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"LAND CONDITION" AS A SURROGATE FOR BIODIVERSITY HEALTH IN TROPICAL SAVANNA RANGELANDS

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ABSTRACT

There are well-established procedures and indicators for assessing and monitoring "land condition" in Australian rangelands. None of the current monitoring programs explicitly encompasses biodiversity, although it has been suggested that some indicators of land condition may also be useful surrogates for biodiversity health. We tested this assumption through detailed biodiversity assessment at sites in a range of condition states in two pastoral regions in northern Australia, the Victoria River District (Northern Territory) and the Dalrymple Shire (Queensland). In each region, and amongst most major taxa (birds, mammals, reptiles, plants, ants), there was significant variation in biotic composition between sites in different condition classes. The relationship between species richness and condition varied between taxa, but in each major taxon we were able to identify species and functional groups that had increaser and decreaser responses to condition. To at least some extent, therefore, conventional land condition assessment in rangelands can also be informative about biodiversity health. However, we also note a number of potential limitations to this conclusion.

INTRODUCTION

There is increasing expectation that Australian rangelands will be managed, by landholders and management agencies, in an ecologically sustainable fashion (eg. Commonwealth of Australia 2003). This requires the capacity to monitor the status of biodiversity across the rangelands, in addition to the existing capacity to monitor "land condition". The latter term, although not necessarily precisely defined, is a widely-used one that captures the notions of minimising soil erosion, retaining vegetative cover and maintaining pasture composition in a desirable state, so as to ensure long-term sustainable production. There are well-established procedures for assessing and monitoring "land condition" in Australian rangelands, with each jurisdiction having institutionalised monitoring programs (NLWRA 2001, Whitehead *et al.* 2001). These rely on a variety of methods, including permanent photopoints, plot-based assessment of vegetation cover, composition and soil-surface condition, and the use of satellite imagery for condition assessment over large areas. Each method also has an associated set of "condition" indicators – for example, the frequency and/or cover of perennial grasses is an important indicator in tropical savanna rangelands.

The existing rangeland monitoring programs do not explicitly monitor biodiversity, although it is recognised that this is a desirable goal (NLWRA 2001). Given the complexity that the term 'biodiversity' encompasses, it will never be possible to directly assess more than a small number of components, and many indicators or surrogates for biodiversity have been suggested for use in rangeland monitoring (eg. Smyth *et al.* 2003). Suggested indicators include a number already used in land condition monitoring and Whitehead *et al.* (2001) considered that validation of these putative biodiversity indicators was a high priority for further research. In this paper we describe some preliminary results from a study in Australia's tropical savanna rangelands that explored the link between land condition and biodiversity. By detailed biodiversity assessment at sites in a range of land condition states, we explored what information about biodiversity status may be contained within the current indicators for assessing land condition. This should then help to determine what additional indicators are required for a robust rangeland biodiversity monitoring program.

METHODS

The study focused on two important pastoral regions in northern Australia – the Victoria River District (VRD; Ord-Victoria bioregion; 17°S 131°E; mean annual rainfall at VRD Stn 640 mm) in the Northern Territory and the Burdekin Rangelands (BR; Einasleigh Uplands bioregion; 19°S 145°E; mean annual rainfall at Greenvale 630 mm) in Queensland. We sampled two major land types in each region, representing a contrast between those that are considered relatively resilient (vertosols and ferrosols) or more sensitive (chromosols and kandosols) to the effects of pastoral use – although only results from the latter type are presented here. Both regions are used for extensive cattle grazing on predominantly native pastures, although there is a generally greater intensity of use in the BR, with smaller properties (100-500 sq km, vs 1000-5000 sq km in the VRD) and generally higher stocking rates (10-25 AE/sq km, vs 5-15).

