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The Biodiversity Forecasting Toolkit: Answering the 'how much', 'what', and 'where' of planning for biodiversity persistence☆

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ABSTRACT

This research reports on a new approach to conservation assessment that seeks to extend the target-based model traditionally underpinning systematic conservation planning. The Biodiversity Forecasting Tool (BFT) helps answer three important questions relating to regional biodiversity persistence: 'how much' biodiversity can persist for a given land-management scenario; 'what' habitats to focus conservation effort on; and 'where' in the landscape to undertake conservation action. The tool integrates fine-scaled variability in vegetation composition and structure with spatial context, which is critical for ensuring the viability of populations. Thus, a raster data framework is employed which deems each location or gridcell in a landscape as contributing to biodiversity benefits to various degrees. At its simplest, just two spatial inputs, vegetation community types and vegetation condition, are needed. Drawing on, as a case-study, a broad-scale biodiversity assessment for NSW, Australia, this paper reports on the successful application of the BFT tool for a variety of functions ranging from interactive scenario evaluation through to conservation benefits mapping.

1. Introduction

1.1. Systematic conservation assessment

Systematic conservation planning aims to maximize the long-term persistence of biological diversity at a collective regional level. It was initially developed to address a shortcoming of approaches that assessed the conservation value of sites in isolation from one another. In particular it introduced the concept of complementarity – i.e. the potential for new conservation areas to complement a portfolio of existing, and/or selected, conservation areas by adding elements of biodiversity (e.g. species) not already represented within this portfolio (Faith et al., 2003; Ferrier, 2002; Margules and Sarkar, 2007; Margules and Pressey, 2000). Systematic conservation assessment (SCA) (*sensu* Ferrier and Drielsma, 2010; Knight et al., 2006; Moilanen, 2012) includes a broad set of methodologies and tools that seek to support the goals of systematic conservation planning (Ferrier et al., 2009; Ferrier, 2005; Margules and Sarkar, 2007; Margules and Pressey, 2000) through actions such as reserve establishment, habitat management, improvement and restoration (Moilanen, 2012).

Systematic conservation planning principles have been encapsulated within a number of GIS-based SCA tools (Sarkar et al., 2006). Among the most widely applied are C-Plan (Pressey et al., 2009), Marxan (Ball et al., 2009) and Zonation (Moilanen et al., 2009). SCA tools are typically designed to perform one or more of the following forms of assessment: optimal plan generation; conservation benefit mapping; interactive scenario evaluation; site-based assessment; and conservation status monitoring (Ferrier and Drielsma, 2010). The success of conservation plans rely on many factors besides the choice of assessment tools (Knight et al., 2006) and it is likely that the strengths of each tool makes it particularly suited to specific applications (Delavenne et al., 2012). Approaches to SCA differ in a number of ways. One major difference is in the biodiversity entities or level of biological organization that is examined. Entities can be a species, habitat types (communities, ecosystems), or genes. Tools such as C-Plan or Marxan are capable of considering multiple entities. They can also combine biological entities with other features including ecosystem services (Moilanen, 2012).

The regional scale is a useful frame for assessing the state and prospects of biodiversity as a whole (Soule and Tergorgh, 1999;

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Margules and Sarkar, 2007; Noss, 1983; Redford and Richter, 1999). A general modeling framework for undertaking regional-scale conservation assessment has been described by Ferrier and Drielsma (2010). It includes inbuilt flexibility allowing its main components to be 'extended' by adding rigor and refinement, where and when this is needed and where the added effort and methodological complexity can be justified.

The 'regional scenario' concept is central to this paper. We use the term generically to refer to any unique regime of land-uses, management actions and environmental conditions across a region at a defined point in time i.e. a regional scenario can describe "what has happened, what will happen, what can happen, and/or how a target can be achieved" (Börjeson et al., 2006). Within this schema of observations and possibilities, the dynamics of landscape can be described by a time-series of linked scenarios.

Conservation planning typically includes phases of project definition, development of strategies and measures (e.g. investment plans, strategic plans, management plans), implementation, adaptation and improvement (Nature Conservancy, 2007). It also has a parallel role in promoting collaborative learning and building discursive communities, catalyzing innovative community action, and helping to dissolve and avoid unproductive conflict (Meppem and Gill, 1998; Sterman, 1994; Trimbur, 1989).

