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Methodological and Ideological Options

Optimised whole-landscape ecological metrics for effective delivery of connectivity-focused conservation incentive payments

Kristen J. Williams [a,*], Andrew F. Reeson [a], Michael J. Drielsma [b,c], Jamie Love [b,c]

[a] CSIRO Ecosystem Sciences, PO Box 1700, Canberra, ACT 2601, Australia
[b] Office of Environment and Heritage, NSW Department of Premier and Cabinet, Armidale, NSW 2351, Australia
[c] School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia

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ABSTRACT

Market-based instruments provide incentives for conservation on private lands, combining the economic efficiency of an auction with ecological site prioritization to select the best sites from those offered by landholders. However, landscape-scale goals such as increased habitat connectivity are difficult to deliver with site-based prioritization metrics. Assessing alternative ways to re-connect landscapes is a complex task, requiring knowledge of how biodiversity will respond over time to alternative conservation actions, such as replanting, managing areas of natural regrowth or protecting existing habitat. It also presents computational challenges since projects must be assessed as combinations rather than individually. We investigated practical aspects of ecological metric design to achieve desired spatial configurations. Realistic, mock bids were submitted by members of the local community in a simulated tender exercise for enhanced cassowary habitat near Mission Beach, Australia. Optimization heuristics helped solve the problem within a reasonable time. Our results demonstrate that integrating whole-landscape assessment models with market-based instruments can feasibly address the inherent complexity when pursuing whole-landscape ecological benefits through cost-efficient and innovative means. Our methodology redresses asymmetries in knowledge about biodiversity in delivering conservation incentive payments, and is justified when policy goals demand a high level of rigor.

1. Introduction

Conservation on private land is essential to the persistence of biodiversity across most landscapes, both to supplement native habitat within reserves and to promote habitat connectivity. Natural areas of habitat on private land can, if functionally connected, play an essential role in connecting larger blocks of habitat managed in reserves (Soule et al., 2004), which can be particularly important in enabling biodiversity to disperse and adapt to climate change (Heller and Zavaleta, 2009). Payments for ecosystem services (including intrinsic biodiversity values) offer a means of providing incentives for private landholders to contribute to conservation, whether by refraining from actions which damage biodiversity (such as clearing native vegetation) or by actively promoting the persistence of species or ecological communities (such as restoration of native vegetation). Given the limited available resources for making such payments, prioritization is essential. Investments should be targeted toward actions that provide the best and most cost-effective conservation outcomes.

Market-based instruments such as competitive tenders (a form of procurement auction) are increasingly being used as a tool to efficiently allocate payments for conservation on private land (Latacz-Lohmann and Van der Hamsvoort, 1998; Reeson et al., 2011a; Stoneham et al., 2003; Windle and Rolfe, 2008). In a typical competitive tender, landholders submit bids to carry out conservation projects on their land. Bids are assessed in terms of the conservation benefits they offer against the amount of money requested by the landholder, enabling those projects which offer the best value for money (i.e. the most conservation outcomes per dollar spent) to be selected. An essential part of this process is the ecological metric used to assess the conservation value of alternative projects submitted in the tender (Windle et al., 2009). A metric must address the complex task of quantifying the relative benefits of conservation actions and expressing them in a single measure. This enables alternative projects proposed through a tender (or other incentive payment scheme) to be ranked in terms of cost-effectiveness, in order to maximize the benefits to conservation of every dollar spent. While considerable effort has gone into developing the economics of market-based instruments for delivering environmental services (e.g., Reeson et al., 2011a), many knowledge gaps remain around the design of rigorous ecological metrics to assess the conservation benefits of competing tenders. We approached this complex problem by adopting trans-disciplinary praxis, whereby a project team with skills across the disciplines of economics, ecology and computer science worked collaboratively (Hadorn et al., 2006).

* Corresponding author. Tel.: +61 2 62464213.
E-mail address: Kristen.williams@csiro.au (K.J. Williams).

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Most conservation tenders to date have focused on the conservation value of an individual site, rather than how it complements the value of other sites within a landscape, because site values are easier to define and verify (Oliver et al., 2005; Parkes et al., 2003). This typically results in a patchwork of funded incentive actions each of which has merit, but when considered collectively at the landscape scale, may not ensure the optimal allocation. For many conservation outcomes the scale and spatial configuration of conservation activities across the landscape is vital (Fahrig, 2003; Gaston et al., 2002). While the detail may vary depending on the species or process in question, ecological understanding clearly indicates a need to jointly assess an aggregate or complement of conservation actions across a number of sites rather than sites in isolation (Faith, 1994; Ferrier and Drielsma, 2010; Sarkar et al., 2006). That is, "the value of biodiversity is more than the sum of its parts"[1] –inherently depending on interconnections among services provided by an ecological system (e.g., Chavas, 2009; Faith et al., 2003). Therefore, we need ways to comprehensively value alternative landscape-scale outcomes, which can be linked (where necessary) with a multi-round tender to deliver cost-effective payments for conservation services in the right place at the right time.