We sampled 48 sites on two properties in the VRD, on red calcareous loams (kandosols) with Silver Box *Eucalyptus pruinosa* and Desert Bloodwood *Corymbia opaca* open woodlands having an understorey of *Sehima nervosa, Chrysopogon fallax, Heteropogon contortus, Dicanthium fecundum, Enneapogon* and *Aristida* spp. In the BR, we sampled 36 sites on three properties, on sedimentary chromosols with a mixture of Box (*E. persistens*) and Ironbark (*Eucalyptus* sp. [Stannary Hills G.W.Althofer 402]) woodlands having an understorey of *Bothriochloa* spp., *H. contortus, Themeda triandra, C. fallax, Aristida* and *Eragrostis* spp. Sites were stratified according to land condition but chosen to otherwise minimise environmental variation. In the VRD, selection of sites in different condition was based on regional land condition mapping produced by DIPE (derived from cover-change analysis of a time series of satellite imagery from the ten years preceding sampling; Karfs *et al.* 2000), supported by aerial and ground inspection. In the BR, site selection was guided by advice from QDPI extension officers and landholders, supported by ground inspection. Due to differences in property sizes, variation in site condition occurred across fencelines or along grazing gradients within properties in the VRD, but between adjacent properties with different management histories in the BR. For the purpose of this paper, we attribute all sites to three simple land condition classes ("poor", "intermediate", "good"), noting that these are relative terms. Compared to "good" sites, "poor" sites typically had low perennial grass cover and frequency, high cover of bare ground and high recent grazing pressure (Fig. 1).
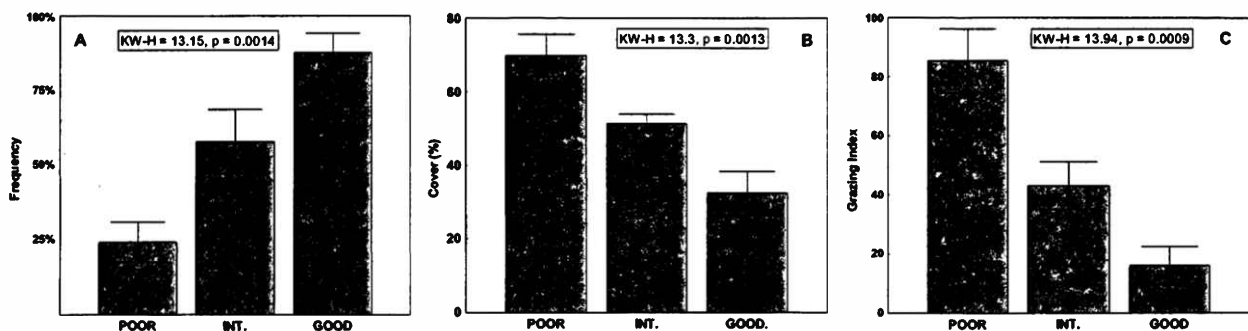

Figure 1. Example comparison of sites in the three condition classes at one of the VRD properties for (a) perennial grass frequency, (b) cover of bare ground, (c) index of recent cattle use. Bars are means, with one SE; Kruskal-Wallis statistic is given in the box.

Biodiversity sampling occurred at 1 ha (100x100m) sites, with groups of sites sampled over a four day period. Within this site, birds were censused during eight diurnal and two nocturnal five-minute visits. Other vertebrates were sampled using 24 Elliott box traps (baited with a mixture of oats, peanut butter, honey and tuna or dog biscuits), four 20 litre pit buckets each with 10 m of drift fence, and three diurnal and two nocturnal, 15-minute searches. Ants were collected using 70 mm diameter pit-traps in a 3 x 5 array, with 10 m between pits, open for 48 hours. Termites were also sampled at selected sites in the NT, although these data are not presented here. A complete floristic list for the site was collected, with cover and frequency of understorey species estimated using 20-25 0.5 sq m quadrats in

a regular grid; these quadrats were also used to measure ground layer cover of vegetation, litter, rock and bare soil. Additional 'habitat' variables were measured at each site, relating to vegetation structure, substrate, recent grazing pressure and fire history.

In this paper we examine whether species composition differs between sites in the three different land condition classes, using ordination (multidimensional scaling, with Bray-Curtis similarity measure and square-root transformed abundance or frequency data) and ANOSIM analysis. We also explore difference between condition classes for species richness and relative abundance of various taxonomic and functional groups, and abundance of individual species, using Kruskal-Wallis tests.

RESULTS

Victoria River District (calcareous loams)

We recorded a total of 240 plant, 72 bird, 9 mammal, 20 reptile, 1 frog and 123 ant species from the 48 VRD sites. There was a pronounced difference in composition between sites from the two areas sampled, for all taxonomic and functional groups (Table 1, Fig. 2). There was also a significant difference between condition classes for composition of all groups other than bird guilds (Table 1), with the poorest separation between classes being for birds. Similar patterns were observed when comparison of condition classes was made separately for the two stations, although the dissimilarity between condition classes for most taxa was more pronounced at one property (VRD2 in Table 1).

Mean plant species richness was lower in "good" sites, which had relatively high richness of perennial grasses but lower richness of annual grasses and annual and perennial forbs (Fig. 3). Richness and abundance of ants was also lower in "good" sites, due particularly to high numbers of "Hot Climate Specialists" (*Melophorus, Meranoplus* and *Monomorium* spp.) in the poorer sites. Reptile richness and abundance was significantly lower in the "poor" sites, with higher numbers of Scincidae in the better sites contributing most to this effect. While there was no significant difference between condition classes in richness or total abundance of birds, there were trends in the relative abundance of bird foraging guilds, the most pronounced being the high abundance of granivores in "poor" sites.

