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What do site condition multi-metrics tell us about species biodiversity?☆

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ABSTRACT

Site-based habitat condition multi-metrics offer a simple surrogate for biodiversity assessment, but their merit has seldom been tested. Three such multi-metrics – *Habitat Hectares*, *BioCondition*, and *BioMetric* – are prominent in Australia. They all measure similar attributes, convert primary data into attribute condition scores (metrics), then weight and aggregate attribute condition scores into a single site condition score (multi-metric). We compared these multi-metrics and tested whether site condition scores were correlated with the species richness of a range of plant, vertebrate and invertebrate taxa recorded from Poplar Box (*Eucalyptus populnea*) woodland remnants in eastern Australia in a range of condition states. Site condition scores ($n = 43$) ranged from 17 to 88/100, and the summed richness of all taxa recorded from sites ranged from 93 to 192 species. The multi-metrics ranked sites similarly ($r_s \geq 0.79$), but *BioMetric* scored sites significantly lower. Site condition scores were significantly correlated with the total species richness at sites (*Habitat Hectares* $r = 0.51$, *BioCondition* $r = 0.49$, *BioMetric* $r = 0.43$), however, 75% or more of the variation was left unexplained. Linear modelling of attribute condition scores (metrics) showed that nearly 50% of the variation in total richness could be explained by a parsimonious model containing only nine condition attributes drawn from the three multi-metrics. This finding revealed that the independent explanatory power available within attribute condition scores (metrics) was not fully utilised by the site condition scores (multi-metrics). To refocus attention on the importance of careful selection, weighting and aggregation of condition attribute scores, and to improve communication and interpretation of the derived site condition multi-metrics, we introduce the *weighted wedge diagram*, a schematic that conveys visually and quantitatively: (i) the condition status of all attributes; (ii) the relative weightings applied to all attributes; and (iii) whether sites are degraded in terms of composition, structure and/or functional components.

1. Introduction

Site condition multi-metrics are used in natural resource management as surrogates for more expensive and time-consuming surveys of species presence and abundance (Andreason et al., 2001; Niemi and McDonald, 2004). Well known approaches are the Habitat Suitability Indices (HSI) and the Habitat Evaluation Procedures (HEP), which have been in use in the U.S. for over 30 years (Brooks, 1997; Hirzel and Le Lay, 2008; U.S. Fish and Wildlife Service, 1980). HEP scores the condition of a range of habitat variables with known or predicted importance to a species, combines scores into a composite HSI, and multiplies the HSI by the area of habitat under consideration to generate habitat units (HUs) for individual species. Individual HUs may be summed across multiple species to represent the amount of habitat lost, impacted, or created, depending on the natural resource management application (Brooks, 1997). "HEP is a method which can be used to document the quality and quantity of available habitat for selected wildlife species" (U.S. Fish and Wildlife Service, 1980). In Australia, the HEP-HSI approach finds analogues in *Habitat Hectares* in Victoria (DSE, 2004; Parkes et al., 2003), *BioCondition* in Queensland (Eyre et al., 2011), and *BioMetric* in New South Wales (DECCW, 2011a,b; Gibbons et al., 2009a,b). However, whereas HEP and HSI

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have mostly been used for well known vertebrate species, the Australian multi-metrics aim to deliver an "integrated view of the habitat for all the indigenous species that may reasonably be expected to use a site" (Parkes et al., 2003). Australian site condition multi-metrics therefore operate within a much broader context of terrestrial biodiversity assessment and conservation (see Gibbons and Freudenberger, 2006; Keith and Gorrod, 2006; Oliver et al., 2002).

The Australian multi-metrics are used for: assessing the loss of biodiversity from clearing native vegetation; determining offsets for these losses; and to prioritise funding for improved management, conservation, and restoration of terrestrial native vegetation (Gibbons et al., 2009a,b; Parkes and Lyon, 2006). They all: measure a similar set of site and landscape-scale attributes (see Appendix S1); convert site data into attribute condition scores (metrics) using benchmark data or expert rules (see Appendix S2); weight attribute condition scores, based largely on the difficulty of attribute replacement (see Appendix S1); and combine weighted attribute condition scores into the site condition multi-metric score, by simple summation (*Habitat Hectares* and *BioCondition*), or summation and multiplication (*BioMetric*). Assessment of the site condition components represents 75% and 80% of the *Habitat Hectares* and *BioCondition* multi-metrics respectively, with the remainder based on landscape-scale attributes (*BioMetric* assesses landscape-scale, and regional-scale attributes separately, see Appendix S1). The multi-metrics are designed to be a transparent, repeatable and defensible assessment of terrestrial habitat condition for biodiversity. They remove the subjectivity associated with previous habitat condition assessment approaches, but continue to strive for an optimal balance between; operational need (rapid, cost-effective, and practical field based approaches suitable for implementation by non-specialists (see Gorrod and Keith, 2009; Gorrod et al., 2013; Kelly et al., 2011)), and rigorous biodiversity science (the on-going search for defensible biodiversity surrogates (see Mandelik et al., 2010; Sakar and Margules, 2002)).

