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When the suit does not fit biodiversity: Loose surrogates compromise the achievement of conservation goals

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ABSTRACT

The use of biodiversity surrogates is inevitable in conservation planning due to the frequent lack of consistent data on biodiversity patterns and processes. Top-down environmental classifications (coarse-filter surrogates) are the most common approach to defining surrogates. Their use relies on the assumption that priority areas identified using surrogates will adequately represent biodiversity. There remains no clear understanding about how the combination of different factors might affect the surrogacy value of these classifications. Here, we evaluate the role of three factors that could affect the effectiveness of coarse-filter surrogates: (a) thematic resolution (number of classes), (b) species' prevalence, and (c) the ability of classifications to portray homogeneous communities (classification strength). We explore the role of direct and indirect effects of these factors with a simulated dataset of 10,000 planning units and 96 species and structural equation modelling (SEM).

The surrogacy value of coarse-filter surrogates depended on the relative match between the extent of classes and species' distributions and the capacity of classifications to portray patterns in species composition (classification strength). Both determine the likelihood of erroneous selection of areas within a class where certain species do not occur. Common species were represented better than random only at high classification strength values (>0.5), while rare species never did. Finer classifications tended to be better surrogates although, when rare species were incorporated, the proportion of species that achieved the target level never exceeded 68%, even for the finest classification. This compromises the suitability of coarse-filter surrogates in areas where biodiversity is patchily distributed or with many rare species. We recommend using composite data sets containing environmental classes and biological data when a high effectiveness for all the species cannot be achieved.

1. Introduction

Conservation planning aims to identify representative and complementary areas for protection or restoration of biodiversity values in the most cost-effective way (Margules and Pressey, 2000). This is a spatially explicit task that requires information on the distribution of biodiversity. Ideally, the distribution of all species across a study region would be known (Grantham et al., 2010). However, data collection is expensive and time-consuming (Balmford and Gaston, 1999; Halpern et al., 2006; Gardner et al., 2008) so, in reality, conservation planners have to deal with incomplete datasets, usually biased spatially (e.g. along roadsides) or toward particular taxa (Funk and Richardson, 2002; Polasky et al., 2000). Moreover, direct observations of biological data, such as sampling plots, are sparse for large parts of the world, including parts of developed countries such as Australia (e.g., Margules and Austin, 1994). Many of these data-poor regions hold some of the richest and most endangered biodiversity (Pimm, 2000).

To overcome the limited coverage of biological data, different surrogate methods have been proposed and used in conservation planning exercises across the globe. This has been fostered by the accessibility of remote sensing and thematic maps from which surrogates can be derived for data-poor areas and at least partial support for the effectiveness of surrogates from studies in the last two decades. The purpose of a surrogate of biodiversity patterns is to portray species distribution patterns so that conservation priority areas selected to represent the surrogates will adequately represent species or other features of interest known only from sparse data. For instance, predictive models have been used to extrapolate available biological information to unsurveyed areas to obtain continuous estimations of species distributions (Loiselle et al., 2003; Wilson et al., 2005; Rondinini et al., 2006). More recent modelling techniques focus on estimating alternative ecological features,

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such as species turnover (Ferrier, 2002), and have proven useful for conservation planning (Arponen et al., 2008).

However, the most commonly used surrogate approach is based on the use of classifications that compartmentalize the spatial extent of study areas into groups or classes, such as vegetation types (Pressey, 2004). When using classification approaches, the conservation problem translates into the identification of a set of areas that represent a particular proportion of each class. The definition of these classes has either been based on *a posteriori* bottom-up classification of biological assemblages (classes represent homogeneous biological communities) or, more commonly, on *a priori* top-down classification of environmental attributes (e.g., soil types, rainfall, elevation) (Arponen et al., 2008). We will refer to these top-down environmental classifications as coarse-filter surrogates hereafter (Stoms et al., 2005). Coarse-filter surrogates can include: (a) habitat types (Dalleau et al., 2010; Heino and Mykra, 2006; Rivers-Moore and Goodman, 2010), (b) environmental classifications (Pressey et al., 2000; Sarkar et al., 2005; Januchowski-Hartley et al., 2011), (c) land facets (Wessels et al., 1999; Lombard et al., 2003; Beier and Brost, 2010) or (d) vegetation types (Trakhtenbrot and Kadmon, 2006; Grantham et al., 2010). The use of coarse-filter surrogates in spatial prioritisation relies on two main assumptions. The first is that the surrogates have been defined according to factors that are assumed to strongly influence the distribution of species. The second, as mentioned before for surrogates in general, is that sampling surrogates within a set of priority areas should represent species and other unmapped variation not directly accounted for (Nicholls and Margules, 1993; Faith and Walker, 1996). However, conflicting results have been reported on the capacity of coarse-filter surrogates, when used alone, to reflect compositional changes in biodiversity and ensure representation of species in priority areas (see Wessels et al. (1999), Wabnitz et al. (2009), and Dalleau et al. (2010) for some supportive examples and Kirkpatrick and Brown (1994), Ferrier and Watson (1997), and Araújo et al. (2001) for some criticism on the use of coarse-filter surrogates).

