Biodiversity and Land Condition in Tropical Savanna Rangelands

Summary Report

Tropical Savannas CRC
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Contents

Abstract

There are well-established procedures for assessing and monitoring "land condition" in Australian rangelands, but no programs that explicitly monitor biodiversity. The primary aim of this project was to explore the link between land condition and biodiversity in representative areas of Australia's tropical savanna rangelands. By detailed biodiversity assessment at sites in a range of "land condition" states, we investigated what information about biodiversity status may be contained within a simple "poor" to "good" categorisation, and the value as surrogates for biodiversity of commonly-used indicators for land condition such as perennial grass cover. Biodiversity sampling - which included plants, ants and vertebrates – was undertaken at 216 sites in 5 landtypes in two important pastoral regions of northern Queensland and the Northern Territory.

The response of biota to land condition was assessed in term of species composition, total species richness, diversity & abundance (broken down into taxonomic and functional groups), and the abundance of individual species. Land condition appears to be most strongly predictive for components of the biota whose ecology is closely linked to characteristics of the ground surface and density of groundlayer vegetation, most notably ants. However, there was only a weak relationship between land condition and many aspects of biodiversity, and the response of biota to land condition was complex and highly variable between taxa, landtypes and locations. The inconsistent response to condition of many species and functional groups made it difficult to identify components of the biota that are most susceptible to degradation, or identify ecological traits that may be indicators of susceptibility. The incorporation of additional habitat variables (such as litter cover, rock cover, tree canopy cover) substantially improved modelled relationships between land condition and biodiversity attributes. Across the 5 landtypes sampled, there was generally poor surrogacy between major taxonomic groups, in terms of site richness, site diversity and assemblage fidelity.

We conclude, therefore, that land condition is, by itself, too blunt an instrument to adequately monitor biodiversity status in savanna rangelands. Nevertheless, improvements in land condition across rangeland landscapes are likely to have positive biodiversity consequences. The incorporation of additional habitat attributes into site-based condition assessment (in a manner analogous to the "Habitat Hectares" approach, but designed for tropical savanna landscapes) would greatly improve information content about potential biodiversity condition. However, comprehensive biodiversity monitoring programs, at local or regional scale, must include the direct assessment of selected biota.

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). There is now a strong demand for robust and practical methods of assessing biodiversity status at a variety of scales in Australian rangelands. This is driven both by the regional monitoring requirements established under the NHT/NAP NRM framework (eg. http://www.nrm.gov.au/monitoring/indicators/index.html; http://www.nt.gov.au/nreta/naturalresources/plans/inrm/inrmplan/index.html), and the desire of landholders to demonstrate or improve their environmental performance.

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 (such as remote sensing of land cover change and plot-based assessment of pasture composition, perennial plant frequency and soil surface condition), which are often summarised to a simple "poor" to "good" scale. Such simple condition ratings are being widely embraced as mechanisms for land managers to monitor their environmental performance, despite the lack of an explicit biodiversity component, and despite a lack of validation of the utility of most of these indicators to capture temporal and spatial variation of a broad range of biota. Consequently, Whitehead *et al.* (2001) considered that validation of these putative biodiversity indicators was a high priority for further research.

The primary aim of this project was to explore the link between land condition and biodiversity in representative areas of Australia's tropical savanna rangelands. By detailed biodiversity assessment at sites in a range of "land condition" states, we investigated what information about biodiversity status may be contained within simple "poor" to "good" categorisations. We extended this analysis to also assess the value as surrogates for biodiversity health of some commonly-used indicators for land condition (such as perennial grass frequency). We then tested whether more robust predictors of biodiversity attributes could be developed by using other habitat variables in addition to the condition variables. Our data was also used to assess surrogacy amongst major taxonomic groups, in terms of species richness, diversity and assemblage fidelity.

We drew on the results from our study, plus other sources, to describe a framework for a robust monitoring biodiversity monitoring program applicable at regional and local scales in tropical savanna rangelands. We also attempted to prescribe some management guidelines that will assist the retention of biodiversity in Australia's northern rangelands.

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 640mm) in the Northern Territory and the Burdekin Rangelands (BR; Einasleigh Uplands bioregion; 19°S 145°E; mean annual rainfall at Greenvale 630mm) 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. 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 km^2, vs 1000-5000km^2 in the VRD) and generally higher stocking rates (10-25 AE/km^2, vs 5-15).

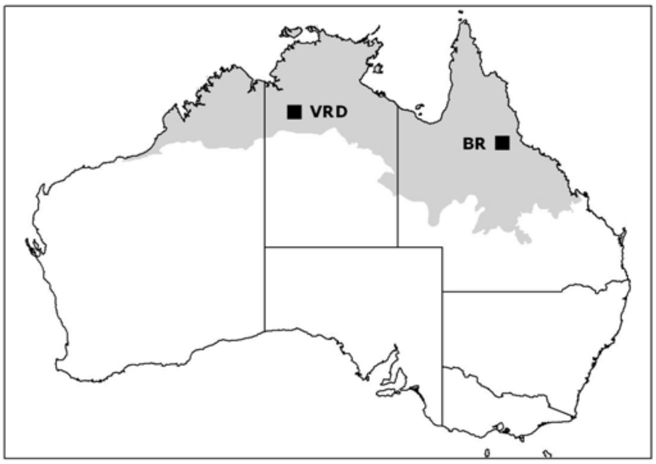

Figure 1. General location of study sites in the Victoria River District (VRD) and Burdekin Rangelands (BR). The extent of the tropical savannas in northern Australia is shaded.