We describe here the Biodiversity Forecasting Toolkit (BFT), a regional-scale, community-level (*sensu* Ferrier and Guisan, 2006) conservation assessment methodology and toolkit that we developed in response to emerging demands for analytical capabilities as we perceived them through our involvement with real-world conservation planning in New South Wales (NSW, Australia) over two decades. The BFT has been applied and iteratively improved since 2002. In contrast to reports that published conservation assessment methodologies have rarely resulted in conservation action (Sewall et al., 2011), applications of the BFT are increasing and its products are now well integrated into biological conservation praxis in NSW. However, until now the salient elements of its architecture have not been published except within individual project reports (see Appendix A).

The BFT extends the prevailing 'target-based approach' to SCA by incorporating elements of process-based modeling, drawn from Metapopulation Ecology, and it considers the complexity of contemporary landscapes by drawing on the principles of Landscape Ecology (Drielsma et al., 2007).

The toolkit includes conservation benefit mapping as well as interactive reporting capabilities, making it user-ready within a scenario planning, learning environment.

In order to illustrate the toolkit, we present an example from a recent case-study in which the BFT was used to undertake SCA for NSW, Australia.

1.2. Why the BFT?

Site-scale approaches to conservation assessment are well-established within conservation planning praxis (Oliver and Parkes, 2003; Parkes et al., 2003). They are designed to assess the potential impact (positive or negative) of individual management proposals, using property-level (site-based) data, interpreted within a regional context (Seddon et al., 2010). However, site-assessment methodologies are not well equipped to consider the combined (cumulative) effect on biodiversity of multiple management actions across an entire region. They cannot model dynamic interactions and complementarities between actions, assess and monitor the status of biodiversity in a whole region, or map potential benefits of management actions across regions. Yet, as conservation resources are limited, these capabilities are necessary to instill confidence that conservation investment is effectively targeted.

Box 1: Dimensions of Complexity in Biodiversity Assessment

1. **All biodiversity** – Despite its near overwhelming complexity, biodiversity conservation seeks to understand and to plan for the persistence of biodiversity in its entirely (Noss, 1990; Redford and Richter, 1999). It is not sufficient to focus on a subset of iconic species, species with economic importance, or those that are endangered. Taking such a piecemeal approach risks condemning common, low profile species and whole ecosystems to a pathway toward extinction.

   Not all species and ecosystems are necessarily equal from a conservation perspective. Those that are distinct (genetically or compositionally) are of particular interest (Vane-Wright et al., 1991).
2. **Whole-of-landscape** – Earlier manifestations of systematic conservation assessment were developed around the less complex aim of maximizing the representation of biodiversity in reserves. Hence a binary view of the world was initially adopted, where only areas within reserves were considered as contributing to the conservation objective. It is now well recognized that the future of a sizable proportion of biodiversity, if not the majority, is managed and will continue to be managed outside of reserve systems (Cowling et al., 2002; Hutton and Leader-Williams, 2003).
3. **Landscape variegation** – Similarly, in earlier assessment frameworks each part of the landscape was considered either part of a habitat 'patch' or part of the transformed agricultural matrix, where the latter was not recognized as providing any benefits for biodiversity conservation. This patch-based view contrasts with what is now recognized as the heterogeneous and variegated nature of many landscapes, emerging in their forms from a complex mix of past and present management, disturbances such as vegetation clearing and soil erosion, regeneration, and pest and weed invasions. It is generally accepted now that the complex arrays of habitat forms, ranging from agricultural land with scattered paddock trees and derived grasslands to pristine ecosystems, contribute to varying ways and degrees to overall biodiversity persistence (McIntyre and Barrett, 1992; Wiens, 1995; With et al., 1997).
4. **Processes** – Ecological processes, such as foraging, dispersal, predation, and seasonality; fluctuations of vegetation structure and function; as well as threatening processes such as weeds and pests, over-grazing and firewood collection; are by definition dynamic and often involve complex non-additive interactions between multiple factors. These processes are best addressed through mechanistic, or process, models (Ferrier and Drielsma, 2010; Noss, 1990).
5. **Forecasting** – In order to maximize conservation effectiveness, conservation effort should not only address the current status of entities; it needs to consider future prospects. The question needs to be asked 'what benefits would result from removing or reducing the threat of undesirable future impacts?' Similarly, expected 'positive' processes such as regeneration and ecological succession, needs to be recognised.

While assessment methodologies need to be practical, the complexity of ecological systems justifies a degree of complexity in models (see Box 1). This need to balance practicality with realism, comes to the fore with any attempt to integrate combine habitat type, quantity, condition and spatial configuration into SCA. These are properties that are at least partially determined by planning decisions on 'where, what and how' to protect, to re-vegetate, or apply other forms of vegetation management.

It is important that assessment methodologies can recognise the heterogeneity or variegation of landscapes (McIntyre and Barrett, 1992). However, it is not sufficient to focus merely on the physical