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Clear consideration of costs, condition and conservation benefits yields better planning outcomes

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ABSTRACT

The conservation benefit of a management action depends on what would have happened in the absence of an intervention, and whether the conservation objective is to maintain the existing biodiversity values, or to restore those that have been lost. How this benefit is calculated and considered in spatial prioritisation analyses could influence the expected cost-effectiveness of management, although this has not previously been explored. Here, we use a comprehensive decision theoretic approach to identify management priorities in a region of ecological, cultural and economic significance, the Great Western Woodlands (GWW) of south-western Australia. To demonstrate how cost, condition and conservation benefits affect prioritisation outcomes, we consider two different conservation objectives: the maintenance of native vegetation communities and the restoration of natural fire regimes. We compare the results from (1) our comprehensive approach, to priorities identified using two alternative approaches: (2) consider generic management costs (travel, labour) and assume that landscape condition is homogenous or (3) use landscape condition as a surrogate for the cost of management, i.e. areas in poor condition are assumed to have high costs. We demonstrate that prioritisation outcomes differ substantially depending on how the benefits and costs of a management action are calculated. Using landscape condition as a surrogate for management costs resulted in priority areas that were least cost-effective. To avoid misspent conservation funding, we argue that care must be taken to incorporate the most appropriate cost and condition metrics into spatial prioritisation analyses, and that conservation benefits must be derived from a clearly specified objective.

1. Introduction

Decisions about where to implement conservation management across a landscape need to take into account both the likely benefits of implementing an action and its associated costs. Conservation planning tools can solve a range of spatial prioritisation problems by identifying priority areas where biodiversity could most efficiently and effectively be protected or managed to ensure its persistence (Moilanen et al., 2009a). These tools focus on the principles of cost-effectiveness and representativeness of conservation features, as it is well understood that explicitly considering both the costs and benefits of conservation is essential when making decisions about where to prioritise investments, in order to identify the most cost-effective options for conserving biodiversity. Despite this knowledge, best practice approaches are rarely followed (Armsworth, 2014; Joseph et al., 2009; Maron et al., 2013; Naidoo et al., 2006).

The benefit derived from a particular management action depends on what would have happened in the absence of an intervention (Ferraro and Hanauer, 2014; Maron et al., 2013; Possingham et al., 2015). Often, the expected benefit of an intervention is simply calculated as the present-day conservation value of a site — for example, the current presence or distribution of species or ecosystems. The assumption behind this approach is that in the absence of the intervention, all of the conservation value of a site would be lost in the future. This would only be reasonable in the case where the existing values are likely to diminish without the security provided by a particular intervention, such as a protected area. This was a key assumption in many early conservation planning analyses which focussed on representation in protected area networks (Possingham et al., 2000; Pressey et al., 1994) and the legacy of this simplifying assumption persists (Maron et al., 2013).

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In recognition that land and seascapes are rarely in a pristine state, several studies have sought to include measures of landscape condition into spatial prioritisation exercises (Fraschetti et al., 2009; Game et al., 2008; Harris et al., 2014; Heiner et al., 2011; Kiesecker et al., 2009; Klein et al., 2009; 2013; Linke et al., 2012; Tallis et al., 2008). Often, the objective of such exercises has been to identify areas where biodiversity should be protected — that is, to maintain the existing values into the future. In order to achieve this objective, it has been common to identify sites for protection that have a low degree of anthropogenic impact, i.e. sites in 'good condition'. This has been achieved in several studies by considering landscape condition as a proxy for the cost of management (Ban and Klein, 2009). For example, Heiner et al. (2011) identified the priority areas that met representation targets for threatened and endemic fish species by minimising the total 'cost'; where cost was an index of cumulative anthropogenic impacts representing landscape condition.

However, considering condition as a proxy for the cost of management could generate misleading results (Armsworth, 2014). The condition of a site does not reveal the type of management action that should be implemented, or who should bear the costs (Adams et al., 2010). The condition of a site is unlikely to adequately capture variation across a full range of cost types, such as transaction, implementation, maintenance and opportunity costs (Armsworth, 2014; Naidoo et al., 2006). Furthermore, combining multiple types of costs (such as condition as a cost proxy and monetary costs) into an analysis is only feasible where each cost has the same unit of measurement (Ban and Klein, 2009). There is currently limited scope to comprehensively incorporate estimates of both condition and cost in a spatial prioritisation exercise (but see Moilanen et al., 2011). Game et al. (2008) and Klein et al. (2013) are two studies that simultaneously consider estimates of condition alongside monetary costs, but they focus only on minimising selection of sites in poor condition, which may not always be the desired conservation objective.