The development of this project was informed by a preliminary study undertaken in the VRD in 1999, when we sampled 45 kandosol sites on 5 properties. In the main study, we sampled a further 216 sites equally divided between VRD and BR. This included 24 sites within the Wambiana grazing trial (BR; O'Reagain *et al*. 2004) which were resampled after a 5-year period in order to test whether changes in land condition, due more or less aggressive stocking regimes, were reflected by changes in biota. In this report, we refer to the 'resilient' sites in the VRD and BR as 'NT clay' and 'QLD basalt' respectively, and the 'sensitive' sites in the VRD and BR as 'NT loam' and 'QLD sedimentary' respectively. The Wambiana sites are differentiated as 'QLD alluvial' sites, and are intermediate in their resilience to impacts of stocking pressure.

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 NRETA (derived from cover-change analysis of a time series of satellite imagery from the 10 years preceding sampling; Karfs *et al*. 2000), supported by aerial and ground inspection. In the BR, site selection was guided by trend patterns in remote sensing (B. Karfs pers. comm.) and 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. All sites were attributed to three simple land condition classes - "good", "intermediate" and "poor" – using the criteria of pastoral land monitoring. These correspond approximately to the "A", "B" and "C" land condition classes a sdecsribed in Grazing land Management (GLM) education packages (eg. Chilcott *et al.* 2003).

Biodiversity sampling occurred at 1ha (100x100m) sites, with groups of sites sampled over a 4 day period. Within a site, birds were censused during 8 diurnal and 2 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 10m of drift fence, and 3 diurnal and 2 nocturnal, 15-minute searches. Ants were collected using 70mm diameter pit-traps in a 3 x 5 array, with 10m between pits, open for 48 hours. A complete floristic list for the site was collected, with cover and frequency of understorey species estimated using 20-25 0.5m^2 quadrats in a regular grid; these quadrats were also used to measure ground layer cover of vegetation, litter, rock and bare soil. Additional 'habitat' and 'disturbance' variables were measured at each site, relating to vegetation structure, substrate, recent grazing pressure and fire history.

Four major sets of analyses were carried out on the biodiversity and other data. The first set examined differences between "poor", "intermediate" and "good" condition sites within each landtype for:

- groundcover, grazing impact and 'habitat' variables;
- species richness, relative total abundance and diversity indices, broken down by taxonomic and functional groups (eg. all vertebrates; all birds; aerial insectivore guild);
- species composition (summarised by similarity matrices), broken down by taxonomic and functional group;
- relative abundance of all individual species (that occurred in sufficient sites to be analysable).

An additional complication was introduced when it became obvious that there were significant biotic differences between box- and ironbark-dominated sites in Qld sedimentary and alluvial landtypes, and between two broad locations in the NT loam landtype, so these were treated as sub-landtypes in the analyses. The response of each variable or species to condition was categorised into 9 response types. A meta-analysis examined the consistency of response types across landtypes (or sub-landtypes) and sought to identify taxonomic or functional predictors of response type.
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A second set of analyses quantified the relationship between individual continuous variables considered to be indicators of condition (bare ground cover; understorey cover; perennial grass frequency and cover) and species composition, biodiversity summary variables, and abundance of individual species, using regression modelling. Again, a meta-analysis sought common (or conflicting) response patterns across landtypes, and taxonomic or functional predictors of these.

The third analyses tested whether endogenous environmental variation (even within the deliberately homogenous set of sites sampled) was better able to predict biodiversity attributes than land condition. Vector fitting within the ordination for each species group in each landtype was used to determine which habitat variables (eg. crown cover, basal area, rock cover, log density) were the strongest predictors for each major taxonomic group. These were then included, along with condition variables, in multiple regression models for each biodiversity variable or species abundance. Again, results were compared across taxonomic groups and landtypes.

The fourth analysis tested surrogacy between major taxonomic groups (ie. whether patterns observed across sites for one taxa were similar to patterns observed for other taxas). Surrogacy was tested for species richness and diversity of taxonomic groups (and some principal functional groupings), and for assemblage fidelity (a comparison of the compositional similarity matrices for each taxa).

Results

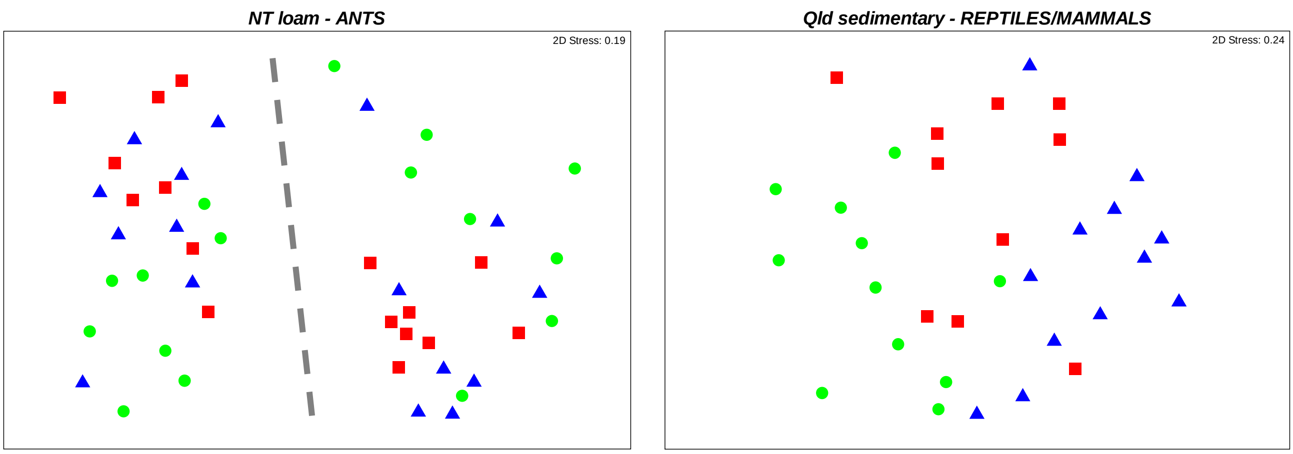
From all sample sites, we recorded a total of 523 plant, 136 bird, 21 mammal, 41 reptile and 300 ant species. As expected, there was considerable species turnover between land types and between regions. However, there was also significant composition dissimilarity within the NT loam landtype between locations (5 pastoral properties in the pilot study and 2 properties in the main study); and within the Qld sedimentary and alluvial sites associated with variation in vegetation (box- or ironbark-dominated systems within a single regional ecosystem).