Previous efforts devoted to the evaluation of the suitability of coarse-filter surrogates have either focused on pattern-based testing of the spatial concordance of environmental classifications with species distributions (e.g., Heino and Mykra, 2006; Oliver et al., 2004; Carmel and Stoller-Cavari, 2006) or on selection-based testing of species representation when surrogates are targeted for identifying priority conservation areas (e.g., Lombard et al., 2003; Sarkar et al., 2005; Grantham et al., 2010). Despite the large scientific literature dedicated to this issue, there are not many studies testing the role of different factors that influence the success or failure of different coarse-filter surrogates (but see Payet et al. (2010) for an example). For example, there are few studies that evaluate both the effectiveness of coarse-filter surrogates and the potential causes of poor or good surrogacy at the same time (Pressey and Bedward, 1991a,b). This constrains the identification of key factors responsible for the effectiveness of coarse-filter surrogates at representing biodiversity. Given the widespread dependence of conservation planning on coarse-filter surrogates, better knowledge of the factors influencing the effectiveness of surrogates is needed to understand their limitations and guide their improved derivation (Pressey, 1994; Lombard et al., 2003).

Here, we evaluate the role of three factors that have been identified as potentially influencing the effectiveness of coarse-filter surrogates: (a) thematic resolution (estimated as the number of classes; Pressey and Bedward, 1991a), (b) species' prevalence (commonness; Kirkpatrick and Brown, 1994), and (c) the capacity of a classification to portray relatively homogeneous biological communities (classification strength, *sensu* Van Sickle and Hughes, 2000). We use a simulated dataset to compare the performance of different coarse-filter surrogates in a system with known properties (similar to Arponen et al. (2008)). We test three levels of thematic resolution (2, 4 and 16 classes) and three different levels of prevalence (common, intermediate and rare). Additionally our simulated dataset contains a wide range of classification strength conditions, from strong classifications with no between-class species overlap and high within-class homogeneity to weak classifications with classes sharing most species. We explore the relative role of these three factors on the effectiveness of coarse-filter surrogates, and make some recommendations to conservation planning practitioners.

2. Methods

2.1. Simulated data

To evaluate the effectiveness of coarse-filter surrogate classification methods, we generated a simulated dataset with 10,000 grid cells. Each grid cell was allocated to one of the 16 equal-area classes of which our original classification was composed (625 contiguous grid cells/class, Fig. 1). Each class contained six species, which occupied its entire extent. In this way, we initially generated a strong classification, with no between-class overlap (classes did

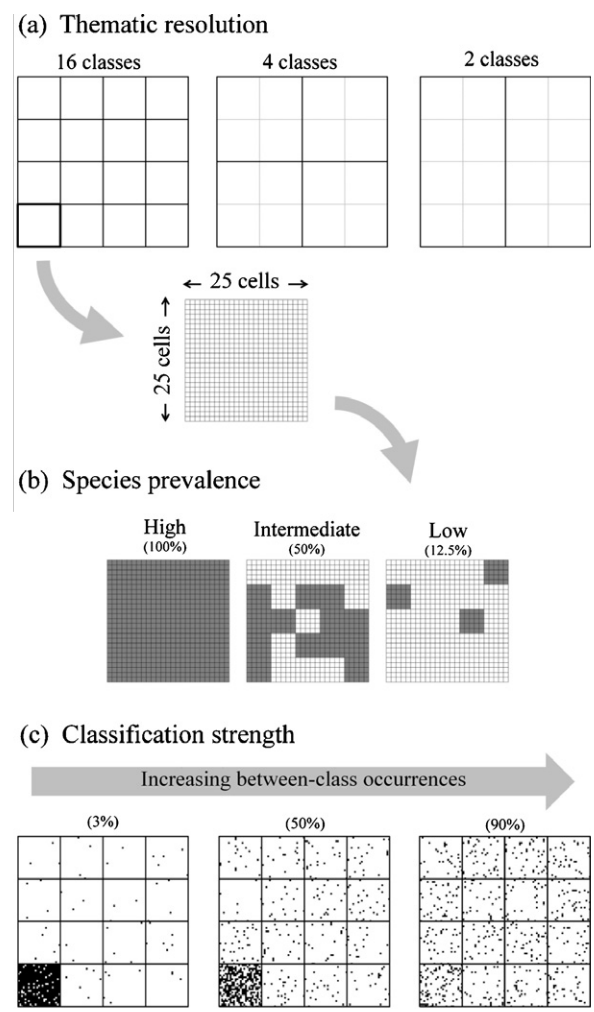

Fig. 1. Study design. Simulated data to test the effect of three different factors: thematic resolution (a), species prevalence (b), and classification strength (c). For classification strength, increasing between-class occurrences was achieved by randomly allocating increasing proportions of occurrences to other classes (values in parentheses indicate the proportions of occurrences from the bottom-left corner class that were randomly reallocated).