To be effective, a landscape ecological metric requires a more integrated model of biodiversity persistence or habitat integrity to account for values associated with the type, extent and condition of habitats (representing biodiversity at the site-level, between sites and across whole regions); how these attributes change over time and with management; and the minimum prerequisites for a broad range of species to persist *in situ* (McCarthy et al., 2004). Building such ecological processes into market-based instruments requires a dynamic or scenario-based approach to the analysis of "value for money". Such an approach is described by Ferrier and Drielsma (2010). Their general modeling framework provides a logical and flexible foundation for integrating multiple pattern and process related factors of biodiversity into conservation assessments, in relatively simple or more complex ways depending on circumstances. It is ideally suited to the design and continuous improvement of ecological metrics for assessing landscape value for conservation service payments within a market setting (Seddon et al., 2010). Here we emphasize that it is the fundamental principles of ecology and the framework in which they are applied that is important to metric design. The detail of the application and associated development costs can be matched to the budget and objectives of the conservation program (Reeson et al., 2011b).

Whole-landscape approaches to conservation require cooperation and coordination among landholders to achieve complementary property-scale plans. However, cooperation among potential competitors in a market-setting can have undesirable outcomes such as price-fixing and holdouts for higher prices, known as collusion. In an experimental economic study, Reeson et al. (2011a) showed that running a tender in a multi-round format can facilitate coordination while maintaining the cost-effectiveness benefits of a competitive auction process. In a multi-round tender landholders are provided with information on the locations or types of projects offered by other landholders (though not their prices), allowing them to adjust their bids in order to provide the most favored landscape-scale conservation outcomes (e.g., conservation corridors). Putting such a landscape-scale tender into practice requires a metric which can adequately assess alternative bids in a landscape context; it must consider alternative packages of bids for their coordinated contributions to biodiversity conservation rather than individual bid rankings.

In this paper we investigate the coupling of a landscape ecological metric with such a tender mechanism. We set out the steps required based around a case study of an iconic landscape in Queensland, Australia. The metric was put to the test in a 'simulated conservation tender' involving landholders from the region who are potentially interested in participating in a competitive tender to connect habitat fragments to support the persistence of cassowary, an endangered bird species. We present the results of our novel research and discuss some of the principles and practical issues of coupling whole-landscape ecological metrics with a market-based instrument to achieve regional biodiversity outcomes.

[1] Bryan G. Norton, a speech at the National Forum on Biodiversity in Washington, D.C., September 21, 1986.

2. Material and Methods

2.1. Study Area and Focal Species

We selected the Mission Beach region of northern Queensland, Australia, to demonstrate the usefulness of integrating a landscape ecological metric and a market-based instrument for pursuing coordinated conservation outcomes. The Mission Beach region (17°53′S, 146°06′E) is renowned for its World Heritage coastal rainforest which is primary habitat for the southern cassowary, *Casuarius casuarius johnsonii,* a large long-lived ground-dwelling bird. Hill et al. (2010a) described the cassowary as a "collaborative focal species" because it links scientific, social and cultural values and provides a basis for uniting diverse players around a common conservation goal. The collaborative focal species idea incorporates: 1) flagship concepts that recognize social significance; 2) cultural keystone concepts that recognize indigenous cultural significance; and 3) ecological concepts that recognize biodiversity significance (Hill et al., in review). Currently, urban development, which is expanding to support tourism and the changing lifestyle choices of Australians, threatens to fragment critical breeding and dispersal habitat for this endangered species (Latch, 2007). Threats to the viability of local cassowary populations are exacerbated by landscape-scale forest disturbances associated with periodic intense cyclones (Turton, 2008). Concerns about the persistence of this species and past failures to implement recovery actions led to the region being established as one of several focal areas for community-based conservation planning (Hill et al., 2010b).

Sufficient knowledge exists about the ecology, biology and habitat use by cassowary to identify areas important to the movement of the bird both seasonally and during juvenile dispersal (Latch, 2007). The local peri-urban community is engaged in conservation restoration initiatives to reinstate connections between isolated habitat remnants, but not all members of the community are equally engaged. The agricultural hinterland produces tropical crops such as sugar and fruits, and while vegetation clearing is controlled, there are few incentives to restore habitat linkages in areas of crop production. The challenge of generating local cassowary recovery action, coupled with wider efforts to protect rainforest, makes the Mission Beach region a suitable case study for testing our novel approach which integrates economic and ecological frameworks to address whole-landscape conservation objectives.

2.2. Landscape-scale Metric Framework

Our ecological metric is an application of the whole-landscape biodiversity assessment framework developed by Ferrier and Drielsma (2010). For a given set of bids, we model the future state of connected cassowary habitat and the complementarities of ecosystem types. Our tender evaluation framework aims to maximize conservation effectiveness for these two ecological criteria within the budget for conservation service payments (Fig. 1). Multiple alternative land use scenarios (i.e., different combinations of bids) are assessed to identify an 'optimal' combination of bids from among those originally submitted in the tender.

The ecological metric comprises two parts – cassowary habitat connectivity and ecosystem complementarity – both of which are informed