There was no significant variation in 'habitat' variables (with a few exceptions) between sites in the three condition classes, suggesting that they had been successfully chosen to minimise environmental variation. By contrast, there were substantial differences between condition classes in groundcover variables typically used to characterise "land condition", as well as variables indicating recent cattle use. "Poor" condition sites typically had high cover of bare ground and low cover and/or frequency of perennial grasses.

Land condition classes and biodiversity

Land condition clearly has some effect on biodiversity, although the extent of this effect was variable between landtypes and major taxonomic groups. There was not a simple relationship between the strength of the condition effect and whether a landtype was considered resilient or sensitive.

For the NT loam, Qld basalt and Qld sedimentary landtypes, there were significant differences between condition classes in <u>composition</u> of most taxonomic groups (Fig. 2, Table 1). The strength of the condition effect generally declined in the order of plants, ants, birds, other vertebrates, although the condition effect was most pronounced for birds and other vertebrates in Qld sedimentary sites. The condition effect was weakly significant only for plants and ants in NT clay sites, and significant only for plants in Qld alluvial sites (although the latter result may be partly influenced by lower sample size in this landtype). Expressing composition in terms of functional groups within the major taxa reduced, rather than improved, the strength of the condition effect in all cases. In the NT loam, Qld sedimentary or Qld alluvial landtypes, the effect of location or vegetation type on condition was more pronounced than the effect of condition (except for ants and vertebrates in Qld sedimentary sites). It is important to recognise that in all cases the relationship between land condition and species composition is at best fuzzily defined (ie. there is some overlap between sites in the different condition classes in ordination space).



<u>Figure 2</u>. Example ordinations of sites by species composition for (a) ants at NT loam sites; (b) mammals & reptiles at Qld sedimentary sites. Symbols indicate condition: green circles, good; blue triangles, intermediate; red squares, poor. The dashed line on (a) separates sites at two locations (but similar soil and vegetation type) in the VRD.

	NT loam	NT clay	Qld basalt	Qld sedimentary	Qld alluvial
sites	*48*	*56*	*48*	*34*	*24*
All plants	***	**	***	***	***
Ground layer plants	***	**	***	***	*
Ants	***	*	***	***	ns
Ant functional groups	**	ns	**	**	ns
All vertebrates	**	ns	***	***	ns
Birds	**	ns	***	***	*
Bird guilds	ns	ns	*	**	ns
Mammals & reptiles	*	ns	*	***	ns

Table 1. ANOSIM analyses testing whether species composition of various taxonomic or functional groups differs between condition classes for each land type. Significant effects of condition are indicated by *=P<0.1, **=P<0.01, ***=P<0.001 (ns=P>0.1).

Land condition had some influence on site species richness and Shannon-Wiener diversity, although the relationship was not consistent across taxonomic groups or between landtypes (Table 2, Fig. 3). The strongest response and most consistent patterns were for the Qld basalt landtype, where poor condition sites had the lowest richness of plants, ants, birds, reptiles and mammals. By contrast, in Qld sedimentary landtype, good sites had the lowest mean plant richness, intermediate sites the lowest ant richness, but intermediate sites the highest vertebrate and bird richness (and there was no significant relationship for reptiles or mammals richness). Ant richness was highest on poor condition sites in the NT loam landtype, but highest on good sites in the NT clay landtype.

In general, between 25% and 55% of species (that occurred in sufficient sites for analysis) in each major taxonomic group and landtype showed a significant response to condition class (Table 3, Fig. 4). However, the relative proportion of species with each response type (eg. increaser, decreaser) varied substantially between land types and taxonomic groups. For example, NT clay and Qld basalt (resilient) landtypes had relatively high proportions of

		NT loam	NT clay	Qld basalt	Qld sedimentary	Qld alluvial
	sites	*48*	*56*	*48*	*34*	*24*
Plants	richness	*	-	***	**	-
	diversity	**	-	***	*	-
Ants	richness	**	**	***	*	-
	diversity	*	**	***	*	-
Vertebrates	richness	-	-	***	***	-
	diversity	-	-	-	*	-
Birds	richness	-	*	**	***	-
	diversity	-	-	**	*	-
Reptiles	richness	**	-	-	-	(*)
	diversity	**	-	*	-	(*)
Mammals	richness	-	-	**	(*)	-
	diversity	-	-	**	(*)	-

Table 2. Summary results for comparison of species richness & Shannon-Wiener diversity of various taxonomic groups between condition classes. Significant effects of condition are indicated by *=P<0.1, **=P<0.01, ***=P<0.001. (*) indicates significant in only one of two sub-landtypes.

decreaser plants and ants, and relatively low proportions of increasers in these taxa. By contrast, NT loam and Qld sedimentary (sensitive) landtypes had low proportions of decreasers and high proportions of increasers in these taxa. However, Qld basalt sites had few increaser bird species, while NT clay sites had a high proportion of increaser, but few decreaser, birds. The Qld sedimentary landtype was notable for a relatively high proportion of species that were most abundant in intermediate condition sites. Increaser and decreaser species were identified in most taxonomic groups in each landtype, except that there were no increaser mammal species (although there were few mammals that occurred in many sites).