Analysing the response to condition of individual species was hampered by the relative rarity of a high proportion of the flora and fauna. Nevertheless, a number of the more common species in each taxon showed obvious decreaser (more abundant in good sites) or increaser (more abundant in poor sites) response patterns (Fig. 4).

Table 1. Results of ANOSIM analyses testing whether species composition of various taxonomic and functional groups differed between condition classes for: all Burdekin Rangeland sites (BR cond); all Victoria River District sites (VRD cond); and sites at each VRD station (VRD1, VRD2 cond). The effect of location on composition was also tested for VRD sites (VRD loc). Numbers are the ANOSIM R statistic, with significance (ns,$P>0.1$; $*$,$P<0.1$; $**$,$P<0.01$; $***$,$P<0.001$). Letters in brackets are results of pairwise comparisons showing which condition classes were significantly dissimilar (eg. GP, PI indicates "good" sites were different to both "intermediate" and "poor" sites, but the latter two were not dissimilar).

| Group	BR cond	VRD loc	VRD cond	VRD1 cond	VRD2 cond
all plants	0.13* (GP, GI)	0.54***	0.19** (GP, GI)	0.13* (GP, GI)	0.25** (all)
ground layer plants	0.14* (GP, GI)	0.66***	0.20** (GP, GI)	0.14* (GP, GI)	0.25* (all)
ants	0.13* (GP, GI)	0.86***	0.20*** (all)	0.17** (PG)	0.23** (all)
ant functional group	0.07 ns (none)	0.14**	0.16** (GP, GI)	0.23** (GP, GI)	0.08* (GP, IP)
birds	0.02 ns (none)	0.56***	0.09* (GP)	0.11* (GP)	0.08* (GP)
bird guilds	0.03 ns (none)	0.14***	0.02 ns (GP)	0.06 ns (GP)	-0.02 ns (none)
mammals/reptiles	0.27*** (GP, GI)	0.28***	0.22** (GP, GI)	0.15 ns (GP)	0.25** (GP, GI)
all vertebrates	0.27** (GP,GI)	0.59***	0.14*** (GP)	0.09* (GP)	0.20** (GP)
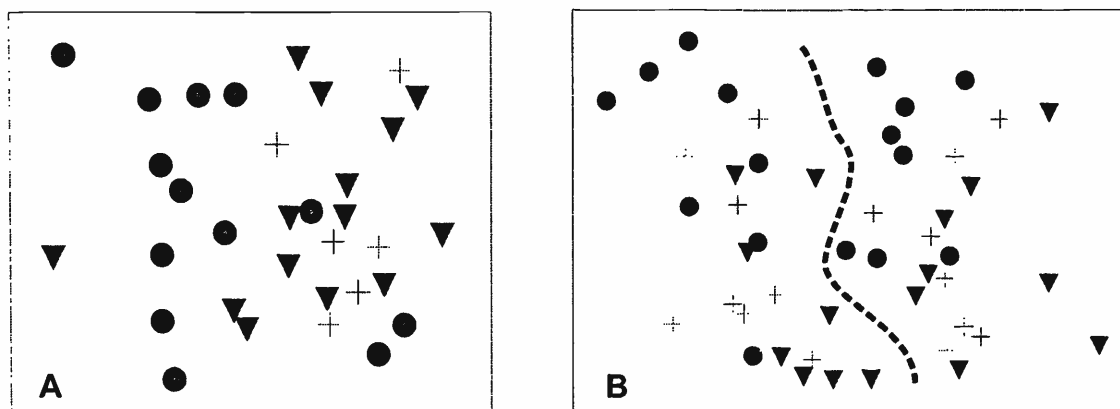
Figure 2. Ordination of sites by species composition for (a) mammals and reptiles at BR sites; (b) ants at VRD sites. Symbols indicate condition: circles, good; crosses, intermediate; triangles, poor. The dashed line on (b) separates sites at the two stations in the VRD.

Burdekin Rangelands (sedimentary soils)

We recorded a total of 210 plant, 70 bird, 12 mammal, 26 reptile, 3 frog and 104 ant species from the 33 BR sites. There was a significant difference between condition classes for composition of plants, ants, mammals and reptiles combined (Table 1), with the effect being most pronounced for the latter group (Fig. 2). In each case, pairwise comparisons showed no significant difference in composition between "intermediate" and "poor" sites, but significant difference between both of these and "good" sites. Bird composition did not differ significantly between condition classes but rather was strongly influenced by local variation in overstorey composition ("Box" vs "Ironbark" woodlands), and further analysis is required to tease out this confounding effect.