The focus of conservation planning is shifting from solely prioritising for protected areas, and towards new objectives of identifying areas for targeted management to ameliorate negative impacts and to improve ecosystem health (Budiharta et al., 2014; Moilanen et al., 2011; Wilson et al., 2010). This includes targeting control of invasive species (Auerbach et al., 2014; Evans et al., 2011), reduction of poaching (Plumptre et al., 2014), or management of fire (Richards et al., 1999; Wilson et al., 2007). In many cases, the objective may be not only to protect the existing values, but also to restore lost values through improving the condition of the system (Law et al., 2015; Possingham et al., 2015). In such cases, conservation management actions may be more efficient and effective if directed towards areas that are currently in poor condition, assuming that the degrading processes can be addressed and condition improved as a consequence. This requires a clear understanding of the conservation objective, and how costs should be considered alongside estimates of condition.

Incorporating condition estimates into spatial prioritisation analyses without explicit consideration of the conservation objective, and the management action(s) that will deliver that objective, could have profound implications for the estimated expected benefits from management. For example, the analysis conducted by Kiesecker et al. (2009) identified the priorities for conservation in areas with high 'landscape integrity', by minimising the selection of sites in poor condition. Landscape integrity was estimated by combining eight factors, including roads, mines, oil and gas pipelines, oil and gas wells, residential development, agricultural lands, as well as invasive species, and fire condition class (Copeland et al., 2007; Kiesecker et al., 2009). Whilst it makes sense to identify sites for protection that are currently not affected by the existing developments, invasive species and inappropriate fire regimes are two pressures that can be reduced through active management; hence a larger conservation benefit (Maron et al., 2013) may have been achieved by prioritising areas affected by these for active management. In the absence of a clearly articulated conservation objective and knowledge of the relevant management actions to meet that objective, there is a risk that condition may be incorrectly accounted for in spatial prioritisation analyses, and the resulting conservation priorities may not deliver the benefits to conservation as expected.

Given this history of confusion, we need an approach to clearly and consistently account for both condition and cost simultaneously in spatial prioritisation — in order to identify where the greatest conservation benefit can be achieved with respect to a particular objective, and at the least cost. Decision science can assist in framing and solving complex problems such as this by: defining clear objectives and constraints related to the problem, evaluating the consequences of management actions with respect to the objectives, and selecting the best option (Gregory et al., 2012; Polasky et al., 2011; Tulloch et al., 2015). A comprehensive decision-theoretic approach would allow the conservation benefit of a given management intervention to be correctly formulated and considered within a spatial prioritisation exercise, along with data on the monetary costs of such an intervention.

In this study, we explore three approaches for incorporating costs, condition and conservation benefits into spatial prioritisation analyses, and discuss their implications for the resulting conservation priorities using a case study of the Great Western Woodlands in south-west Western Australia. We define two different conservation objectives: maintaining native vegetation in its current condition, and restoring natural fire regimes through improving landscape condition. We develop and apply a comprehensive decision-theoretic approach for incorporating condition by using information on the condition of sites to calculate the conservation benefit of particular management actions (Maron et al., 2013). We then compare the results from our (1) comprehensive approach, to spatial priorities identified using two alternative approaches commonly applied in conservation planning: (2) consider generic management costs (travel, labour) and assume that landscape condition is homogenous, and (3) landscape condition is used as a surrogate for the cost of management, i.e. areas in poor condition are assumed to have high costs.

2. Methods

2.1. Study region

Our study region is the Great Western Woodlands (GWW) of south-western Australia, which stretches east from the agricultural wheatbelt of Western Australia towards the western edge of the semi-arid Nullarbor Plain (Fig. 1). Covering an area of almost 16 million hectares, the GWW is the world's largest remaining Mediterranean woodland. The eucalypt-dominated woodland is contained within a mosaic of shrubland and mallee which supports a globally significant diversity of flora and fauna (Fig. 2, Judd et al., 2008; Watson et al., 2008). The Mediterranean-style climate of low and variable rainfall coupled with infertile soils has historically prevented the incursion of intensive agriculture and livestock grazing, leaving the GWW in a largely intact state. Although the region escaped the historical large-scale clearing for intensive wheat and sheep farming, approximately a third of it is under pastoral lease for cattle or sheep. In addition, historical logging to support the expansion of mining operations from the late 1800s till the mid-1900s has influenced vegetation structure and terrestrial carbon stocks (Berry et al., 2010). Present threats to biodiversity in the region include changes in fire regimes, ongoing mining operations and exploration activity, as well as introduced herbivores, carnivores and weeds (Fig. 3, Watson et al., 2008). Climate change is expected to result in a general warming trend with drying from the north to south, with further impacts on rainfall and fire frequency (Prober et al., 2012). We divided the study region into 1 km^2 square planning units (162,163 in total) which we employed as sites available for management.