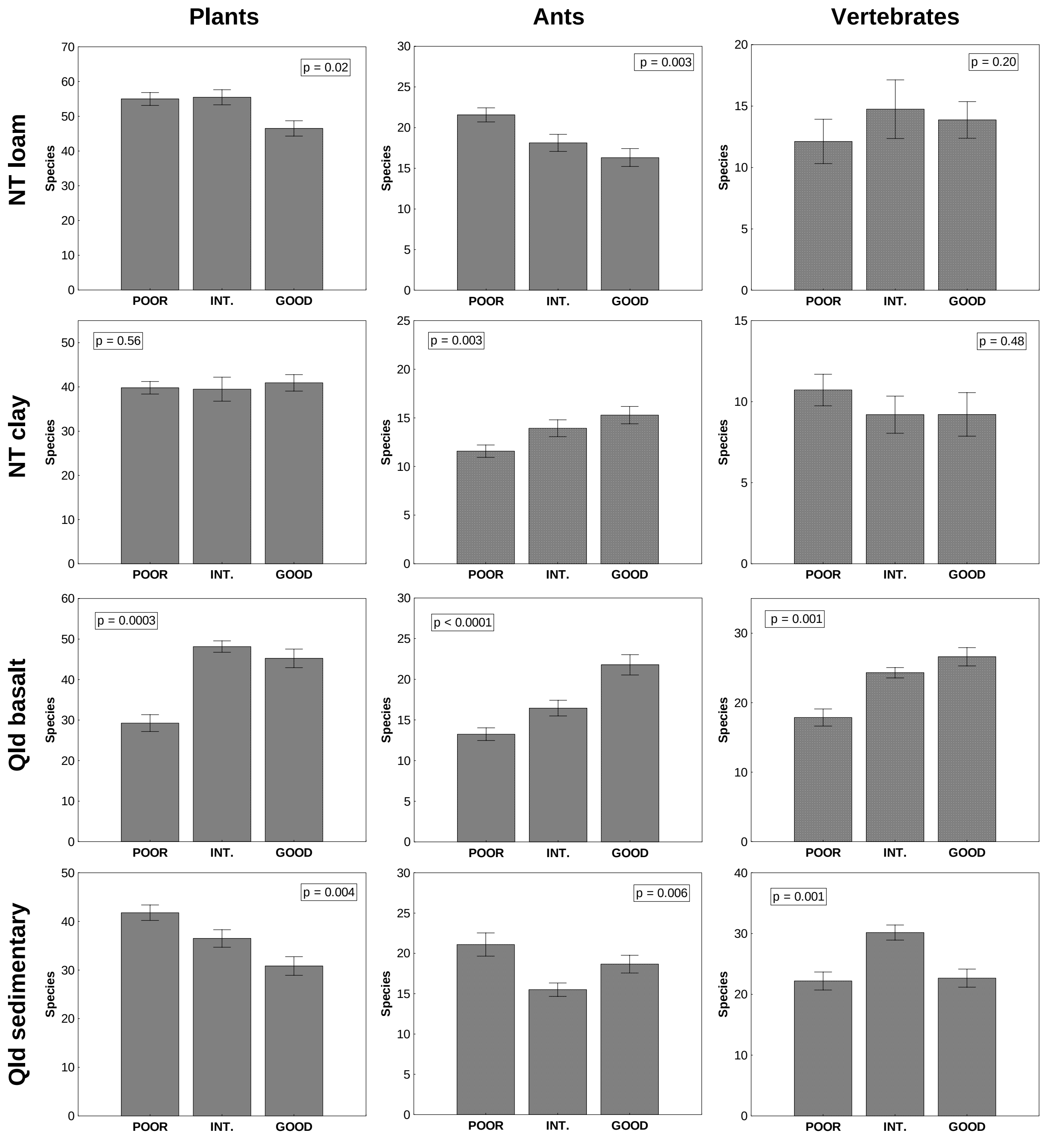


Figure 3. Variation in mean species richness of plants, ants and all vertebrates between condition classes, in four landtypes. P value is the significance of a Kruskal-Wallis test for difference between condition classes.

		NT loam	NT clay	QLD bas	QLD sed	QLD alv
Sites		*48*	*56*	*48*	*34*	*24*
Species analysed	*P*	*123*	*97*	*96*	*85*	*75*
	A	*56*	*37*	*63*	*64*	*33*
	B	*32*	*34*	*64*	*59*	*43*
	R	*10*	*12*	*19*	*20*	*12*
	M	*3*	*5*	*5*	*4*	*5*
Increaser	P	35.4%	17.6%	11.5%	26.9%	3.6%
	A	33.3%	5.4%	12.8%	19.2%	23.7%
	B	15.4%	35.3%	6.3%	20.6%	14.6%
	R	-	25.0%	10.5%	29.1%	7.1%
	M	-	-	-	-	-
Intermediate	P	6.4%	4.1%	6.3%	10.3%	12.0%
	A	4.5%	2.7%	-	6.8%	5.3%
	B	12.8%	-	1.6%	27.9%	-
	R	10%	8.3%	-	12.5%	7.1%
	M	-	-	-	25%	25%
Decreaser	P	14.1%	28.8%	30.2%	10.3%	6.0%
	A	16.7%	29.7%	23.8%	6.8%	7.9%
	B	23.1%	8.8%	20.4%	7.3%	10.4%
	R	40%	-	10.6%	16.7%	14.2%
	M	33.3%	20%	20%	-	-
Extreme	P	-	2.1%	-	8.2%	3.6%
	A	1.5%	-	1.6%	5.5%	2.6%
	B	-	2.9%	-	2.9%	2.1%
	R	-	-	-	-	-
	M	-	-	-	-	-
Neutral	P	49.6%	47.4%	51.0%	43.3%	74.7%
	A	42.4%	62.2%	61.9%	56.2%	60.5%
	B	46.2%	52.9%	71.9%	41.2%	72.9%
	R	50%	66.7%	78.9%	41.7%	71.4%
	M	66.6%	60%	80%	75%	75%