The mean richness or total abundance of many taxonomic and functional groups did not differ significantly between condition classes. However, the "good" sites had relatively low richness of plants, high richness and abundance of mammals, high richness of ants, and low abundance of birds (Fig. 3). The abundance of a number of the more frequent species in each taxon also showed pronounced 'increaser' or 'decreaser' responses to condition class. A small number of species were most abundant in the intermediate condition sites (Fig. 4).

DISCUSSION

These preliminary results provide evidence for substantial variation in biodiversity related to variation in land condition, within some tropical savanna land types. We have used only a crude delineation of condition, although we note that this mirrors the simple 'ABC' (or similar) condition assessment schemes presented in a number of Grazing Land Management manuals. Further analysis will examine the relationship between biodiversity variables and specific indicators, such as the frequency of perennial grass and various parameters provided by remote-sensed time-trend analysis.

The variation in composition between condition classes did not translate to a consistent relationship between land condition and species richness for all taxonomic groups. Interestingly, for plants and ants there was higher richness at sites in poorer condition, presumably because a high density of perennial grass excludes many other forbs and provides poor habitat for the many thermophilic ant species. This suggests that one goal of management should be to maintain habitat heterogeneity, rather than aim for a uniform sward of perennial grasses, even though this may appear to represent 'optimal' land condition. Conversely, the high species diversity in poor sites does not imply that entire landscapes in poor condition are desirable (from a biodiversity perspective), because such landscapes would lack many decreaser species.
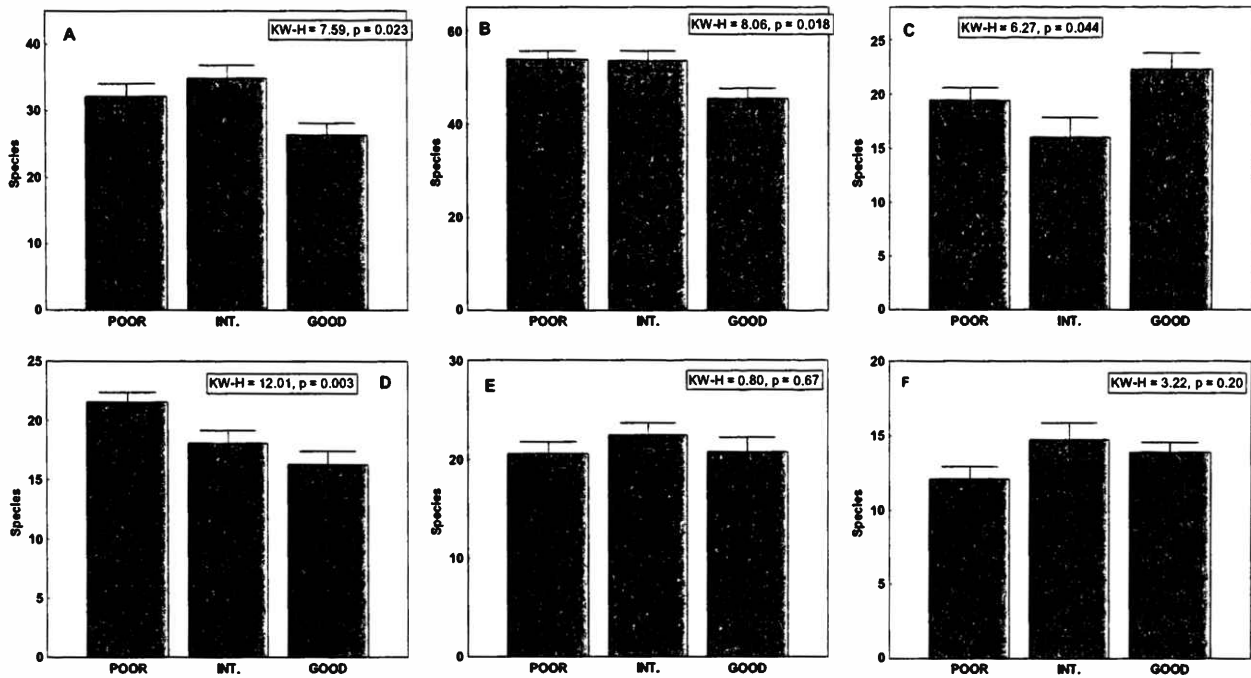
Figure 3. Mean species richness (with one SE) of sites in the three condition classes for (a) plants, BR; (b) plants, VRD; (c) ants, BR; (d) ants, VRD; (e) vertebrates, BR; (f) vertebrates, VRD.
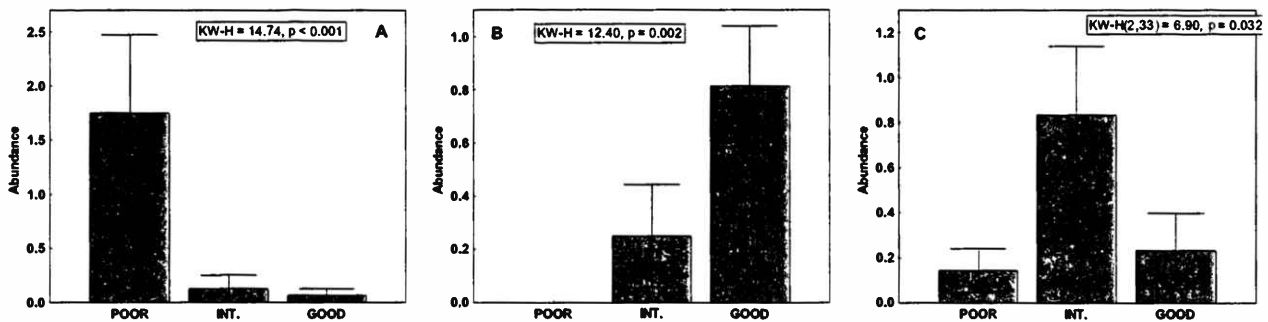

