ARE CURRENT MEASURES OF LANDSCAPE HEALTH USEFUL INDICATORS OF ARTHROPOD COMMUNITY STRUCTURE IN RANGELANDS?

A.B.C. Kwok and D.J. Eldridge

School of Biological, Earth and Environmental Sciences,
University of New South Wales, Sydney, NSW, 2052

ABSTRACT

We investigated the use of several current measures of landscape health (Landscape Function Analysis, structure/composition/function (SCF)) as surrogates or indicators of arthropod biodiversity in the Pilliga region of NSW. We sampled arthropods (beetles, ants, wasps, spiders, butterflies) and measured landscape health at 43 Bimble Box (*Eucalyptus populnea*) remnants. We investigated the response of each of the arthropod taxa (abundance, species/family richness, and community composition) to variation in landscape health. There were very few consistent relationships between landscape health and species/family richness, or the total abundance of individuals in each taxa. In contrast, the community composition for three orders (beetles, ants, and spiders) consistently varied in relation to landscape health (for both sets of measurements), though the ability landscape health to explain this variation was quite weak. Responses to landscape health were both species- and family-specific, and index-dependent. Overall therefore we found that two current measures of landscape health reflect variation in the arthropod community composition of arthropods (albeit weakly), but were of limited use in indicating species richness or the total abundance of arthropods.

INTRODUCTION

There is an increasing need for biodiversity indicators and surrogates as land managers, regional managers, and governments attempt to inventory and monitor changes to the biological landscape. Ideally these surrogates or indicators should be quick and simple to sample and monitor, require minimal training and specialist knowledge, and be able to reflect a wide range of plants and animals.

Landscape Function Analysis (LFA) is a widely used method for determining landscape health (e.g. Ludwig *et al*. 2004, Watson *et al*. 2007). LFA is a set of measurements designed to indicate landscape resource organization (e.g. proportion of *biological* patches, such as perennial grasses and log mounds that function to capture scarce resources (i.e. water and nutrients)) and soil surface condition (e.g. protection from rainsplash erosion, leaf litter accumulation, cryptogam cover). It provides a sound theoretical and empirical basis on which to assess the functional integrity of the landscape, that is, the ability of the landscape to capture, retain and utilize resources (Ludwig *et al*. 2004). Landscape Function Analysis requires minimal training, is based on persistent landscape features, and can be completed relatively quickly compared to traditional methods used to survey landscape health.

There is an intuitive link between the health of a landscape and its ability to support flora and fauna. A greater amount of resources such as water and nutrients within the landscape allows for greater plant productivity, and presumably translates into a greater amount of food resources and shelter for animals. That is, functional integrity should be a surrogate for habitat quality, and thus biodiversity potential and species persistence (Ludwig *et al*. 2004).

While there is some evidence of a positive relationship between biodiversity and landscape health (e.g. Ludwig *et al*. 1999, 2004), these studies are too few in number, geographical and taxonomic scope to allow for wider generalizations to be made. Indeed, Hunt *et al*. (2003) consider the lack of information surrounding these links as a major factor limiting the use of LFA as a biodiversity indicator. The aim of the current paper therefore is to evaluate the effectiveness of several current measures of landscape health as indicators of arthropod biodiversity and community structure in a semi-arid woodland of eastern Australia.

METHODS

Location and experimental design

This study was conducted in the Pilliga region of NSW, roughly 100 km north of Coonabarabran in the north-eastern NSW. Forty-three bimble-box (*Eucalyptus populnea*) woodland remnants (sites) were chosen, which varied in size, shape, isolation, and surrounding landuse, though these characteristics were not quantified. Within each site a 50 m fixed transect was established, which formed the basis for all sampling. To sample arthropods, 10 pitfall traps were located in a two by five grid pattern (traps 10 m apart) centred along the 50 m transect. All traps were active for 11 days.

We derived a total of nine landscape health indices. Six indices are derived from standard LFA measurements. Three of these are of soil surface attributes (stability, nutrients, infiltration), and three are of landscape organisation attributes (number of patches, average obstruction width, and average fetch length). For a detailed explanation of LFA methodology and how these indices are calculated, see CSIRO (2008).

Three indices, structure, composition and function (*sensu* Noss 1990), collectively referred to hereafter as SCF, were derived from 24 measures. Structure is based on the cover of trees, shrubs, perennial and annual grasses, forbs, bare ground, cryptogams, litter, log and debris, and landscape patchiness. Composition is derived from the number of tree, shrub, and groundstorey species, the proportion of plant perenniality and natives, and the degree of shrub regeneration. Function is based on the degree of mistletoe infestation, canopy dieback, the extent of tree hollows, the cover of erosion and perennial grass butts, soil organic matter, and soil texture. For information on how these are scored see Eldridge and Koen (2003).

Statistical analyses

Simple linear regression was used to investigate the relationship between each landscape health index and the species richness, total abundance of individuals, or species composition (from non-metric Multidimensional Scaling (MDS) axis 1 scores) within each arthropod order. Three groups were also analysed in greater detail, wandering spiders, ground beetles, and ant functional groups (after Anderson 1997).

We used Canonical Correspondence Analysis (CCA) to investigate how the composition of the arthropod community was structured in relation to landscape health. These analyses were confined to wandering spiders (species and family), ground dwelling beetles (species and family), and ants (species, genus, and functional group). Forward selection with Monte Carlo permutation tests were used to judge the significance of each variable to the species data.