Table 3. For each landtype, proportion of individual species in each major taxonomic group (P=plants; A=ants; B=birds, R=reptiles, M=Mammals) that have a significant difference in abundance between condition classes, divided into 5 response types. The proportion is of the total number of species in that group and landtype that occurred in sufficient sites for analysis, as shown in the second row.

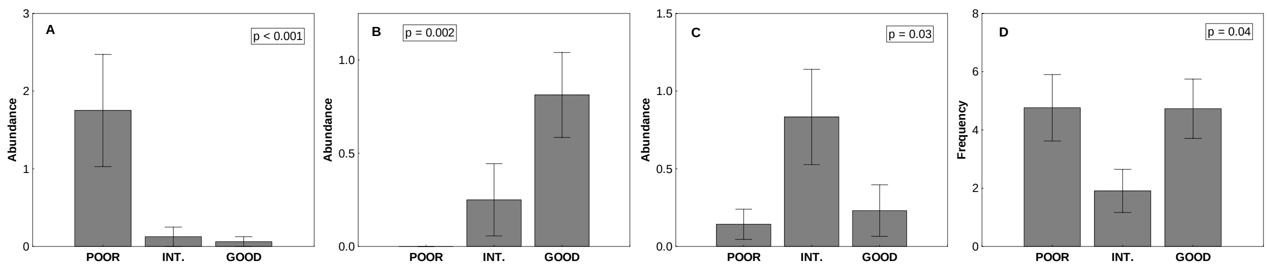


Figure 4. Examples of species' response patterns: (a) INCREASER: Crested Pigeon *Ocyphaps lophotes*, NT loam; (b) DECREASER: Western Chestnut Mouse *Pseudomys nanus*, NT loam; (c) INTERMEDIATE: Robust Rainbow-skink *Carlia schmeltzii*, Qld sedimentary; (d) EXTREME: Pea-bush *Sesbania simpliuscula*, NT clay.

Between 20 and 30% of all species in each taxonomic group had a significant response to condition in more than one landtype. However, very few species had a consistent response across landtypes. In fact, many species showed a contradictory response (eg. increaser and decreaser) in different landtypes, or even within sub-types within one landtype. This made it difficult to identify attributes that may predict species' response to condition. Unsurprisingly, all plant species with a consistent decreaser response were palatable perennial grasses. Amongst bird functional groups, Granivore and Foliage/Trunk Insectivore foraging guilds had a relatively high proportion of increaser species, whilst Ground Insectivore and Foliage Insectivore/ Nectarivore guilds had relatively many decreaser species.

Land condition variables and biodiversity

Continuous variables commonly used to assess condition (bare ground cover, understorey cover, perennial grass cover) had significant predictive power for many biodiversity variables in most landtypes (Table 4). However, most regression models were relatively weak; for example, explaining between 7% and 16% of the variation in plant species richness. The models were generally strongest for ant richness (although not in the NT loam landtype), and there were relatively strong models for bird richness in the Qld sedimentary landtype. Model adequacy was similarly variable for functional groups in different landtypes, although models tended to be relatively strong for richness and/or abundance of Hot Climate Specialist ants and Granivore bird guilds.

		NT loam	NT clay	QLD bas	QLD sed	QLD alv
Sites		*48*	*56*	*48*	*34*	*24*
Species analysed	*P*	*123*	*97*	*96*	*85*	*75*
	A	*56*	*37*	*63*	*64*	*33*
	B	*32*	*34*	*64*	*59*	*43*
	R	*10*	*12*	*19*	*20*	*12*
	M	*3*	*5*	*5*	*4*	*5*
Species richness (% deviance explained)	P	16	10	7	-	-
	A	-	20	32	12	14
	V	-	-	-	25	10
	B	-	13	-	29	-
	R	13	6	-	-	14
	M	-	8	7	10	-
% Species significant	P	36	58	22	27	33
	A	46	42	40	28	32
	B	38	62	20	32	13
	R	50	42	21	29	43
	M	67	40	50	0	0
% deviance explained in species models range (mean)	P	7-52 (18.5)	5-53 (12.5)	8-26 (13.8)	10-44 (21.0)	13-46 (29.8)
	A	9-44 (20.1)	6-28 (12.7)	7-23 (12.0)	10-33 (18.2)	13-53 (24.6)
	B	9-35 (15.6)	7-28 (13.0)	6-16 (10.1)	11-54 (26.4)	13-41 (26.8)
	R	9-47 (22.5)	8-25 (17.6)	9-20 (13.0)	10-21 (13.8)	13-22 (16.7)
	M	14-24 (19.0)	18-24 (21.4)	- (11.0)	-	-

Table 4. Summary results from regression models testing the relationship between continuous variables used to assess condition (bare ground cover, understorey cover, perennial grass) and biodiversity variables, for each landtype. Third row shows % deviance explained in models for total species richness of major taxonomic groups (P=plants, A=ants, V=all vertebrates, B=birds, R=reptiles, M=Mammals). Fourth row shows the proportion of species (that occurred in sufficient sites to analyse) for which there was a significant model (models with <5% deviance explained were discarded); fifth row shows the range and mean for % deviance explained.