Figure 4. Examples of species' response patterns: (a) Crested Pigeon *Ocyphaps lophotes*, VRD (increaser); (b) Western Chestnut Mouse *Pseudomys nanus*, VRD (decreaser); (c) Robust Rainbow-skink *Carlia schmeltzii*, BR (intermediate).

The relative sensitivity of the various taxonomic and functional groups to differences in condition varied somewhat between sampling locations, although in all cases bird composition was least sensitive. This may reflect the scale of sampling, in that birds integrate variation in the landscape over broader areas than the other taxa considered here. Nonetheless, bird composition was sensitive to relatively minor habitat variation within the BR box/ironbark woodlands, and all taxa showed considerable compositional dissimilarity between the two VRD sample locations. While there were generally consistent responses to condition for species common to the BR and VRD, there is of course a high species turnover between such geographically distant regions. Therefore, to develop predictive relationships between land condition and biodiversity composition that can be widely generalised, we need to be able to confidently allocate taxa to response types, whether from empirical evidence or on the basis of ecological characteristics. This has been attempted for some taxa, such as the functional group classification for ants (eg. Andersen *et al.* 2004). In this study, closely related ants in different locations showed similar response patterns, while response patterns were also consistent between locations for other groups such as bird foraging guilds.

Some of the potential limitations on the use of land condition (as currently assessed) as a surrogate for biodiversity health in rangelands have also become clearer to us in the course of this study. It is likely

that biodiversity responds in a complex fashion to both the spatial and temporal configuration of land condition across a landscape. The increasing use of remote sensing for condition assessment may help overcome the inability of plot-based assessment to provide spatial context, but we still have a very limited understanding of how spatial patterning of condition affects biodiversity at a landscape or regional scale. Equally poor is our knowledge of how biodiversity responds to changes in condition over time and whether regional improvement in condition is matched by similar improvement in biodiversity status. Another important issue is that condition monitoring concentrates on the more extensive pasture types in a region (as we have done in this study). However, rare and restricted ecosystems (eg. riparian zones) may have very high biodiversity significance, and the condition of the surrounding matrix may not adequately describe the condition, or biodiversity status, of these important zones. More generally, our restricted sampling was uninformative about the response of the rarest species to land condition. The lack of true reference sites (i.e. areas with minimal impact from pastoral use over the past century) also means that we cannot readily assess how close the current biotic composition in "good" condition sites is to what may be considered the 'intact' ideal. Finally, perceptions of condition may diverge between pastoral managers and ecologists. Kutt and Fisher (this volume) provide an example of areas dominated by introduced pasture grasses, which would be assessed by conventional monitoring techniques as being in "good" condition, whilst having poor biodiversity status. These limitations do not imply that land condition monitoring can tell us nothing about biodiversity status, but rather support the view that rangeland biodiversity monitoring programs must always incorporate a raft of indicators, operating at a variety of scales (Whitehead *et al.* 2001, Smyth *et al.* 2003).

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