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Evaluating the effectiveness of overstory cover as a surrogate for bird community diversity and population trends

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ABSTRACT

Landscape features are often used as surrogates for biodiversity. While landscape features may perform well as surrogates for coarse metrics of biodiversity such as species richness, their value for monitoring population trends in individual species is virtually unexplored. We compared the performance of a proposed habitat surrogate for birds, percentage cover of vegetation overstory, for two distinct aspects of bird assemblages: community diversity (i.e. species richness) and population trends. We used four different long-term studies of open woodland habitats to test the consistency of the relationship between overstory percentage cover and bird species richness across a large spatial extent (>1000 km) in Australia. We then identified twelve bird species with long-term time-series data to test the relationship between change in overstory cover and populations trends. We found percentage cover performed consistently as a surrogate for species richness in three of the four sites. However, there was no clear pattern in the performance of change in percentage cover as a surrogate for population trends. Four bird species exhibited a significant relationship with change in percentage overstory cover in one study, but this was not found across multiple studies. These results demonstrate a lack of consistency in the relationship between change in overstory cover and population trends among bird species, both within and between geographic regions. Our study demonstrates that biodiversity surrogates representing community-level metrics may be consistent across regions, but provide only limited information about individual species population trends. Understanding the limitations of the information provided by a biodiversity surrogate can inform the appropriate context for its application.

1. Introduction

A wide variety of both biotic and abiotic features of landscapes have been used as proxies of biodiversity in both marine and terrestrial environments. In marine environments, for example, geomorphic characteristics such as sea floor depth, temperature and sediment attributes are suggested as abiotic surrogates of benthic biodiversity patterns (McArthur et al., 2010). In terrestrial environments, structural features of a landscape are often suggested for use as biodiversity surrogates. These include abiotic measures such as geodiversity, climate and topographical features of the landscape (Hjort et al., 2012), and biotic measures such as vegetation structure or type (Schwab et al., 2002; Smith et al., 2007; Banks-Leite et al., 2011; Barton et al., 2014). While important structural features of a species' habitat may be easier to measure, they are not always effective surrogates of broader biodiversity (i.e. abundance and distribution of species) (Hermoso et al., 2013). This means that thorough evaluation of a potential biodiversity surrogate is necessary to determine the specific situations in which they perform well and which ones they do not.

The first step in evaluating the performance of a surrogate is to define the particular goal against which the surrogate is being evaluated (Wiens et al., 2008). Broadly speaking, most biodiversity surrogates are used for either systematic conservation planning (e.g. reserve design) (Rodrigues and Brooks, 2007) or for monitoring (Wintle et al., 2010). For example, the objective of reserve design is often to maximize representation of biodiversity within or among areas (Margules and Pressey, 2000), and a particular surrogate(s) may be used as a proxy for other components of biodiversity (Rodrigues and Brooks, 2007). The objective of a monitoring project, however, may be to assess community diversity, population status, or trends for the purpose of baseline data or in response to some type of management action (Block et al., 2001). Importantly,

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Table 1
The number of sites that temporal data on percent overstory cover and bird diversity was collected.

Study	Number of sites	Sampling years birds	Sampling years vegetation
Nanangroe	112	1999, 2005, 2011	1999, 2005, 2010
Southwest Slopes	138	2002, 2004, 2008, 2013	2002, 2004, 2008, 2013
Environmental Stewardship	324	2010, 2011, 2012, 2013	2010, 2011, 2012, 2013
Western Murray Woodlands	105	2008, 2010, 2012	2008, 2010, 2012

a surrogate that has been identified for one objective may not be appropriate for other, even closely related, objectives (Caro, 2010).

Biodiversity surrogates are often targeted at measuring broad community-level aspects of biodiversity such as species richness and composition (Magierowski and Johnson, 2006). Community-level metrics can provide important information about the number and kinds of species present, but do not provide any detailed information about population trends of individual species. Information on population trends, however, can provide early warnings of species in decline prior to its complete loss (Lindenmayer and Cunningham, 2011). Once a species is lost, it may be difficult to restore. Furthermore, the decline of a population represents a threat to biodiversity in and of itself by drastically reducing the abundance of organisms in an environment which results in changing interactions within ecosystems (Dirzo et al., 2014). While extinction events, even local ones, tend to be relatively rare, a wide range of populations are suffering declines (Dirzo et al., 2014). Community metrics and population trends therefore represent two informative and complementary approaches to biodiversity monitoring, yet are different objectives for a biodiversity surrogate.