The continuous condition variables also had some predictive power for the relative abundance of 13-67% of individual species (that occurred in sufficient sites to analyse) in each taxonomic group and landtype (Table 4; ignoring mammals, for which there were few analysable species). Again, models were generally weak (mean deviance explained ranges from 10-30%), but explained over 50% of deviance in the abundance of a small number of species. In general, predictive power was greater in the sensitive landtypes than the resilient ones.

Two other variables used to describe land condition – perennial grass frequency and perennial grass basal area – did not perform better than perennial grass cover in the predictive models for biodiversity variables, in NT landtypes.

Other habitat variables and biodiversity

For most major taxonomic groups in most landtypes, other habitat variables were more strongly correlated than condition variables with the arrangement of sites in ordination space (ie. they are more strongly related to species composition). Important habitat variables varied between taxonomic group and landtype but generally included a variable relating to ground cover (notably litter cover); one or two variables relating to the density of the mid or upper vegetation layers; and a variable relating to land use impacts (dung score, grazing score or distance from water).

Most predictive models for biodiversity variables and abundance of individual species were significantly improved (from that using condition variables) by the addition of one or more habitat variables (Table 5). When habitat variables were included, there were significant models for 35-86% of individual species in each taxonomic group and landtype, and the mean deviance explained by these models improved substantially. The improvement was most marked for the Qld basalt landtype. In general, all habitat variables tested were useful in at least some models, and their relative importance varied both between landtypes and taxonomic groups.

		NT loam	NT clay	QLD bas	QLD sed	QLD alv
Sites		*48*	*56*	*48*	*34*	*24*
Species richness (% deviance explained)	P	16	27	57	12	-
	A	19	32	52	44	14
	V	8	-	-	25	10
	B	8	13	37	29	-
	R	20	6	-	-	15
	M	16	8	9	21	-
% Species significant	P	71	73	57	52	54
	A	73	61	71	42	61
	B	66	71	72	53	35
	R	70	58	57	43	86
	M	67	60	50	0	33
% deviance explained in species models range (mean)	P	6-52 (18.9)	6-61 (21.1)	6-59 (17.6)	9-44 (22.0)	13-77 (33.9)
	A	8-58 (21.5)	7-38 (16.9)	7-80 (19.1)	10-40 (23.1)	14-64 (30.5)
	B	9-40 (18.5)	8-37 (15.5)	6-91 (22.2)	9-24 (25.2)	16-41 (27.3)
	R	8-47 (26.0)	6-37 (18.4)	7-36 (16.0)	12-33 (19.5)	13-61 (31.7)
	M	16-46 (30.8)	18-24 (20.8)	(11.0)	-	(15.0)

Table 5. Summary results from the inclusion of additional habitat variables in regression models testing the relationship between continuous condition variables and biodiversity variables (as for Table 4).

Surrogacy

Each major taxonomic group was generally a poor surrogate for other taxa. Apart from taxonomic groups that were obviously related (such as vertebrates and birds), correlations between most taxa were weak or not significant for both total species richness and Shannon diversity. Across all sites there was a relatively strong correlation between richness of perennial grasses and richness of vertebrates, birds, bird guilds and reptiles (although this was not true for all landtypes). Interestingly, plant diversity was relatively strongly negatively correlated across all sites with vertebrate richness and diversity, bird diversity and bird guild richness, and reptile richness Assemblage fidelity between less-related taxonomic groups was quite variable between landtypes, although in few cases was there a strong correlation (>0.5) between similarity matrices. Ant functional groups and bird guilds were generally poor substitutes for the use of all bird and ants species in compositional analysis.

Other results

Changes in land condition within the grazing trial at Wambiana over 5 years were accompanied by substantial changes in biodiversity (Kutt *et al.* 2004). Encouragingly, improvements in condition in lightly-grazed treatments (despite severe drought condition over the last three years of the trial), were accompanied by increased abundance of a number of species known to be decreasers (e.g. the small mammals *Leggadina lakedownensis* & *Planigale maculata*), suggesting the biota in that area has retained some capacity to recover.

An important consideration when assessing land condition was highlighted by the sites in the Qld basalt landtype, approximately half of which contained varying cover of the introduced perennial grass *Bothriochloa pertusa*. The relative cover of *B. pertusa* had a pronounced influence on the composition of vertebrates at these sites, particularly birds. The species richness of both vertebrates and plants was also significantly lower at sites with high cover (>5%) of *B. pertusa* (Kutt & Fisher 2004). This grass species is considered palatable and productive and sites with a high cover of *B. pertusa* would be rated in relatively good condition from a pastoral perspective. However, the biodiversity at these sites would not be comparable to good condition sites with a high cover of native plant species.

Summary

In summary, land condition, as it is typically assessed and monitored in savanna rangelands, provides some information about the status of biodiversity. This is particularly so in some landtypes, where there is a strong contrast between good and poor sites. Unsurprisingly, land condition appears to be most strongly predictive for components of the biota whose ecology is closely linked to characteristics of the ground surface and density of ground layer vegetation, notably ants. However, land condition is only weakly predictive of many components of biodiversity, and the response of biota to land condition is complex and highly variable between taxa, landtypes and locations. We conclude, therefore, that land condition is, by itself, too blunt an instrument to adequately monitor biodiversity status in these rangelands. Nevertheless, improvements in land condition across rangeland landscapes are likely to have positive biodiversity consequences.