Literature associated with each of the Australian multi-metrics suggests a positive relationship between site condition scores and the status of species-level biodiversity, assessed via species inventory (see Appendix S2), however, few authors have tested the predictive power of this relationship (see Giblett, 2011; Gorrod, 2012; Peacock, 2008; Weinberg et al., 2008), and none has done so using plant, vertebrate and invertebrate data combined. Even accepting that Connell's (1978) intermediate disturbance hypothesis (which predicts that sites with moderate disturbance will have more species than undisturbed sites) may sometimes be true (but see Fox, 2013), we would expect low species richness at low scoring sites, and moderate to high species richness at high scoring sites (when sites sample the same vegetation community).

Our aim was to evaluate the above hypothesis for the three multi-metrics, *Habitat Hectares*, *BioCondition* and *BioMetric*, by testing how well the site condition scores (excluding landscape attributes, see Appendix S1) explained the species richness of terrestrial plants, vertebrates and invertebrates collected from eucalypt woodland remnants in eastern Australia. We also tested the same hypothesis using linear modelling of the unweighted attribute condition scores (metrics). Our interest in these relationships was restricted to a "within-vegetation-community" comparison of sites, and we do not suggest that species richness per se (e.g. between vegetation communities) is a valid measure of biodiversity status or value (see Humphries et al., 1995; Oliver and Beattie, 1997; Sakar and Margules, 2002). We also acknowledge that even within the same vegetation community, sites in different condition states, may provide habitats and resources for different suites of indigenous species, and assessments of species richness take no account of this complementarity of sites (see Faith et al., 2003; Sakar and Margules, 2002). The inability of contemporary site condition multi-metrics to account for within-vegetation-community complementarity has already been noted (McCarthy et al., 2004; Parkes et al., 2004).

2. Methods

Our study was located on the northern floodplains of New South Wales Australia, within an area of 50 km × 50 km described by the 1:50,000 Burren Junction (8637-N) and Pilliga (8637-S) topographic maps (148°30′–149°00′E and 30°00′–30°30′S). Existing vegetation mapping (Peasley, 1999) was used to select candidate study sites within mapped Poplar Box (*Eucalyptus populnea* subsp. *bimbil*, L.A.S. Johnson and K.D. Hill) woodland remnants (mapped woody vegetation crown cover ≥5%). The Poplar Box woodland community was selected for study because it once had a broad distribution in eastern Australia, but has been extensively cleared and continues to be vulnerable to further clearing and over-grazing (Benson, 2006). Candidate sites were assessed by field inspection and 43 were selected to provide a range of condition states resulting from a range of past land use and land management intensities (that is, a range among sites in; woody and non-woody native vegetation cover, overstorey age structure, amount of fallen timber, woody recruitment, weed cover, cover of litter, and stock disturbance of bare ground). Sites were located on both private properties ($n = 34$) and travelling stock routes ($n = 9$). Poplar Box woodland was not present in the nearby State Forests, and there were no conservation reserves in the study area.

Sites were located centrally within small remnants (<10 ha) or at least 100 m from the remnant edge. At each site, a 50 m fixed transect was located in an area representative of the remnant. Transects were orientated along the length of maximum slope (generally <1%) and were the fixed location about which habitat assessments were undertaken (see Appendix S2) and species biodiversity data were collected for: ants, beetles, spiders, wasps, flies, butterflies, frogs (as an unintended by-catch), reptiles, birds, vascular and non-vascular plants (bryophytes and lichens) (see Appendix S2). Habitat assessment data, or data derived from the vascular plant surveys, were used to calculate attribute condition scores for each of the three multi-metrics (see Appendix S2).

Before exploring the predictive power of the relationships between multi-metrics and species richness, we tested whether the three multi-metrics scored sites similarly. We used one-way ANOVA on homoscedastic data (Levene's test, Statsoft, 2010) to test the significance of differences between site condition score means. Spearman rank order correlation was then used to test whether the three multi-metrics' site condition scores ranked sites similarly. Finally, Pearson's correlation was used to detect significant negative correlations between the species richness of different taxonomic groups prior to summing the richness of all taxa to derive measures of (sampled) total site richness.

To explore the predictive power of the relationships between multi-metrics and species richness, Pearson's correlations were calculated between site condition scores (multi-metric), and the richness of all taxa combined ("total richness" hereafter), and the richness of different taxonomic groups ("taxon richness" hereafter). To further elucidate any relationships with species richness, Pearson's correlations were also calculated between attribute condition scores (metric) and total richness, and taxon richness. Where Pearson's correlations were calculated, scatter-plots were checked for evidence of non-linear relationships.

Distance-based linear modelling (DISTLM) was used to find the most parsimonious set of condition attributes for explaining total richness (PERMANOVA statistical package, Anderson et al., 2008). DISTLM is robust to non-normal data, and errors do not need to be normally distributed as p-values are obtained through permutation