Percentage vegetation cover has been identified as a potential surrogate for bird diversity (Banks-Leite et al., 2011; Barton et al., 2014). It has long been established that bird assemblage diversity and composition is associated with vegetation structure (MacArthur and MacArthur, 1961; Davies and Asner, 2014). In particular, overstory cover (e.g. forest cover, canopy cover) has been shown to have a positive relationship with species richness, occupancy and abundance of bird communities in a range of habitats including pine plantations (Owens et al., 2014), urban habitats (Ferenc et al., 2013; Chong et al., 2014), and in northern hemisphere forests (Trzcinksi et al., 1999; Müller et al., 2010) and southern hemisphere forests (Cunningham et al., 2014b). This is due, in part, to the strong mechanistic links between vegetation cover and species diversity via enhanced resource provision and niche availability (Recher, 1969). However, several studies also have documented that individual species respond differently to vegetation cover (Reidy et al., 2014) with increased cover not necessarily resulting in a positive response from all woodland birds (Cunningham et al., 2014a; Rayner et al., 2014).

In this study, we evaluated whether a proposed habitat-based biodiversity surrogate (i.e. percentage overstory cover) consistently represents two different yet complementary monitoring objectives: bird species richness and population trends.

First, we evaluated the consistency of percentage overstory cover as a surrogate for bird species richness. This objective focused on the representativeness of overstory cover for bird diversity at any one point in time or space. We predicted a consistent surrogacy relationship should hold if the mechanistic relationship between vegetation structure (e.g. overstory cover) and bird communities (e.g. richness) was strong enough to be a reliable surrogate in similar habitats. We tested this consistency by examining associations between percentage overstory cover and bird species richness in a systematic manner across four longitudinal studies from different geographic regions that comprise similar vegetation types yet experience different anthropogenic pressures. Our approach to this first objective was similar to many traditional species-habitat association studies that quantify static measures of biodiversity and vegetation structure.

Second, we tested whether the temporal change in percentage overstory cover was associated with trends in individual species' populations. This objective focused on the usefulness of overstory cover as a surrogate for monitoring change over time in bird populations. We tested this by focusing on bird species common to two of the longitudinal studies that span >10 years of data. Our approach to this second objective was different from the first because we were explicitly interested in quantifying how change in the surrogate (i.e. overstory cover) was associated with change in the target (i.e. species populations). We therefore analyzed the relationship between the changes in the surrogate and target over time, and not their static raw values. Specifically, we addressed the following two questions:

1. Is the surrogate relationship between percentage vegetation cover and bird species richness consistent across geographic regions and over time?
2. Can the change in percentage vegetation cover be used as a robust surrogate for trends in individual bird species' populations?

2. Methods

We compared the relationship between the species richness and percentage vegetation cover in four geographically distinct large-scale, longitudinal studies conducted in southeast Australia (Fig. 1) that had repeated sampling for both overstory cover and bird species richness (Table 1). We used a subset of these studies that had both overstory cover and bird population data that spanned 10 years or more to determine if the change in percentage cover predicted the trend in bird populations (Nanangroe and Southwest Slopes Restoration studies; Table 1). We identified 12 species of birds that commonly occurred in these studies and used them to compare patterns of change in percentage cover to population trends (Table 2, Table S1).

The longitudinal studies we use in this study provided an excellent opportunity to evaluate consistency of percentage cover as a

Table 2
The number of sites at which each species was encountered at least once over the course of the monitoring period (Nanangroe: 1998–2013; Southwest Slopes Restoration: 2002–2013).

Species	Number of sites	
	Nanangroe	Southwest slopes
Australian magpie (*Cracticus tibicen*)	135	130
Black-facked cuckoo-shrike (*Coracina novaehollandiae*)	102	104
Brown treecreeper (*Climacteris picumnus*)	66	60
Common starling (*Sturnus vulgaris*)	85	111
Grey shrike-thrush (*Colluricincla harmonica*)	108	84
Red wattlebird (*Anthochaera carunculata*)	110	71
Red-rumped parrot (*Psephotus haematonotus*)	78	126
Rufous songlark (*Cincloramphus mathewsi*)	92	114
Striated pardalote (*Pardalotus striatus*)	111	124
Superb fairy-wren (*Malurus cyaneus*)	86	58
White-plumed honeyeater (*Lichenostomus penicillatus*)	94	111
Willie wagtail (*Rhipidura leucophrys*)	89	113