RESULTS

Linear relationships at the species level

At the species level, a total of 16 arthropod characteristics were inspected for linear relationships with nine landscape health variables. This resulted in 144 possible results. Of this number 13 (~9%) were statistically significant ($P < 0.05$) when subjected to simple linear regression analysis. Significant results were spread across five of the landscape health measures, although stability (6) accounted for just over half of all statistically significant results. Ten of the 13 statistically significant results were related to the species composition of the taxa (MDS1) in relation to the landscape health variable. The maximum amount of variation explained by a measure of health (not including those related to composition) was 16.8%.

For ground beetles and wandering spiders in relation to landscape health variables, three of 54 potential results were statistically significant ($P < 0.05$). These were all for wandering spiders, and three were in relation to species composition. For ant functional groups, seven of 72 results were statistically significant ($P < 0.05$). Six of these indicated a change in the overall composition of ant functional groups.

Community composition in relation to landscape health

Landscape Function Analysis (LFA)

For wandering spiders, ground beetles and ants, LFA variables could only explain small portions of the variation in the species/family data (minimum % variance explained for four axes was 13% for ants at the genus level, maximum 29.9% for ground beetle families). The eigenvalues were also low (range 0.046 to 0.372), indicating short arrows on the resulting biplots (Figure 1a). Forward selection results indicate that the only variable consistently contributing to explaining variation the data was stability (significant at $P < 0.05$ for four out of seven analyses). The general pattern (i.e. species/family specific responses to each landscape health variable) was consistent across all taxa. Variables often showed some conflict in the direction of influence, relative to each other, on the fauna.

Structure, Composition, and Function (SCF)

Results were similar for SCF, with landscape health only explaining small amounts of variation in the species data (minimum 8.5% for ground beetle species, maximum 14.9% for ground beetle families). The eigenvalues were also low (0.04 to 0.257), again indicating short arrows on the resulting biplot (Figure 1b). Forward selection results indicate that the only variable consistently contributing to explaining variation in the species data was structure ($P < 0.05$ for three out of seven analyses). As with LFA, responses of family/species to variation in SCF were variable, though in the latter there was less conflict between the indices in the direction of effect relative to each other.

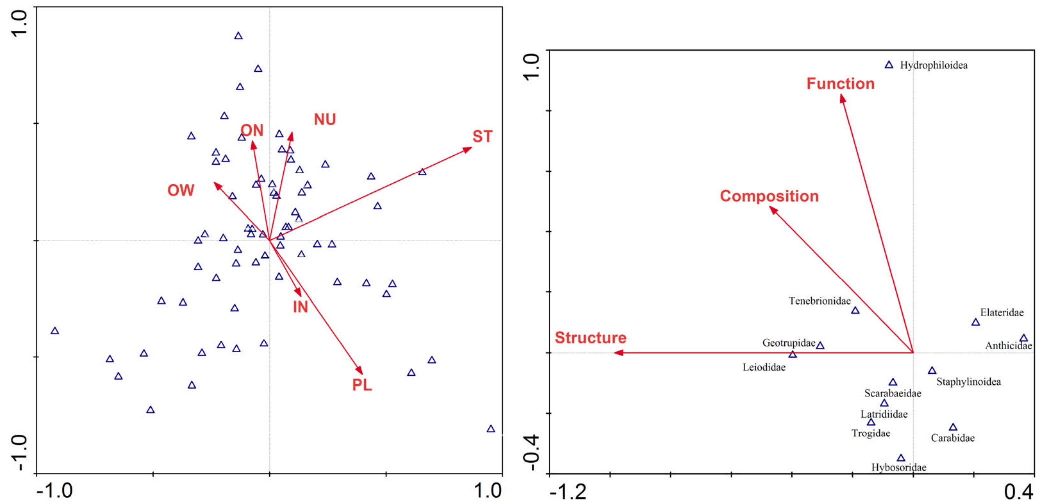

Figure 1: Canonical Correspondence Analysis (CCA) biplots for ground dwelling beetle a) species in relation to LFA variables and b) families in relation to SCF. Triangles represent a single species in a), and a family in b). For LFA, OW = average obstruction width, ON = number of obstructions, NU = nutrients, ST = stability, PL = average patch length and IN = infiltration.

DISCUSSION

The results of this study suggest LFA and SCF, two sets of landscape health measures, are able to reflect variation in the community composition of arthropods, albeit weakly, but are of limited use for detecting differences in arthropod richness or abundance. We found very few consistent relationships between any arthropod order and any measure of landscape health in terms of species/family richness or total abundance of individuals. However, our results suggest that the community *composition* of arthropods does vary, albeit weakly, in relation to landscape health. The exact nature of these responses was species-, family-, and taxa-specific, and dependent upon the specific measure of health. Thus, there remains potential for these measures to be used as indicators of arthropod community structure, though clearly we need to establish whether these links are consistent across landscapes and whether or not the weak relationships are a true reflection of the degree to which landscape health and the arthropod fauna are linked. Further research is required to investigate these issues.

There have been very few studies investigating the links between animals and landscape health which explicitly use LFA (or SCF). Ludwig *et al*. (1999) used LFA to investigate how variation in the quantity and quality of vegetation patches affected plant and grasshopper diversity, showing that declines in patch characteristics were mirrored with declines in the diversity of both plants and grasshoppers. Further evidence of a link between animals and landscape health is provided by Ludwig *et al*. (2004), who noted that the activity of two species of medium-sized mammals was greater in an area of high functional integrity compared to an area of low functional integrity, though activity was not quantified. It should be noted, however, that unlike previous studies, we investigated potential variation in landscape health as it exists over a much broader geographical area (geographically separated 'sites'), rather than along a clear gradient of landscape health. Regardless, our results contrast with those of previous research, and while the sampled taxa did not overlap, very few of the arthropod taxa in our study showed marked responses to variation in the landscape health of the landscape as might be expected on the basis of past research. Further research is underway to establish whether the relationships observed in the present study are consistent across multiple landscape types.

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