The study helped to clarify some of potential limitations and difficulties in the use of land condition as a surrogate for biodiversity health in rangelands. These include:

- biodiversity likely responds in a complex fashion to the spatial configuration of land condition across the landscape. Biodiversity status will be poorly predicted by limited point assessment of land condition;
- current biodiversity status is likely influenced by the history of land condition, other management influences such as fire frequency, and fine-scale climate variability, factors which are not necessarily reflected by current condition;

- rangeland condition assessment generally fails to capture the condition of rare and restricted ecosystems, although these are generally areas of high biodiversity significance;
- simplistic categorisations of land condition cannot adequately encompass the range of responses found in many biotic groups across different habitats;
- perceptions of condition (and changes in condition) may diverge between ecological and production viewpoints (for example, in relation to introduced pasture and woody thickening).

While we identified the response to condition of many species in 5 landtypes, this study was largely unsuccessful in generalising which components of biodiversity are most susceptible to deterioration in land condition. Rather, we showed that the response to land condition at the level of major taxonomic groups, functional group and individual species is quite idiosyncratic, with few consistent (and many inconsistent) responses across different landtypes and within groups. This meant that it was difficult to identify ecological traits that were useful predictors of response to condition. A similar idiosyncratic response in many species has been noted in grazing gradient studies across arid rangeland environments (Landsberg *et al.* 1997).

The Technical Report includes an overview of the literature concerning biodiversity decline in tropical savannas, and rangelands more broadly. Some faunal groups have been identified as having a high proportion of declining species (such as granivorous birds; Franklin 1999, Franklin *et al.* 2005). Interestingly, this study identified a relatively high proportion of granivorous birds as increaser species, emphasising that a broad range of responses to condition is likely to be found in most groups.

Biodiversity monitoring in tropical savanna rangelands

Our study concluded that current programs for monitoring rangeland condition are insufficient to adequately monitor the health of biodiversity in the northern Australian rangelands. A number of related studies have also sought to develop robust frameworks for monitoring biodiversity in the Australian rangelands more broadly (Whitehead *et al.* 2001, Smyth *et al.* 2003, Hunt *et al.* 2006). Appropriate monitoring programs will depend on the purpose of monitoring (eg. adaptive management; reporting on environmental performance; regulatory requirements), scale (State, regional, enterprise, property, paddock, ecosystem) and resources (technical, logistic and financial). While a broad range of surrogates can be monitored, and it is appropriate to do this at broader scales, we emphasise that a comprehensive biodiversity monitoring program will require direct assessment of selected biota and a considerable investment in both effort and expertise.

In the Technical Report, we review previous efforts to develop or refine programs for rangeland biodiversity monitoring, and extract important guidelines and a ‘best-bet’ list of indicators for biodiversity (primarily based on that in Hunt *et al.* (2006)). These will form a solid basis for the develop of biodiversity monitoring programs at regional or enterprise scales, appropriate to tropical savanna rangelands, but we emphasise that such programs must be developed on a case-by-case basis though consultation between management bodies and biodiversity experts. Paucity of basic biodiversity information, lack of fine-scale environmental mapping and difficulty in precisely delineating biodiversity values remain substantial bars to successful biodiversity monitoring in many regions of the northern rangeland.

Several schemes have also been recently developed or are proposed for rapid assessment of “habitat condition” in more intensively used parts of southern Australia (eg. Habitat Hectares: Parkes *et al.* 2003; Biodiversity Benefits toolkit: Oliver 2004; BioMetric Decision Support Tool: Gibbons *et al.* 2004) and grazed lands in Queensland (BioCondition Tools; Eyre 2006).

Based on the results of this study, we recommend 5 key areas for further work, which will contribute to improved techniques for biodiversity monitoring:

i) Incorporation of additional important habitat variables into site-based condition assessment (similar to the Habitat Hectares and BioCondition Tools approach). This study has demonstrated that these variables can have high predictive power for at least some biodiversity components. Appropriate variables in the landtypes we sampled included those relating to habitat complexity in the understorey (litter cover, density of fallen logs, termite mounds) and structural complexity of overstorey vegetation. Additional studies should refine appropriate habitat indicators for a broad range of landtypes and regions.

ii) "Benchmarking" to describe the expected richness and composition of various components of the biota in a range of landtypes and vegetation types in very good condition, through a combination of sampling "best-on-offer" sites and reference to existing and historical data. This is important in order to be able to test whether the fauna and flora actually remains intact (or near-intact) in sites that are rated in good "biodiversity condition" using habitat indicators.

iii) Further investigation of the relationship between biodiversity condition and spatial configuration of patches in different land condition states across broader landscapes. This is important in order to be able to link biodiversity status to landscape-scale condition assessment derived from remote sensing.

iv) Continued baseline biodiversity survey at regional scales, using repeatable (and well-documented methodology). The value of resampling large numbers of sites for revealing long-term trends in biodiversity status have been demonstrated in several locations in northern Australia (eg. Woinarski & Catterall 2004; Woinarski *et al.* 2006).

v) Implementation of model biodiversity monitoring programs (that incorporate direct assessment of select biota) at enterprise, reserve or regional scales. There remain very few examples in northern Australia, and the value of these as demonstration programs cannot be overstated.

Retention of biodiversity in Australia's northern rangelands

Ee used the results of this study, published reports (eg. McIntyre *et al.* 2002, Hunt 2003, Fisher *et al.* 2004, Williams 2004), unpublished data and the knowledge of the project team[1] to develop broad guidelines for land management that will help to maintain biodiversity values (see box below). Many of the guidelines are generally applicable, but site- or region-specific information relating to biodiversity values and threats may also be required, and we note that in some regions such information may be difficult to access, or non-existent. Ideally, these management guidelines would be applied in concert with appropriate biodiversity monitoring in an adaptive management framework.

[1] including material available on the Tropical Savannas CRC "North Australia Land Manager" website: http://www.landmanager.org.au/

Management guidelines for retention of biodiversity in tropical savanna rangelands.

