern Australia. Although these areas may adequately address wilderness conservation objectives, these areas alone will not meet the biodiversity conservation objective of comprehensively representing biodiversity in a network of conservation areas. Identifying areas important for the conservation of biodiversity on the basis of species richness does not ensure that all species are represented as it fails to account for the principle of complementarity – the contribution of the total set of selected areas (i.e. currently protected areas or other areas included in the conservation plan) towards representing biodiversity (Williams et al., 1996).

We develop two alternative approaches to identify areas important for the conservation of biodiversity in terms of both wilderness quality and biodiversity representation. In the first approach we achieve biodiversity representation goals in areas with intact native vegetation. In the second approach we achieve biodiversity representation goals anywhere across the landscape while placing an emphasis on identifying spatially compact intact areas. To achieve biodiversity representation objectives, we identify areas that comprehensively represent a wide spectrum of biodiversity features using the principle of complementarity. Finally, since there are limited funds available for conservation, we achieve these objectives for a minimum cost, where the cost is determined by the conservation action under consideration, which in this case is the purchase of land for protection (Carwardine et al., 2008; Naidoo et al., 2006). Other conservation actions (e.g. stewardship agreements with private land holders) could be assessed using our prioritization approaches.

We test our approaches in Australia (Fig. 1) – a country considered to be globally significant for both biodiversity and the existence of areas of high wilderness quality (Booth and Traill, 2008; Mittermeier et al., 2003; Mittermeier et al., 2004). In March 2008, the Australian government announced a commitment of $180 million dollars to expand the National Reserve System (Department of the Environment, 2008). This money will, in part, be dedicated to the acquisition of additional land for protection and is a primary reason we have focused on identifying land acquisition priorities in this paper. Systematic conservation planning in Australia has given priority to comprehensively representing habitats and species, without sufficient regard to the issue of adequacy and the protection of large and intact areas (Commonwealth of Australia, 2005). However, there is increasing recognition of the importance to biodiversity conservation of protecting high quality wilderness areas in Australia (Woinarski et al., 2007) with several international and national agencies establishing multi-million dollar initiatives with this mandate (Booth and Traill, 2008; Kenney, 2007).

2. Methods

We used sub-catchments (aka watersheds) as the planning unit ($n = 62,630$) for the selection of priority areas in our analysis as they are more amenable at capturing ecological processes than the more commonly used square or hexagon planning units (Klein et al., 2009). The sub-catchments are an average size of 50 km^2 and 800 km^2 in the intensive and extensive land use zones, respectively.

2.1. Defining intact areas

We define intact as those areas where the vegetation cover has not been severely modified since European arrival. We use a classification called VAST (Vegetation Assets, States and Transitions), which categorizes land cover into seven states according to the degree of post-European settlement anthropogenic modification as the result of land use activities including pastoralism, intensive agriculture and timber harvesting (Thackway and Lesslie, 2006; Thackway et al., 2007). The VAST framework has been applied to the Australian continent using available land cover and land use data, producing a geographic data layer in raster format at a 1 km grid cell resolution. Of the seven classes, we used the two classes ('Bare and Residual') containing the least modified vegetation to define 'intactness' and identified sub-catchments with at least 50%, 70%, and 90% of these VAST classes to illustrate the spatial variation arising from using different thresholds of intactness.