These guidelines are primarily aimed at management at an enterprise scale, and complement biodiversity management actions at regional (as defined in regional Natural Resource Management Plans) and State scales (eg. NT Parks and Conservation Masterplan).

1. Maintain cover and diversity of native perennial grasses

- this will help guarantee the survival of many native plant and animal species
- this is already a goal of good pastoral management, and ways to achieve it are described in Grazing Land Management manuals (noting that the use of exotic species is counter-productive)
- management strategies may include conservative and/or variable stocking rates, wet-season spelling, rotational grazing, and the maintenance of appropriate fire regimes

2. Where possible, use grazing strategies that rest large areas of country

- this will assist in the seeding and recruitment of native plant species, improve breeding success in some native animals, and reduce predation on some species
- may be achieved by wet-season spelling or rotational grazing systems
- particularly important where there are high stocking rates

3. Protect special areas, by fencing out stock if necessary

- special areas include key habitat for threatened species; important breeding areas for animals (such as waterbirds); vegetation types that are very sensitive to grazing; and remote or unwatered country (see below)

4. Where possible, retain and protect natural waterholes

- waterholes and creeklines are usually rich in plant and animal species; contain species that are not found elsewhere in the region; and often have special species or breeding areas
- these areas are also vulnerable to damage by concentration of stock
- where possible, fence off waterholes and major creeklines and pipe water outside the fences (although not into previously ungrazed areas)

5. Retain some areas on the property (of each habitat) with little or no grazing pressure

- this will help maintain populations of all species on the property, particularly the ones most sensitive to grazing
- ideally, the non-grazed areas would be 5-10% of the area of each land type on the property
- ideally, these areas would be in a few large blocks rather than tiny, scattered areas
- having little or no grazing pressure may be achieved by controlling the spread of waterpoints and/or by fencing “refuge areas”
- this principle becomes more important as pastoral use is intensified

6. Try to maintain a variety of burning regimes

- different plant and animal species require different fire regimes – so a variety of burning practices will benefit most species
- avoid either no fire, or very frequent fire, over large areas of country
- avoid burning large areas of country in most years
- a patchy pattern of burning is ideal, with some areas that are not burnt for a long time. This can be achieved through cool winter burns, or storm burning

- the period areas are best left unburnt will vary from region to region, and local information should be sought as to appropriate periods

7. Maintain structural and micro-habitat diversity

- leaf litter, fallen logs, standing dead trees, large trees with hollows and termite mounds are important are all important habitat for some species
- a diverse midstorey with trees and shrubs of a variety of ages and sizes contributes to habitat diversity
- avoid grazing and fire regimes that reduce this diversity over substantial areas

8. Control problem weeds and restrict further spread

- this is a standard management practice on most properties
- identify and target weed species that threaten special areas or special species (eg. taking over areas used by breeding waterbirds)
- exotic pasture species can be considered as weeds to native wildlife. Ideally all introduced species should be avoided, but if exotic pastures occur, prevent these species becoming dominant over large areas

9. Control feral grazing animals

- this is a standard management practice on most properties, and reduces total grazing pressure
- concentrations of feral animals may damage special habitats, even in areas set aside for conservation

10. If possible, reduce numbers of feral predators

- cats (and in some areas, foxes) kill large numbers of native animals, but are very difficult to control
- dingos may help keep cat and fox numbers down. Dingos can also help control feral pig numbers (which damage wetlands and riparian areas), and reduce the numbers of large macropods (which contribute to total grazing pressure.

11. If possible, avoid clearing native vegetation

- clearing, especially over large areas, dramatically affects many native plants and animals
- if clearing is considered essential, restrict clearing to <30% of each land type (habitat) on each property, and create mosaics of cleared and uncleared vegetation, rather than extensive clearings.
- retain substantial buffers of native vegetation around watercourses and wetlands, and retain connecting strips of native vegetation within cleared areas
- the trade-off for clearing should be lower stocking rates and/or improved spelling in other parts of the property
- in certain cases, it may be important to control the invasion of native grasslands by woody plants, or ecologically undesirable thickening of tree or shrub layer, through appropriate fire management

12. If possible, avoid using introduced pasture plants

- where introduced pastures are considered essential, make sure introduced species can't spread outside a controlled area
- prevent exotic pastures from becoming dominant monocultures, as this can reduce wildlife diversity, and eliminate palatable native grasses
- restrict introduced pastures to a small, concentrated portion of the property (such as those that are already cleared or in poor condition)
- the trade-off for introduced pastures should be lower stocking rates in other parts of the property

13. Be informed about biodiversity

- find out what habitats and species occur on your property
- try and observe annual and seasonal patterns of wildlife on your property

- find out where the special places and special species occur, and what special management they might require
- seek expert advice or assistance if necessary

14. Be aware of changes in biodiversity

- are some species declining or disappearing?
- are some species getting more common?
- are new feral (pest) species appearing?
- these changes may indicate management issues that need to be addressed
- if possible, keep a record of your biodiversity observations

15. Have a property management plan that considers biodiversity

- the plan would address all the issues listed above
- the biodiversity management section would integrate with the property grazing land management systems
- the property plan should be developed in the context of regional biodiversity values, neighbouring and regional landuse patterns, and regional and State NRM or conservation plans
- seek expert advice or assistance if necessary

Further Information

Additional information can be sought from Alaric Fisher (alaric.fisher@nt.gov.au) or Alex Kutt (alex.kutt@csiro.au). Summary and detailed information about biodiversity monitoring in the rangelands arising from this project is available through the Tropical Savannas CRC website (www.savanna.edu.au) and LWA website (www.lwa.gov.au).

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